The Performance Economy

Second Edition

Walter R. Stahel

The Performance Economy

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Walter R. Stahel

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Without them, this book would not have risen from the mist of daily chores and taken the structured shape it has now.

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List of Abbreviations/Glossary

AIG	American International Group, New York, N.Y.
AMS	Agricultural Management Services, a business model of selling and buying performance
ATM	automated teller machine
B2B	Business to Business (transactions)
B2C	Business to Consumer (transactions)
B2G	Business to Government (transactions)
bn	billion (a thousand million)
BOO	Build-Own-Operate, a business model of the Lake Economy
BOT	Build-Operate-Transfer, a business model of the Performance Economy
BP	British Petroleum
Bt	Bacillus thuringiensis
c2c	cradle to cradle, see http://product-life.org/en/cradle-to-cradle for the origins of the term
CERN	European Nuclear Research Centre, Geneva, Switzerland, www.cern.ch
CHF	Swiss Francs (currency)
CHP	combined heat and power (technology)
CMS	Chemical Management Services, a business model of selling and buying performance
CNC	computer numerical control
CNG	compressed natural gas
CNT	carbon nano-tubes
CO	carbon monoxide, a greenhouse gas
CO_2	carbon dioxide, a greenhouse gas
CPP	Consumer Pays Principle
CSP	Chemical Strategies Partnership
CSR	corporate sustainability report
cXc	multiple cradle to cradle re-use loops with an Extended Performance Responsibility of manufacturers, such as Xerox equipment, Kodak single use cameras (SUC), rent-a-molecule business models

DEI	decoupling environmental indicator (OECD); the term 'decoupling' refers to breaking the link between 'environmental bads' and 'economic goods'
DNA	deoxyribonucleic acid
DSI	decoupling sustainability indicators (Stahel) refer to the ratio resulting from the growth of a positive factor and the shrinking of a negative factor, which are causally linked; such as the 'value-per-weight ratio' and the 'labour-input-per-weight ratio' of the Performance Economy
EDS	Electronic Data Systems, Plano, TX
EEEG	Erneuerbare Energien-Einspeise-Gesetz, German energy feed-in law for electricity from renewable energies
EGNOS	European Geostationary Navigation Overlay Service
EMAS	Environmental Management and Audit System
EMPA	Federal Laboratories for Materials and Testing, part of ETH Zurich
EMS	Energy Management Services, a business model of selling and buying performance
EOLSS	Encyclopedia of Life Support Systems, organised under the auspices of UNESCO Paris
EPA	US Environmental Protection Agency, Washington DC
EPeR	Extended Performance Responsibility, a key strategy of the Performance Economy
ESA	European Space Agency
ESCO	Energy Service Companies
ETHZ	Federal Institute of Technology Zurich
EU	European Union, a political union of 27 countries
EUR	the euro (€) is the official currency of 16 of the 27 member states of the European Union (EU). The states are known collectively as the Eurozone
EUR/kg	Value-per-weight, a new metric of the Performance Economy, a decoupling sustainability indicator
FDG	Fluorodeoxyglukoses
Fe_2O_3	iron(III) oxide; ferric oxide
FFV	flexible fuel vehicle

FM	Real Estate Facility Management
FSE	Functional Service Economy; its focus is on the economically efficient functioning of goods and systems in use, which opens up opportunities of selling performance through system solutions
G-MS	Generic Performance-Based Management Services
g2c	grave-to-cradle, a re-use loop of the molecules of end-of-life of goods, such as Interface's ReEntry2 process to recover PA6 and 66 from used Nylon carpets to produce new carpet fibre (g2c is a new term coined by the author)
GE	General Electric Corporation, incorporated in the State of New York
GHG	greenhouse gases
GMO	genetically modified organisms
GNP	Gross National Product
GPS	global positioning systems
GTZ	*Deutsche Gesellschaft für Technische Zusammenarbeit* (German Technical Cooperation society), Bad Eschborn
HMO	Health Maintenance Organisations
HP	Hewlett Packard, Palo Alto, CA
IBM	International Business Machines Corporation, Armonk, NY
ICE	*Intercity Express*, the German high speed trains
ICM	Integrated Crop Management Services, a business model of selling and buying performance instead of goods
ILFC	International Lease and Finance Corporation, Los Angeles, CA
INTERFACE	Interface Corporation, Atlanta, GA
IP	Integrated Production in agriculture
IPM	Industrial Plant Management
ISAAA	International Service for the Acquisition of Agri-Biotech Applications
IT	information technology
JTI	Joint Technology Initiative of the European Union
kg	Kilogram
Lake Economy	its focus is on the efficient utilisation of goods that are property of their manufacturer or of fleet managers; the Lake Economy opens up a number

	of profitable opportunities for innovative products and services
LCA	Life Cycle Analysis
LCD	liquid crystal display (technology)
LDC	Less-developed countries
LED	light-emitting diode (technology)
LEU	Large End-Users
LOHAS	Lifestyles of Health and Sustainability
Loop Economy	the objective of the Loop (or circular) Economy is to bring used goods and molecules back into new uses in a *grave-to-cradle approach,* reducing both 'end of pipe' waste volumes (after use) and the demand for virgin resources at the 'beginning of pipe' (base material production)
LPG	liquefied petroleum gas
MDS	motor diagnostic service of Mobil Oil Company
METI	Japanese Ministry of Economy, Trade and Industry
mh	manhours
mh/kg	labour-input per kilogram, a new metric of the Performance Economy, a decoupling sustainability indicator
MIPS	Material Input Per unit (or year) of Service
MRI	magnetic resonance imaging
MS	multiple sclerosis
NASA	US National Aeronautic and Space Authority
NASSCOM	National Association of Software and Service Companies of India
NOx	nitrogen oxides, a GHG
O&M	operation and management, a business model to maintain performance over time
OECD	Organisation for Economic Co-Operation and Development, Paris
OEMs	original equipment manufacturers
OLED	Organic Light Emitting Diodes (technology)
PBL	Performance-Based Logistics, a business model of selling and buying performance to armed forces
PECVD	plasma-enhanced chemical vapour deposition
PET	polyethylenterephthalat
PEFC	polymer electrolyte fuel cell (technology)

PFI	Private Finance Initiative, a business model of selling and buying performance
POS	point of sale, where in the industrial economy the responsibility for a product is transferred from the manufacturer to the consumer
PPP	Public-Private Partnerships
PTS	Plane Transport System
PV	photovoltaics (technology)
PVC	polyvinyl chloride
QM2	Queen Mary 2
R&D	research and development
RAF	Royal Air Force
REACH	the EU Registration, Evaluation and Authorisation of Chemicals process
REI	Resource Efficiency Index (a new term coined by the author)
reman	short for remanufacturing, a business model to maintain performance over time
RFID	Radio Frequency Identification chips (technology)
SaaS	Software-as-a-Service, a business model of selling and buying performance
SAMARIS	European Sustainable and Advanced Materials for Road Infrastructure, a EU research project
SMEs	small- and medium-sized enterprises
SO_2	sulphur dioxide
SO_x	sulphur oxide
TiO	titanium oxide, a chemical compound
TLS	Textile Leasing Services, a business model of selling and buying performance
tonne	a metric tonne of 1000 kg
TRI	Toxic Release Inventory
TVA	Tennessee Valley Authority, a federally owned corporation in the United States created by congressional charter in May 1933 to provide navigation, flood control, electricity generation, fertiliser manufacturing, and economic development in the Tennessee Valley, after the Great Depression
UNESCO	United Nations Educational, Scientific and Cultural Organisation, Paris

UNIDO	United Nations Industrial Development Organisation, Vienna
Value-per-weight	a new metric of the Performance Economy, a decoupling sustainability indicator
VAT	Value Added Tax
VIPs	vacuum insulation panels (technology)
VOCs	volatile organic compounds (a class of chemicals)
WEEE	waste electrical and electronic equipment
°C	degree centigrade
°K	degree Kelvin

Preface

The Performance Economy was written in 2005 and first published in 2006 as a work in progress. In 2007, it was translated into Mandarin Chinese under the leadership of Professor Zhu Dajian (Tongji University, Shanghai). During this period, I had the opportunity to discuss the contents and terms of *The Performance Economy* with the translators and I was impressed by the difficulty in defining and translating the meaning of certain terms and concepts as they are depicted (such as 'performance').

This second edition of *The Performance Economy* has been thoroughly revised and reviewed to make reading easier and smoother. In order to facilitate comprehension, it was decided to interchange Chapter 2 and 3 so that the order of presentation became, (1) producing performance, (2) selling performance, and, (3) maintaining performance over time. Unchanged from the first edition is the philosophy of learning from reality – what Hannah Arendt calls *vita activa* or, reality as it develops.

While reading and collating the background material for this edition, I noticed that the greatest progress in the real economy (which this book is meant to reflect) has occurred in the fields mentioned in Chapter 2 (selling and buying performance). In the past, the Performance Economy was driven by economic actors such as *Xerox* **selling** customer satisfaction, and fleet managers such as airlines and leasing companies. But within the last five years, the concept of **buying** performance has increased substantially, and not only in the area of Public-Private Partnerships (PPP). The US Administration now openly declares that their preferred procurement option is buying services instead of hardware. Even a high tech government buyer such as *NASA* has stated that the Space Shuttle is the last piece of complex hardware that it will own and operate. Indeed, the trend of buying services instead of goods may become the biggest driver of the transition from an industrial to a performance or functional service economy.

Selling performance is spreading through industrialised countries in other ways as well. Among the latest examples are turbine manufacturers (such as *Rolls-Royce*), selling power-by-the-hour instead of jet engines (see Section 2.4.1.1), and *Michelin*, the French tyre manufacturer, selling what it calls 'Michelin Fleet Solutions' (or pay-by-the-mile services) to lorry fleet operators instead of truck tyres.

The *Michelin* example is a good way to show that the know-how gained from selling performance can be used to conquer other markets and sectors. For instance, in 2006, *Michelin* won a performance-based logistics contract from the US armed forces by selling performance packages that include maintenance and repair worldwide. Payment is procured per service unit, such as the number of landings for aircraft tyres, and miles driven for road vehicles (see Section 2.4.1.3).

Another on-going novelty in the debate on sustainability is the preoccupation with climate change and the emission of greenhouse gases (GHG) – particularly CO_2. The vision of a low-carbon economy has been intensively proposed by policymakers in the UK and the US, and the desire to reduce carbon emissions is ubiquitous. Unfortunately, most people still do not see the link between dematerialisation and the work of the *Factor Ten Club* 15 years ago, which I started with Prof Schmidt-Bleek. As shown in Chapter 4 of this book, the overruling issue should not be GHG emissions but resource consumption in industrialised countries. If this is reduced by 90 per cent – a factor of 10 – GHG emissions will not only be reduced by a similar amount, the acidification of soils, air, and aquifers will also be reduced.

I hope that the present global debate on climate change will open the eyes of many actors, including business managers, politicians, policymakers and journalists, to the opportunities that abound in the Performance Economy. As a growing number of studies show, it certainly is possible to reach a much more sustainable society through a resource-respectful economy – one with a substantially higher value-per-weight ratio – that is with more wealth and welfare and greatly reduced resource consumption.

The energy debate will also change in the coming years. As buildings and equipment become increasingly energy efficient in use, witness plus energy buildings, the embodied energy becomes dominant in a Life Cycle Analysis (LCA); maintaining embodied energy investments over time will increasingly be in the limelight.

Thank you to all the people who over the years have contributed to, and stimulated, my research in this field. This includes my colleagues and students at the Faculty of Engineering and Physical Sciences, *University of Surrey* (UK) and the Graduate School of Environmental Studies at *Tohoku University* (Japan) as well the contacts at the Geneva Association (www.genevaassociation.org) and our multi-lingual friends of the Product-Life Institute (http://product-life.org) at the Kozminski University in Warsaw who have started to translate the English website into German, Polish, Russian and Spanish.

Geneva, July 2009
Walter R. Stahel

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Introduction

For the last decades, the economies of many industrialised countries have been characterised by a combination of continuously high resource consumption with related high waste volumes, of rising public debt often accompanied by persistent unemployment and slow economic growth.

This book proposes new strategies that can overcome the short-comings of the Industrial Economy in an integrated way, namely to:

- produce higher wealth and economic growth with considerably lower resource consumption – Chapter 1.
- promote the business models of the Functional Service Economy that focuses on the performance of goods and services, uses the utilisation value as its central notion of economic value and private-sector initiatives to finance public works – Chapter 2.
- create more manual and skilled jobs with greatly reduced resource consumption – Chapter 3.

These objectives of the book, and its structure, are shown in Figure I.1.

The tools to achieve these objectives are new business models, new metrics, and a shift in thinking.

The new business models

This book focuses on the role of entrepreneurs and other innovators and on how they change the dominating business models of the Industrial Economy towards those of the Performance Economy by:

1 Exploiting SCIENCE and knowledge as drivers to uncouple revenue and wealth creation from resource throughput by focusing on smart materials, smart goods and smart solutions.

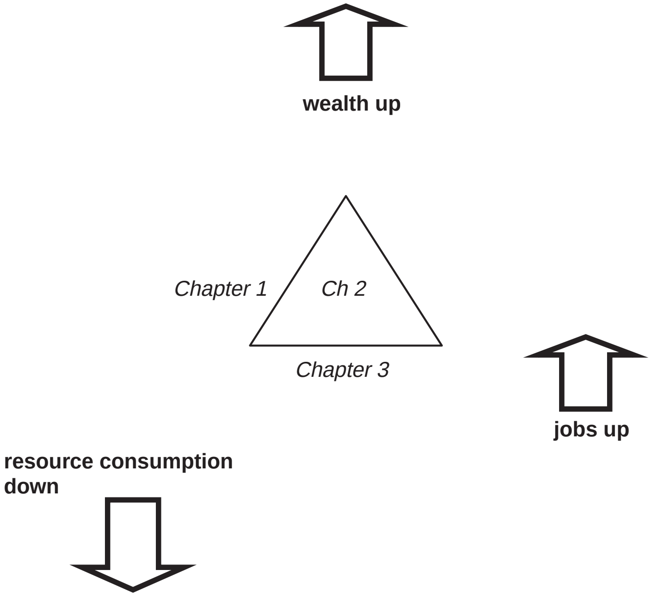

Figure I.1 Graphic presentation of this book's objectives and structure

2 Applying the business models of the Functional Service Economy with an extended PERFORMANCE RESPONSIBILITY of economic actors over the full life cycle of their products to increase wealth and welfare.
3 Creating more JOBS locally by shifting the focus of optimisation from the resource throughput of the industrial or 'river economy' to the asset management of the Lake Economy, that is, in-sourcing jobs instead of out-sourcing work.

The new business models of the book mean a shift from the manufacturing to the Performance Economy, of which the Functional Service Economy is an integral part. The Functional Service Economy is a set of innovative business models that *integrate* products and services into winning solutions to create wealth and jobs with considerably less resource consumption, and provide economic incentives to internalise the costs of risk and waste.

The Performance Economy is as relevant for industrialising and less-developed countries, as it is for industrialised countries. It enables the latter to overcome some of the shortcomings that the Industrial Revolution has run into 200 years after its introduction.

Developing countries can leapfrog to the same vision of the future! Examples of build-own-operate (BOO) (e.g., hydropower plants in India) and private finance initiatives (PFI) (e.g., the Three Gorges Dam in China) are increasing at a fast rate in emerging economies.

The Performance Economy is knowledge-based and uncouples wealth creation from resource throughput.

The Performance Economy as proposed in this book is the most promising of new business models. Its strategies have a long track record, illustrated by numerous examples that hopefully will serve as an inspiration to readers.

Even if there will always be a manufacturing sector in the economy, the manufacturing of goods and its business models are changing and will continue to do so in mature industrialised economies. New wealth and new jobs have been created through integrated corporate strategies in Western countries. But there is no room for complacency in a globally competitive world, for economic actors in emerging economies have started to exploit many of these business models, too.

The message of the Performance Economy is relevant to actors in all economic sectors. Its success in the sense of a competitive sustainability can be measured with the Performance Economy's three metrics.

The new metrics

In today's Industrial Economy, a higher throughput (resource consumption) means economic growth and an increased Gross National Product (GNP) as well as higher corporate revenues and more jobs. But the reverse is also true: the high standard of living in industrialised countries is based on high annual resource consumption, which has led to 20 per cent of the world population consuming 80 per cent of all resources. Thus, a globalisation of the Industrial Economy's business model is not feasible, nor is the present Industrial Throughput Economy compatible with a global future. It is industrialised countries that need innovative business models to show the paths towards a competitive and sustainable growth in future.

This book proposes new metrics that can help to overcome these problems in an integrated way, namely:

- 'value-per-weight' of goods – measured by the value-per-weight metric: *€ per kg*, or *$ per kg, or £ per kg* (to produce wealth and growth with minimal resource consumption, Chapter 1),

- 'sustainable profits by internalising the costs of risks and waste over the full service-life' of goods – measured in degree of internalisation of the total cost of risks and liabilities, (to shift the responsibility for performance and quality over the full service life from the consumer/user to the economic actors, Chapter 2),
- 'labour-input-per-weight' of activities – measured by the labour-input-per-weight metric *man-hours per kg* (to create local skilled jobs with minimal non-renewable resource consumption, manpower being a renewable resource, Chapter 3).

These metrics of the Performance Economy are *qualitative* and quantitative and correspond to its three goals of increased wealth creation, more jobs and reduced resource (materials and energies) consumption (Figure I.2).

These metrics are measurements of sustainable competitiveness in the form of absolute decoupling indicators. They enable to document the changes with regard to the three key dimensions – economic, ecologic and social welfare – of the sustainability triangle (Figure 4.1).

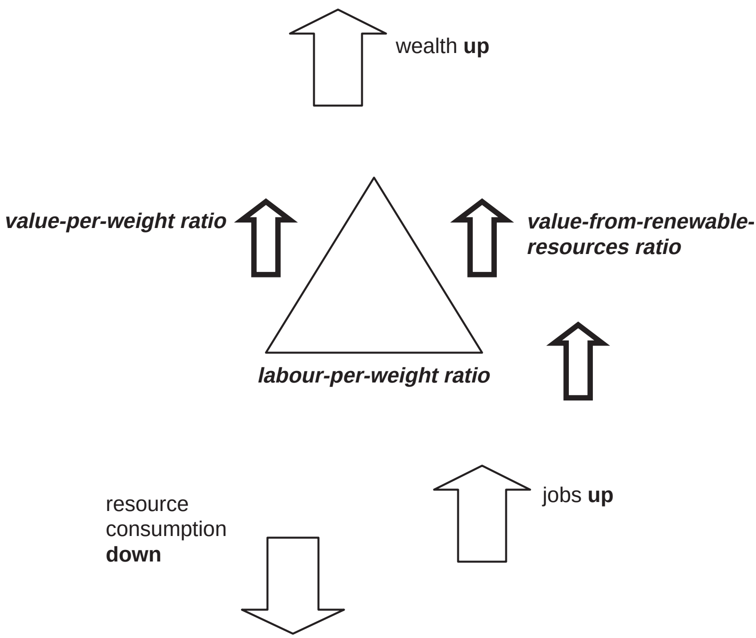

Figure I.2 Graphic presentation of the new metrics

A shift in thinking

The Performance Economy moves the economy towards sustainability. Chapter 4 shows why the Performance Economy is a key tool in the shift towards a sustainable economy. The objectives of the Performance Economy are *qualitative* and quantitative and correspond to its three goals of increased wealth creation, more jobs and reduced resource (materials and energies) consumption.

By contrast, the metrics of the dominating Industrial Economy measure the *monetarised* resource throughput at the point of sale: GNP and corporate annual sales. These are *quantitative* measures; traffic accidents have the same short-term impact on GNP and the bottom line of hospitals and car manufacturers as for instance finding a better cure or producing innovative equipment to improve people's health. This thinking of the Industrial Economy is applied to all sectors, from agriculture to durable goods and services, leading to a situation where success in health and education, for instance, is measured by the expenses incurred in state budgets instead of the quality improvements achieved (for example in Pisa tests).

The same mistake is made in national accounting. Economic wealth measured as Gross Domestic Product (GDP) does not consider wealth reduction in (natural) capital through, for instance, pollution and loss of biodiversity. The wealth and health lost in accidents and natural disasters – the full economic losses – are not deducted from national assets. Actions to clean up pollution and to eliminate waste are, however, added to the GDP, as are the costs to heal the victims of traffic accidents and to replace the crashed cars, despite the fact that overall wealth is unchanged.

The Performance Economy shifts economic thinking from 'doing things right'[1] to 'doing the right things'.

Stephan Schmidheiny's book *Changing Course*[2] and C.O. Holliday's *Walking the Talk* were the peak of an industrial movement **of doing things right**, a practical introduction to new and necessary methods of running businesses so that the realities of business and the marketplace support the realities of the environment and the needs of human development. Its concepts include:

- Clean production processes and the eco-design of goods, which have reduced environmental impairment, such as the release of toxic substances into the environment and the volumes of manufacturing waste. Other factors, such as the volumes of goods transported and the distances over which they are transported, and the vulnerabilities of the global production systems, however, have continued to increase.

- Corporate reporting in environmental areas and measuring the progress of doing things right. New standards were created, such as Environmental Management and Audit System (EMAS) in Europe and ISO 14000 internationally, to certify conformity. This required experts to do the assessments and staff to process the certificates, thus creating thousands of jobs.
- To turn the linear Industrial Economy into a circular economy, by substituting a grave-to-cradle approach for a linear end-of-life equal waste behaviour.

In industrialised countries, this change of course has led primarily to a greening of the economy and increased material recycling. It has ignored the underlying economic and social potential of wealth and job creation of the Lake and the Loop Economy described in Chapter 3. And recycling ignores the discounted resource efficiency of the 'Factor Time' (see Table 3.3).

In less-developed countries, the circular economy of reusing goods and recycling materials is commonplace. Local repair shops keep goods alive as long as possible, and scavengers assure a recovery of most material with a market value. Unfortunately, these goods and materials are often of a low quality and cannot compete with new ones. In contrast with the above,

The Performance Economy changes the role of the economic actors in a market economy to doing the right things, in addition to doing them right:[3]

- Doing the right things includes a preference of sufficiency before efficiency, and a focus on systems solutions before a product and manufacturing focus. Virtuous loops replace existing vicious loops; reversed incentives replace economies of scale; and smart system thinking with built-in resilience and redundancy replaces amalgamations of manufactured goods in use.
- The three goals of the Performance Economy – exploiting science, creating jobs at home and exploiting the opportunities of an extended performance responsibility – can be pursued independently. Economic actors thriving to achieve all three goals in a coordinated way, however, will reap substantial synergetic benefits.

The shift to the Performance Economy changes the role of the consumer/user:

- The Performance Economy introduces the notion of Consumer Pays Principle (CPP). Normally, national infrastructures, such as state-owned electricity grids, drinking water supply and waste water systems, even roads, are paid by all taxpayers independently to the intensity with which they use them. The use of infrastructures built as Private Finance Initiatives, in contrast, is billed to the individual user according to his 'consumption'. Road tax schemes have started to introduce CPP also on public roads, in for instance London City and Stockholm.

The shift to the Performance Economy changes the role of nation-states:

- In the phase of 'doing things right', command-and-control policies were an appropriate approach, at least in law-abiding societies, to protect the environment and human health.
- 'Doing the right things', in contrast, is based on innovation and creativity. Command-and-control policies no longer work, as they cannot seize emerging opportunities nor transform them into innovations that can be rapidly introduced into the market. Instead, nation-states can promote innovation, education, research and entrepreneurial risk taking. They can also speed up the creation of new local jobs by taxing the use of non-renewable resources instead of taxing labour, and they can reward pro-active entrepreneurs accepting a performance responsibility over the full life cycle through both incentives and appropriate framework conditions. But nation-states cannot be creative entrepreneurs that take entrepreneurial risks – witness the legacy of socialism in Eastern Europe!

The shift to the Performance Economy also changes the role of resources: the goods of today are the resources of tomorrow at yesterday's prices.

1
Producing Performance

> Daring to exploit emerging opportunities, using science and knowledge as drivers to uncouple revenue and wealth creation from resource throughput.[1]
>
> 'If we did all the things we are capable of, we would literally astound ourselves'
>
> Thomas A. Edison

Why the shift? How it works! How to measure it!

1.1 Why the shift to Producing Performance?

This shift is imperative for our welfare; it is feasible and its progress can be measured.

It is imperative because, today, the 20 per cent of the world population living in industrialised countries consumes 80 per cent of all resources. A globalisation of the Industrial Economy's business model is thus neither feasible nor compatible with a global future.

At the same time, industrialised countries face increasing public spending, due partly to the rising health and pension costs for an ageing population, partly to the maintenance costs for ageing infrastructure. New strategies of wealth creation by the private sector without material consumption are thus needed to avoid increasing national debts and global resource scarcities. Revenue and wealth creation can be uncoupled from resource throughput through radical innovation, away from bulk goods and towards radically more efficient smart solutions! This uncoupling can be measured by a new metric of value-per-weight, which is described below.

The shift is feasible because seizing the opportunities of the Performance Economy requires innovation accompanied by an intelligent use of smart solutions from science and technology, supported by a balanced assessment of opportunities and risks. In Continental Europe, the focus has shifted to an analysis of emerging risks. Innovation can then be hindered, or even made impossible, by phantom risks! Asia and North America tend to focus on opportunities, not risks. This difference in attitude may well create a regional divide in competitiveness within the coming decade.

And the shift's progress can be measured. Economic actors, innovators, politicians and consumers need a simple metric to judge the economic resource productivity of goods and services, and this metric is: value per weight (€ per kg, or $ per kg, or yen per kg)! This metric empowers consumers and producers to judge the sustainability of competing goods directly at the point of sale. Table 1.1 gives some examples.

The arrow in Table 1.1 shows that the value-per-weight ratio dramatically increases when shifting from the bulk goods of the Stone Age to the smart goods of the Performance Economy, placing goods of the Industrial Economy half way in between.

Table 1.1 The shift in the value-per-weight ratio from bulk goods to smart goods

	Value-per-weight ratio of goods of the		
	Stone Age Economy Cent/kg	Industrial Economy €/kg	Performance Economy (mio) €/g
BULK GOODS, e.g.			
sand and gravel	1 cent/kg		
steel	40 cent/kg		
automobiles		20 €/kg	
SMART GOODS, e.g.			
razor blades		500 €/kg	
remanufactured car engines		500 €/kg	
spinnaker cloth		800 €/kg	
memory stick			8 €/g
'rebif' interferon			5 million €/g
enzymes			10 million €/g

The new metric of value-per-weight enables one to divide today's economy into two distinct groups:

- **bulk goods** from the Stone Age Economy and the Industrial Economy and
- **smart goods** produced in the Industrial Economy and the Performance Economy.

Turning raw steel into automobiles – shifting from a Stone Age product to an industrial product – enabled a 25-fold jump in the value-per-weight ratio. A similar jump can again be achieved by turning an old engine into a new one – shifting from a manufacturing to a service activity. Remanufacturing the key components of an automobile, such as its engine, is a key capability in shifting from the Industrial Economy to the Performance Economy in the sense of the Lake and Loop Economy sketched out in Chapter 3.

Table 1.2 shows a sample of typical products of the Stone Age and the Industrial and the Performance Economies with their value-per-weight ratios.

Table 1.2 Value-per-weight – a new metric for economic sustainable productivity[1]

	Value-per-weight ratio of goods of the		
	Stone Age Economy Cent/kg	Industrial Economy €/kg	Performance Economy (mio) €/g
Stone Age Economy *(high throughput, minimal 'hidden material rucksack')*			
bulk goods			
sand and gravel	1 cent/kg		
cement	6 cents/kg		
ready-mix concrete[2]	4 cents/kg		
raw diamonds			2500 €/g
Industrial Economy *(not including the 'hidden material rucksacks', which are often a multiple of the product weight)*			
bulk goods			
hydroelectricity	1 cent/40 kg[3]		
steel production	40 cents/kg		
filet steak		20 €/kg	
automobiles		20 €/kg	
Chateau Suduiraut (sauternes)[4]		80 €/kg	

Table 1.2 Value-per-weight – a new metric for economic sustainable productivity – (*continued*)

	Value-per-weight ratio of goods of the		
	Stone Age Economy Cent/kg	Industrial Economy €/kg	Performance Economy (mio) €/g
Foie gras		80 €/kg	
Borazon		2000 €/kg	
Caviar			1000–30,000 €/kg
smart goods			
razor blades		500 €/kg	
remanufactured combustion engines[5]		500 €/kg	
natural fragrances		700 €/kg	
notebook PC		700 €/kg	
spinnaker cloth[6]		800 €/kg	
spectacle frames			5000 €/kg
cut diamonds			7000 €/g[7]
Performance Economy *(minimal 'hidden material rucksacks')*			
smart solutions and goods			
memory stick[8]			8 €/g
Ambergris[9]			20 €/g
amorphous carbon coatings[10]			0.04 million €/g
Fe_2O_3 tracer for drug delivery[11]			0.1–0.5 million €/g
'rebif' interferon[12]			5 million €/g
enzymes[13]			up to 10 million €/g

[1]The value-per-weight ratio shown here is calculated at the point of sale. A gross value-per-weight ratio takes into account all the material flows caused by the manufacturing of the product.
[2]€50–100/m^3.
[3]10 cent/kWh, and 400 litres of water to produce 1 kWh.
[4]A sweet white Bordeaux wine; the price for an average year is €60 per bottle of 75 cl.
[5]See detailed data in Section 3.4.2.
[6]Cloth produced by Meyer-Mayor AG for competition yachts, 30 g/m^2 at a price of €22m^2, see Section 1.2.2.3.
[7]1 carat equals 1 gram; average quality.
[8]See Section 1.2.2.4 for details.
[9]Ambergris is a natural fragrance found in the stomach of sperm whales.
[10]See Section 1.2.2.4.
[11]Information supplied by Dr Margarethe Hofmann, Lausanne, see Section 1.2.2.4.
[12]Price for a dose of 22 millionth of a gram; Rebif is produced by Serono; see Section 1.2.2.2.2 for details.
[13]In a process where an enzyme replaced a chemical catalyst containing heavy metal, resource productivity increased by factor 36,000. Information supplied by Diversa Corp.

The metric of value-per-weight is applicable to all physical goods and services related to them, including sufficiency and loss prevention in the Performance Economy. For other goods of the Performance Economy, such as immaterial goods, intellectual assets and services of the knowledge economy (R&D, software, brands, education and marketing), it may be difficult to establish a physical 'weight' at the point of sale (POS). These are nevertheless smart solutions to create a high value and economic growth.

1.1.1 The Stone Age Economy – cents per kilogram[2]

1.1.1.1 Bulk materials

In industrial economies, bulk products of the Stone Age Economy still account for over half of the annual resource throughput, amounting to 80 tons per capita, Japan being the exception with 40 tons per capita. As the materials of this economy go mostly into infrastructure and buildings, a major efficiency increase is possible by extending the service-life of these durable goods, thus reducing the material input per year of service (MIPS).[3] This strategy is part of the goal of the Performance Economy: to create more jobs at home by shifting from resource throughput to asset management.

One sparkle glimmers in the Stone Age Economy: raw diamonds!

1.1.2 The Industrial Economy – € per kilogram[4]

1.1.2.1 Bulk industrial goods

The value-per-weight ratio of Industrial Economy bulk materials – coal, steel and electricity – is only a slight improvement over Stone Age Economy products. But by embedding these materials into high-value-added consumer goods, such as vehicles and white goods, the Industrial Economy achieves a considerable increase in the value-per-weight ratio. Yet, there is hardly a difference in the value-per-weight ratio between bulk goods resulting from industrial agriculture (filet steak) or from industrial technology (automobiles).

The value-per-weight ratio of most agricultural goods is similar to that of bulk industrial goods, ranging from €2/kg for milk and bread to about €20/kg for a good steak and rising to €80/kg for *foie gras*, a French specialty banned in some countries for cruelty to animals. Cut diamonds and caviar are the exception in the Industrial Economy, commanding sales prices ranging from €2000 up to €30,000/kg!

1.1.2.2 Smart industrial goods

Smart goods, such as razor blades and notebook computers, have a considerably higher value-per-weight ratio than that of bulk goods. Applying smartness enables a higher value-added to products. Spectacle frames, for instance, have a value-per-weight ratio of up to €5000/kg.

Extending the product life of bulk durable goods, such as cars (the remanufactured combustion engines in Table 1.2) and buildings, allows achieving a high value-per-weight ratio similar to that of smart goods. This approach maintains existing wealth, instead of substituting new for old wealth, and thus reduces the material input per year of service (MIPS). In addition, this strategy of managing existing assets creates skilled jobs in the region where the goods are used (see Figure 3.5).

1.1.3 The Performance Economy – (million) € per gram[5]

1.1.3.1 Smart solutions

Nano- and biotechnologies have enabled a small part of the Industrial Economy to shift towards the Performance Economy. According to the studies on the Japanese industry by Prof. Ryoichi Yamamoto,[6] between 1992 and 2003, resource productivity in the manufacture of memory devices increased 10,000-fold, thanks to the evolution from micro- to nanotechnologies, while the rest of the Japanese industry rose twofold – that is, resource consumption per unit of wealth sank by 50 per cent.

> Between 1992 and 2003, resource productivity in the manufacture of memory devices swelled 10,000-fold.

Importantly, the example of memory devices demonstrates that in an environment of rapid technological change, smart goods of the Performance Economy can quickly turn into bulk goods if competition intensifies and the economy of scale drastically reduces unit costs.

Other innovations towards a much higher value-per-weight ratio come from other nanosciences, such as nanochemistry; medical biotechnology applications and red life sciences; white life sciences; material sciences; and a convergence of different scientific disciplines far beyond an interdisciplinary level.

There is no clear distinction between biotechnology and chemistry, or between material technology, nanotechnology and chemistry. Miniature chemical reactors, for instance, are based on nanotechnologies. Revisiting the concept of scientific disciplines will boost the development of the Performance Economy but also question the way universities function today.

Many of these new products are either invisible to the human eye or represent intangible solutions; others cannot be patented and their production processes are therefore not disclosed. In such cases, traditional control functions may not work. But an extended performance liability by the manufacturer over the full life cycle of its products – rather than state regulations – may speed up their commercialisation. Insurance can provide the necessary safety nets for society.

The Functional Service Economy exploits the opportunities by extending performance responsibility over the full life cycle of products to create wealth and welfare. This strategy of how to achieve sustainable profits with an internalisation of the costs of risk and of waste is developed in Chapter 2.

1.2 Producing performance: How it works!

The Performance Economy's strategies have existed for some time as part of smart solutions developed in the knowledge economy, such as:

- creating wealth from knowledge (Section 1.2.1),
- exploiting scientific and technological progress (Section 1.2.2),
- prevention strategies (Section 1.2.3),
- sufficiency strategies (Section 1.2.4) and
- systems solutions – smart engineering solutions (Section 1.2.5).

The winners in the long term will be companies that integrate the intelligent use of science into their corporate strategy (see the example of DuPont de Nemours in Section 1.2.1) and nation states that foster the development of the Performance Economy.

The outstanding examples described below fall into two groups:

- Pioneers or explorers that open up new opportunities but may not be the most successful companies in the longer term.
- Champions that are exploiting ideas successfully. (Champions can be former pioneers.)

1.2.1 Smart solutions – Creating wealth from knowledge

- DuPont de Nemours, an example

DuPont de Nemours is cited as a pioneer for integrating the Performance Economy into corporate strategy and creating revenue from knowledge. Largely a self-insured company, DuPont has an enviable track record of not only teaching other companies in all economic sectors on how to apply safety management but also putting its belief and capabilities into practice.

DuPont started out in the early 19th century as a manufacturer of black powder, which then was the state-of-the-art explosive. At the beginning of the 20th century, it changed its strategy and began developing chemicals and polymers, inventing in the process products such as Nylon fibres and Teflon coatings. At the turn of the third millennium, the company again refocused itself on science-, biology- and knowledge-intensive solutions, which, with their high value-per-weight ratio, are keys to the Performance Economy.

This international company's new bold objectives also include a transition from oil as a main resource to non-depletable (renewable) feedstock. By 2015, its objective is to double its revenue from non-depletable sources to at least US$8bn. In 2008 total revenues reached over US$6.5bn. A number of strategic decisions led DuPont to sell Conoco, its oil company, despite its enviable safety record, as well as its pharmaceutical and textile fibre businesses, which contributed to DuPont's success story of the 20th century!

DuPont de Nemours is among the few industrial companies that at the beginning of the third millennium have redefined their corporate strategy in the sense of the Performance Economy. The following comparison shows the radical innovation involved:

Former business model	New business model
Volume driven	Value driven
Energy and resource intensive	Knowledge intensive
Inherently hazardous/toxic	Inherently safe
Linear systems	Circular systems
Chemistry and physics	Biology and information
Internal out	External in

The company expects to save US$2bn by reducing its greenhouse gas emissions by 65 per cent by the year 2010. The goal is to hold total energy use to 1990 levels. In 2009, DuPont reported that between 1990 and 2007 it saved over US$3bn through energy-efficiency projects. In fact, in 2007 alone DuPont actually achieved an 8 per cent decline in energy use compared to 1990.

DuPont's future activities are based on a new vision of 'Innovation through science' and focus on five platforms:

1 Safety and Protection (the chemical company with the best safety record, based on its own standards and procedures). The mission of this platform – which in 2008 registered sales of US$5.7bn – is to extend the company's knowledge, technology and experience to deliver solutions that protect people, property, operations and the environment. DuPont de Nemours is selling its knowledge to other companies under the slogan of 'Safety Excellence – Business Excellence' through its Safety Resources Division, which is part of this growth platform.
2 Electronics and Communication Technologies: The objective is to deliver innovative science to electronics, communication and industrial markets worldwide.
3 Coatings and Colour Technologies, part of Integrated Crop Management (ICM) services[7]: The aim is to leverage DuPont technology and knowledge of the titanium dioxide, coatings and ink jet businesses to create added value for customers and deliver innovative high-performance products.
4 Performance Materials: Its strategy is to deliver material innovations for a more secure, comfortable and sustainable world.
5 Agriculture and Nutrition, part of Integrated Agricultural Management services[8]: The goal is to increase the quality, quantity and safety of the global food supply chain by leveraging DuPont's strength in biology, chemistry and biotechnology.

1.2.2 Exploiting scientific and technological progress – Living with uncertainty

> We all depend on industrial goods and technology. A life without the applications of technology and the enlightenment of science is unthinkable. Men who become slaves of what they despise will end in disaster.
>
> Jeanne Hersch, Swiss philosopher (1901–2000)

Scientific and technological breakthroughs are generally spasmodic. Long periods of stagnation may be followed by a spurt of developments. However, such revolutionary progress always tends to make understanding and execution more complex. A single discovery can trigger a rapid advance in technology in many fields. For example, application of a single scientific concept in the mid-19th century transformed the steel industry by making steel products much less expensive and more readily available. Traditionally, the carbon that made pig- and cast iron brittle was pounded out with hammers to produce much tougher, more malleable and durable steel. As the process was slow, labour-intensive and expensive, the availability of steel was limited. An abstracted understanding of the oxidation process led to the recognition that blowing air through or over molten iron drove out the carbon, thus quickly leading to inexpensive steel-making technologies, such as the Bessemer and Siemens processes. These technologies, in turn, facilitated myriad steel-based developments throughout the engineering and construction sectors, which then began producing the weapons, bridges, steel building frames, ships and machines that dominated the second half of the 1800s. The price paid by society, however, has been new forms of environmental pollution and greater resource consumption, both of which are awaiting further conceptual developments for amelioration.

Iron and steel have been used for centuries. Yet, the technologies depending on iron and steel have evolved relatively slowly and to a limited extent. Marrying these technologies with a single step in understanding led to a rapid advance. In this way, each generation inherits past scientific and technological ideas, which may not always be fully understood and carry an uncertain future value and inherent risks. This inheritance can be turned into future wealth or ignored to avoid jeopardising existing wealth.

Scientific progress does not follow the calendar but, for the purposes of this argument, these ideas are examined century by century. For example: The 19th century inherited progress in a number of areas, among them:

- energy: steam,
- mobility: bicycle, ship propeller,
- telecommunications: telegraph,
- print: typography and
- new opportunities through the exploitation of culture-related technology: daily newspapers.

The 20th century inherited key progress in such areas as:

- energy: oil, electricity, dynamos, electric motors, light bulbs,
- mobility: electric railways and trams, elevators, cars and motorbikes,

- telecommunications: wireless telegraph, telephone,
- print: typography, typewriters and
- new opportunities through the exploitation of culture-related technology: photography, movies, world exhibitions.

Thanks to science the 21st century inherited several technologies and knowledge tools to achieve higher wealth and a higher value-per-weight ratio – and higher resource productivity. Among them:

- energy: nuclear, photovoltaic panels, fuel cells and hydrogen,
- mobility: aircraft, jet engines and rockets, space travel, helicopters,
- telecommunications: television, telecom by satellites, cellular phones, Internet, digital newspapers,
- life sciences: vaccines, DNA (deoxyribonucleic acid),
- material sciences: plastics, nanosciences and
- new opportunities through the convergence of sciences.

If the 20th century was dominated by advances in physics, the 21st century will be the era of biology. Freeman J. Dyson (Dyson 2007) is among the experts convinced that over the coming five decades the domestication of biotechnology will dominate our lives similarly to the domestication of computers since the 1950s.

Up to the 1980s, natural resources and capital goods were considered the ingredients to economic expansion. This changed with two articles by Paul Romer, an American economist, published in the *Journal of Political Economy* – 'Increasing Returns and Long-Run Growth' (1986) and 'Endogenous Technological Change' (1990) – in which Romer described the knowledge economy. Knowledge itself could drive increasing returns on investments in knowledge. And each knowledge breakthrough will deliver a bigger payoff, which in turn fosters higher levels of economic growth.

Some of these inherited knowledge tools as well as lessons to be learned from the past are explored below.

1.2.2.1 The past role of scientific and technological progress

Technological progress at the beginning of the Industrial Revolution was a quantitative, not a qualitative, jump. Technology has always existed as a 'lever towards progress' since the beginning of human activity. There is no major difference between the pre-historic 'engineers' who specialised in honing stones to produce arrowheads or cutting tools, and the engineers of the first Industrial Revolution who developed tools that by today's standards are extremely simple.

However, it is crucial to make an adequate distinction between craft-based technologies and later science-based ones. The former are built on 'cut-and-try' principles, whereby the relevant skills are largely manual and handed down by imitation from master to pupil, and there is no underlying, systematic, theoretical basis that can be communicated between generations. If the inter-generational master-pupil chain is broken the skill is lost. Science-based technologies benefit from the fact that the principles on which they are founded are recorded in an abstract notation and can thus be acquired without person-to-person contact and allow dissemination between unrelated technological groups.

Even the steam engine was nothing more than a sophisticated control system of increased pressure produced by a volume of water transformed by heat into steam in a given space. When water turns to steam, mass is conserved while volume and pressure become exchangeable (through the input or output of useful work – the thermodynamic principle behind all steam expansion engines). The real problem was to create and produce the materials, containers and related equipment capable of resisting the pressure and releasing the steam under control.

It was only at the end of the 19th century that the manufacture of tools and products started to depend on scientific knowledge, namely, research and the understanding of problems that go beyond sensory perception. We know how to cut wood and how boiling water transforms into a larger mass of steam. But we need scientific research to discover that the same molecules found, for instance, in cotton fibres can be reproduced in a similar, but not equal, way using oil as raw material.

Up to the mid-1920s, investment in research laboratories in industry or elsewhere was not consistent. The cost of production could be accounted for only in terms of labour and capital costs. Scientific research and exploitation of technology based on science began only in the 1930s and then were fully and professionally exploited during and after World War II. Today, research and development absorb up to 30 per cent of the sales income of a technologically advanced sector.

While the results of industrial in-house research and later contract research were easily absorbed into the economy, because the researchers were engineers, research at universities has led to problems of innovation transfer and possibly a higher risk aversion. As the engineers in industry are detached from these 'outside' research results, they generally adopt a not-invented-here syndrome.

By separating the thought processes of science from those of 'invention' (the origin of all technology), societies can harness a single scientific thought to a wide range of technologies that can cross-fertilise each other. At the same time, the experience of the technologists is fed back into the rational framework being developed by the scientists – and in some instances, technologist and scientist are the same person. This cumulative feedback was both a consequence and a driver of the 'Enlightenment' that in the 18th century institutionalised rationalism, challenged 'given' authority and made a philosophy out of a logical, rational approach to problem-solving. It was the keystone of the Industrial Revolution and has shaped much Western philosophy.

Modern life sciences, material sciences and nanosciences are an acceleration of the trend of using science to develop smart solutions, which began in the second half of the 20th century. But today, the playing field has changed. Research in the 21st century is now played in a global arena and is no longer a race between individual corporations or countries.

At the same time, performance can be frightening to some. The energy efficiency of the physical mechanism of nuclear reaction, which powers sunlight, is a million times more efficient than chemical combustion (oxidation), but its applications are disputed in some highly developed countries.

1.2.2.2 Smart solutions from life sciences

Life sciences enable quantum leaps in the value-per-weight ratio, compared to traditional processes, and take place in a more natural environment. Biotech processes, such as enzymes, work at ambient temperatures and pressures and need low energy and material inputs compared to traditional chemistry. In addition, these processes are normally water-based and use CO_2-neutral biological resources, whereas traditional chemistry uses volatile organic compounds (VOC) that are oil-based. Less toxic substances are used, and the safety efforts needed are thus smaller and cheaper.

Despite these advantages, biotech processes face many obstacles. Traditional processes are well established and run on existing plants; new processes demand new investments and can lead to stranded capital in existing technology. Small start-up firms may thus act faster than traditional companies. In addition, there are cultural differences between regions. Some countries have a general reserve against biotech processes that use plants to produce specific products.

Yet the domain of life sciences has a long track record of successes relating to the objectives of the Performance Economy. They can be grouped into five domains:

- white (process-related) life sciences: chemistry, bioprocesses, bio-based industry, enzymes,
- red (medical) life sciences: biopharmaceuticals,
- green (agricultural) life sciences,
- blue (marine) life sciences and
- grey life sciences: environmental biotechnologies, such as the bioremediation of polluted sites.

The industrialisation of life sciences and biotechnology is only at its beginning. The first phase of genetically modified organisms (GMOs) was to facilitate growth, while the present second phase is to reinforce naturally available nutrition. In the following phases, scientists will introduce new additional elements in GMOs, either to provide better products or to make plants tolerant so that they can grow in a 'hostile' environment, such as arid zones.

Some examples of the first three domains, which are summarised below, are only the tip of the proverbial iceberg. More examples are published almost daily in scientific and professional journals worldwide. One recent example is rice taking nitrates from air instead of water, which could reduce the need for water by 90 per cent.

1.2.2.2.1 Smart solutions in white (process-related) life sciences

Catalysts have played a key role in chemistry. The latest recognition of their role is the attribution of the 2005 Nobel Prize in Chemistry to Yves Chauvin (France), Robert Grubbs (US) and Richard Schrock (US) for their work on understanding the mechanism of metathesis and on developing the catalysts that enable metathesis in the laboratory. Catalysts are materials that are necessary to speed up chemical reactions without being used up in the process. In the past, they were often based on heavy metals; in future they will increasingly be based on biotechnology.

Industrial enzymes – including made-to-measure enzymes in innovative areas of application – started to change the chemical industry some 50 years ago. Fast-growing biotech companies such as GENEART of Germany offer made-to-measure enzymes and are tapping into innovative areas of applications in a multi-million dollar market. Biopolymers and bio-based products will also continue to make inroads. Similar to crude oil refining that started with distillation and ended up combining it with sophisticated reaction engineering, biorefining stands ready for the same transformation, with recovery of sugars being combined with a variety of new fermentation and thermo-chemical steps.[9]

Enzymes are widely used both in industrial applications and in domestic products such as laundry detergents. But most are derived from organisms that live at relatively high temperatures and work best above 40°C. Reducing the temperature at which they operate would produce huge energy savings and would allow enzymes to be used in low-temperature applications in the food and pharmaceutical industries, and in biosensors for environmental monitoring.

Among the pioneers of biotech applications in process technologies are:

- The **Upjohn Company** (now Pharmacia) in the mid-1990s developed a biotechnology that enabled the cracking of process waste, thus increasing the yield in a given production process from 3 to 100 per cent, increasing resource productivity 30-fold and reducing costs by an even higher ratio as waste costs disappeared.
- **DuPont de Nemours'** first commercialised bioconversion process, also in the mid-1990s, produced a key intermediate for a new herbicide and replaced a heavy-metal, catalyst-based process. This new process reduced waste loads by 99 per cent and waste disposal and catalyst costs by US$4.6 million per annum.
- **Verenium Corporation (previously known as Diversa until 2007)**, a US start-up biotech company, collects enzymes from extreme climates and puts them to work in the white life sciences of clean process technologies. In 2009, Verenium announced its partnership with British Petroleum (BP) to build a plant to use next-generation cellulosic ethanol to convert non-food feedstock (including agricultural waste, wood products and renewable grasses) to fuel, instead of processing food crops, in Highlands County, Florida.

In one case, Verenium achieved a 30,000-fold resource productivity increase by altering the specificity of an aliphatic amidase to hydrolyse an aromatic amide. The value-per-weight rate grows accordingly.

Verenium achieved a 30,000-fold resource productivity increase by altering the specificity of an aliphatic amidase to hydrolyse an aromatic amide.

- **Coldzymes – Enzymes to** technologically **upgrade washing machines.** Researchers from the British Wye College and a Belgian University developed coldzymes from bacteria collected in Antarctica and the Alps, working on a European Commission-financed project finished in 1998.[10] Coldzymes can be used for washing clothes in cold water. As 90 per cent of the energy consumed in washing clothes is used to heat water, coldzymes reduce the energy consumption of washing machines by 90 per cent.[11] Any old washing machine thus becomes economically and ecologically hyper efficient, and new washing machines no longer need heating elements! In 2007, Procter & Gamble began commercialising detergents based on coldzymes in selected European markets. The energy used in the enzyme manufacturing now greatly dominates the energy used by the washing machine. The obstacles encountered in the commercial application of coldzymes, which are typical for systems solutions, are covered later in this chapter.

The impact of bio-based industrial processes is ubiquitous and of particular interest to the pharmaceutical, chemical and food industries. The economic impact of industrial biotechnology is growing, due to four drivers: rising oil price, end-consumer pull, greenhouse gas emission reductions and scientific progress. DuPont, for instance, has identified the bio-based area as part of its Platform 5 strategy to achieve sustainable growth (see Section 1.2.1).

Thanks to today's technology, a wide variety of products are being developed from biomass: antibiotics, citric acid, sorbitol, ethers, bioethanol, biobutanol, acrylamide, pigments, oils, fatty acid, lactic acid and biopolymers. These building blocks can be transformed into a number of finished products and substances, such as textiles and plastics. Compared to traditional chemistry, bio-based materials provide cleaner manufacturing processes and renewable products and resources.

Scientists have recently genetically modified a plant, *Arabidopsis thaliana*, to produce an organic plastic similar to prolypropylene, a commonly used plastic.

Japanese cosmetics manufacturer Shiseido announced in October 2008 that it has joined forces with the Brazilian chemical manufacturer Braskem SA to develop cosmetics containers made from sugarcane-derived polyethylene. These efforts are clearly aimed at 'green' consumers.

1.2.2.2.2 Smart solutions in red (medical) life sciences

The human body can be regarded as a bioreactor. Although human organs cannot yet be produced in the laboratory, the human organism can already be stimulated to heal itself by producing certain types of tissues. Alternatively, researchers can produce synthetic copies of proteins produced by the human body. Sometimes this demands the transplant of adult stem cells, e.g. in eye problems. These treatments are often based on a combination of scientific disciplines, such as bio-, nano- and material sciences. Among the pioneers of biotechnology in medical applications are:

- **Serono, turning performance knowledge into revenue**. Rebif is an interferon-beta 1a, produced from animal cells through biotechnology by Serono, a leading Swiss-based biotech company that was bought in 2007 by the German Merck pharmaceutical company for Sfr16 million (€10m) and now known as Merck-Serono. Rebif is the most efficient cure that exists today to slow down the progress of illnesses based on a weakness of the immune deficiency system of the human body, such as multiple sclerosis (MS). Rebif is administered in doses of 22 or 44 micrograms that add up to an annual need of 3.5 or seven milligrams per patient. Its retail price in pharmacies to patients is the equivalent of €5 million/g; the annual cost to a patient is €20,000. But this investment keeps many patients considerably longer away from a wheelchair, thus substantially improving their quality of life and reducing overall health costs.

The retail price of Rebif to patients is the equivalent of €5 million/g

  Up until its acquisition, Serono manufactured three products, the total production volume of which was less than two kilograms per annum! Yet the revenue generated from the sale of this minute quantity made it the leading biotech company outside the US and number three worldwide. In addition, the benefits were sufficient for Serono's owner to finance the Alinghi racing yacht that won the 2004 America's Cup in New Zealand.
- **Orphan drugs**, which treat rare diseases, are of little commercial interest for manufacturers, except if they can achieve a high price. A treatment for a rare enzyme-based illness, afflicting one per million people, for instance, costs €500,000 per annum for each patient.
- **Cancer treatments** based on life-sciences designer molecules are being developed by many pharmaceutical companies. While there is general agreement on their medical efficiency, some people object

to their price, ranging from €30,000 per annum for Glivec, Avestin and Herceptin to €20,000 for a two-month treatment of Erbitux. A worldwide study conducted by Brian Druker at Oregon University showed that after five years of designer molecular treatment there was a survival rate of 89 per cent, which is 20 percentage points higher than the previous standard treatment. The real alternative is not 'no treatment' but future cancer prevention and surgical intervention (see also the example of 'Molecular diagnostics of breast cancer' in Section 1.2.3).

- **Pay-for-performance approach to cancer treatment.** As there is a demand for high cost-benefit analysis for expensive drugs in the UK and the USA, Johnson & Johnson launched its new cancer treatment Velcade with a money-back guarantee. The medicine, which averages €30,000 per patient a year, will be invoiced only if it can be shown that Velcade had indeed stopped the tumour's progress.
- **Nanoparticles as tracers**. The Japanese Toto Ltd has collaborated with Yokohama University to develop a possible way of reducing the side effects of cancer drugs by using the photocatalytic properties of titanium oxide (TiO). The new procedure exploits TiO's property to deactivate the cancer drug so that only the tumour is attacked and side effects are reduced. The idea is to deliver the cancer drug attached to nanograins of polymer-coated TiO that are small enough to be taken up by cells. The healthy tissue surrounding the tumour is exposed to ultraviolet light that activates the TiO and degrades the cancer drug, but because the area of the cancer is not exposed to the ultraviolet light, the drug inside the cancer cells remains intact and active.
- **Fe_2O_3 tracer for drug delivery**. This example of nanoparticles increasingly used in medical and technical applications is shown as 'magnetic ferrofluids' in Section 1.2.2.4.

The high cost of life science medicine per patient is often criticised and even blamed for rising health costs. This shows the difficulty of many experts to come to grips with system thinking over longer periods. However, the efficiency of these products cannot be judged by their sales price but by the result, measured in quality of life maintained over a longer period of time. Saving a human life and allowing people to continue working have an impact on economic revenue (contributions to taxes and social insurance) and expenses (reduced health costs) that both need to be taken into account.

1.2.2.2.3 Smart solutions in green or agricultural life sciences

Smart solutions and bulk goods exist side by side in the green life sciences. Smart goods fulfil new needs, create new functions and are based on new processes, whereas bulk goods are biofuels and biocombustibles that are 'greener' alternatives to bulk goods of the Industrial Economy. The metric of value-per-weight allows drawing the line between bulk goods and smart solutions.

Among the smart solutions are genetically modified organisms (GMOs), but also biomaterials synthesised on the bases of bacteria, biocultures from biomaterials, and biopolymers and solvents made from biomolecules.

Since 1995, biotechnology has triggered an agricultural revolution outside Europe. According to the International Service for the Acquisition of Agri-Biotech Applications (ISAAA), 1.3 million farmers in a record 25 countries planted 125 million hectares of biotech crops in 2008, versus 81 million hectares in 2004. Fifty-three per cent of soybeans today are genetically modified, followed by maize (30 per cent), cotton (12 per cent) and canola (5 per cent). If the USA as pioneer country is still the leader with 62.5 million hectares, one-third of the genetically modified organism (GMO) surface worldwide is located in Argentina, Brazil, India, China and Canada. The ISAAA forecasts that the global GMO surface will almost double to top 200 million hectares cultivated by 20 million farmers by 2015.

But no country comes near the USA in total GMO hectares: 85 per cent of its maize crop is Bt corn; 87 per cent of its soybean output and 90 per cent of its cotton. However, emerging economies lead by China, India and Brazil are catching up fast; any of the three might soon overtake the USA.

Europe so far has abstained from planting GMOs, with the exception of Spain, where biotech corn was grown on 65,000 hectares in 2008, compared to 58,000 ha in 2004. In 2008 seven European Union countries officially planted Bt maize, which covered 107,719 hectares, a 21 per cent year-on-year increase from 2007. The seven EU countries listed in order of biotech hectarage of Bt maize were Spain, Czech Republic, Romania, Portugal, Germany, Poland and Slovakia. Because of its domination in GMO research, the USA attracts many young European scientists and leading European companies, such as Syngenta.

The biotech pioneers in green life sciences include:

- **Hybrid rice in the Philippines**. Filipinos are Asia's biggest rice eaters, consuming on average 400 grams per day per capita. Increases in the price of rice, or shortages, are thus a political issue, which the government counters regularly with subsidies. The Philippines is a major rice producer but also a net rice importer, as the traditional rice varieties do not produce a harvest sufficient to feed the whole population. In some mountain areas, such as the famous rice terraces of Banaue – a UNESCO world cultural heritage site – the harvest is even insufficient to feed the rice farmers and their families.

A new variety of genetically modified hybrid rice has three major advantages over traditional rice: it contains vitamin A and prevents blindness of the elderly, it is drought resistant and its yield per acre is a multiple of the present variety. In view of these advantages, the Philippine Government decided in 2003 to plant the hybrid rice in the hope of turning the country from a rice importer to a net rice exporter and thus considerably improving the country's balance of trade.

In 2002, the country had 20 ha of experimental farms in Davao Oriental, according to the Philippine Department of Agriculture. In 2003, the country had 3500 ha of hybrid rice. Farmers who previously harvested only 3.5 tons or 70 cavans of rice per hectare can now reportedly harvest up to 130–160 cavans per hectare per season.[12] Despite its advantages, hybrid rice had not yet witnessed a commercial breakthrough by 2008. It however continues to be an integral part of research projects. In fact, there is a hybrid rice that is resistant to 'Tungro', a viral disease, and has a high nitrogen-use efficiency.

China may soon take the lead of GMO rice. Officially, no such rice is planted today, but China rice imports into the European market have recently been rejected because of contamination with GMO rice. It can be expected that the Chinese government will officially permit GMO rice plantations – which might make it easier for such countries as the Philippines to follow them.

- **Cassava** is another staple food under research, which in its natural form is low in proteins and difficult to store. Correcting these 'genetic defects' and adding vitamin A and E through genetic modification would help million of people feeding mainly on cassava today. As this research is supported by the Bill & Melinda Gates Foundation, the resulting GMO plants will not be patented and remain in the public domain.
- **RIKEN's drought-tolerant plants**. One of Japan's independent administrative institutions, the Institute of Physical and Chemical

Research (RIKEN), announced on 3 December 2004, that it had successfully identified a drought stress-activated protein kinase (SRK2C) contained in plants and produced a drought-tolerant plant. Its commercialisation is unknown.

- **Bt (Bacillus thuringiensis**). Bt has become one of the major tools to combat insects. Peter Lüthy, a Swiss professor emeritus and leader in the research on Bt, today works on pilot projects to fight malaria-infected mosquitoes around Lake Victoria in Africa and in Lugano in southern Switzerland. Working in Africa demands close collaboration with the local population and administrations.

  Another application of Bt is in agriculture to fight crop-damaging insects. The use of Bt worldwide is estimated at US$144 million, of which 56 per cent is in crop and 44 per cent in non-crop applications. Two-thirds of the use in non-crop applications is in forestry, followed by one-fifth of applications in public health. Yet, the role of Bt in forestry is not dominant; the global market for pesticides in forestry is estimated at US$750 million, of which Bt accounts for less than 10 per cent.[13]

  According to ISAAA, Brazil planted GMO crops on 16 million hectares in 2008; 60 per cent of the soybean and 15–30 per cent of the corn harvests now come from GMO plants.

  Of all countries that have recently turned to GMO plants, China has been the quickest adapter. Bt cotton was introduced in 1997; by 2004, 3.7 million ha out of a total surface of planted cotton of 5.6 million ha were reserved for GMO crops. In north-east China, nearly all cotton plantations use Bt seeds. In the north-west however, where cold winter temperatures reduce the number of pests, Bt cotton is not dominant.

  In India, Bt cotton was introduced in 2002; a year later, it was planted on 100,000 ha and in 2004 on 500,000 ha, in 2008 this figure had risen to 7.6 million hectares, equivalent to 85 per cent of the total cotton acreage. In the beginning, the Bacillus thuringiensis gene made Bt cotton resistant to attacks from insects, thus requiring considerably fewer chemical sprays per annum than conventional cotton. Today, 150 different variations of Bt cotton exist in India and allow a choice according to regional needs. Ninety-five per cent of Indian cotton farmers today use Bt cotton; it is estimated that the use of pesticides has shrunk by 40 per cent while the yield has risen by 30 to 40 per cent.

Bt seeds cannot be planted in the European Union. However, the European Commission in 2005 granted Monsanto permission to sell its

GMO maize GA21 and MON863 as foodstuff, and MON863x810 as feed-stuff for animals. In April 2009, the German Government joined Austria in banning the planting of MON810, disregarding the European Union's acceptance of MON810 seeds.

Ethical questions arise in some countries with regard to certain applications of green life sciences: Cultivating GMO crops like hybrid rice makes sense in countries with a shortage of food, such as the Philippines. In Brazil, GMO soybean cultivation, which is now the norm, has considerably reduced agrochemical use and related health hazards. In Continental Europe, which enjoys a large surplus of agricultural produce, part of the population opposes the use of GMO plants, which has forced industry and academia to pursue research abroad. While local agriculture, often heavily subsidised, does not need GMO crops today, it may depend on this research later.

Genetic modification technology is opening the door to arguably the most significant advances yet in agriculture, focused on improving the 'output traits' of crops. Plants consist mainly of starch and cellulose. Through genetic modification, we are beginning to understand how to modify these components so that plants can be 'dedicated' to the production of other substances such as industrial raw materials. There are already two major processes in the USA producing various types of plastic from genetic modification maize – a renewable method of replacing oil-based manufacturing. In the pipeline are raw materials for a growing range of hitherto oil-derived industrial products such as pharmaceuticals, paints and cosmetics. These advanced applications mean that farmers will be producing far more valuable crops than today's cereals, pulses and root crops destined for human or animal consumption. Given the enhanced demand for quality of production and timeliness required by such crops, they will be more suited to developed countries. This, in turn, may allow developing countries nearer the Equator to assume a bigger role in producing commodity food crops whose lower value per tonne renders them unattractive for the higher-cost/lower yield agricultural economies of developed countries.

The above are examples of smart solutions in green life sciences. Other examples concerning bulk biogoods that are simply 'greener' alternatives to bulk goods of the Industrial Economy – such as biodiesel, bioethanol and processes turning waste into fuels – do not fulfil the criterion of a higher value-per-weight ratio are described in Section 3.4.3.3.

Using foodstuffs to produce car fuel in a world where hunger is still a reality for a third of the total population is questionable. Yet many industrialised countries with surplus agricultural production favour this trend. There is, however, no question about the importance of projects to transform wood and agricultural waste into car fuel that is being studied in many countries. Examples of transforming surplus produce into marketable products are listed in Section 3.4.3.3.

The next generation of green life sciences will increasingly be characterised by the phenomena of a convergence of science. Future smart applications of life sciences will be in biotechnology, in food and nutrition and in bioengineering to produce new materials, processes and products. The Scottish Crop Research Institute (SCRI), for example, is involved in work to treat Alzheimer's disease with blackcurrants. Using waste from the production of blackcurrant juice, the researchers are looking for compounds in the berries that block or slow the protein damage causing the illness. Scientists at the Rowett Institute in Aberdeen have discovered a tomato extract that prevents blood platelets from being activated in response to stress and ageing, which may help to treat heart disease.

1.2.2.3 Material sciences

There have been many recent advances in material sciences, notably lightweight air- and spacecraft, which represent a reversal of the historic 'bigger-better-faster-safer' syndrome that was persistent from the Wright brothers to the Airbus A380 double-decker plane.

The development of lightweight spacecraft is but one spectacular advance that has also led to other innovations. Global automated teller machines (ATMs) to draw cash worldwide with a local bank card, global mobile phone services and new forms of civil society developing through the Internet are but a few examples that would have been unthinkable if it were not for the revolutions in modern material sciences enabling cheap space activities.

Research into lightweight aircraft with inflatable wings – as well as inflatable bridges and structures – is supporting the trend towards lightweight or dematerialised solutions. New materials will also impact 'old' goods, such as traditional aircraft. The successors to the Boeing 737 and Airbus A320 could offer reductions in fuel consumption of 20 per cent, and in purchase price of 40 per cent, thanks to the use of new high-performance materials.

Superconducting materials[14] are a good illustration of the patience needed in innovation. To appreciate the revolutionary aspect of the 1986 discovery of the first high-temperature superconductor, it is useful to review its historic development. In 1908, Kamerlingh Onnes succeeded in liquefying helium at a temperature of 4.2 K or –268.9°C. Three years later, he discovered that mercury completely lost its electrical resistance at this temperature. However, it turned out that zero resistance is not a sufficient condition for superconductivity, and more discoveries were necessary to advance superconductivity, such as the Meissner effect of an external magnetic field and the formulation of a microscopic theory of the phenomenon by Baarden, Cooper and Schrieffer, were necessary to advance superconductivity.

But it still came as a shock when in 1986 J.G. Bednorz and K.A. Müller from the IBM Zurich laboratory announced the discovery of a Ba-La-Cu-O compound (–243°C) that led to the scanning tunnel microscope, which opened the door for nanosciences, and for which Bednorz and Müller later received their Nobel Prize. Progress leapt forward and produced an avalanche of publications. The next decisive step came less than a year later when the group of C.W. Chu from the University of Houston and of M.K. Wu from the University of Alabama discovered the Y-Ba-Cu-O compound, enabling superconductivity above the boiling point of nitrogen (–195.8°C), which can now be substituted for the expensive helium as coolant.

Today, researchers continue to look for the ideal cheap superconducting material that will work at room temperature. The race is still on, and nobody knows who will win. Among the pioneers:

- **Scaled Composites in space.** SpaceShipOne and its carrier plane White Knight won the Ansari X Prize of US$10 million on 4 October 2004, when it became the first privately manned and financed spacecraft to fly higher than 100 km twice within two weeks over the Mojave Desert in California. Brian Binnie thus became the second commercial astronaut of history. SpaceShipOne broke the sound barrier three times and reached an altitude of 100,124 m before gliding safely back to Earth.

  A few days earlier, the car-sized spacecraft, weighing less than two tons, had performed a first flight. Its pilot Mike Melville, the first private astronaut, aged 63, broke several unwritten rules: that spacecrafts must be heavy, state-owned and can be flown only by young people!

  Another product designed and built by Scaled Composites that has made headlines is 'Virgin Atlantic Global Flyer', with which Steve Fossett made the first non-stop round-the-world flight by a single pilot in March 2005. But already before, other extraordinary planes, such as Proton, designed by Scaled Composites founder Burt Rutan had proven that radical innovation in aviation could come from a small company based in a hangar in the Mojave Desert. Spectacular pictures are on www.scaled.com.

The latest product of this creative company is SpaceShipTwo, which will be used by Virgin Galactic, Richard Branson's company, to start commercial space travel in 2010 from airports in the USA and Sweden. The maiden flight of SpaceShip Two's carrier plane took place in December 2008 and SpaceShipTwo is expected to be ready for its first test flight in the second-half of 2009.

Boeing's dreamliner 787 will be the first commercial aircraft to consist of 50 per cent of fibre composites, including large parts of its wing and fuselage.

- **PAC-Car II running without energy.** PAC-Car II, a three-wheel research vehicle designed by the Swiss Federal Institute of Technology in Zurich, won the Shell Eco-Marathon in Ladoux, France, in June 2005, when it drove around the course with a performance of 5385 km per litre (12,666 mpg US). The shell of the car made from carbon fibre materials weighs 10 kg, the whole car 29 kg. The vehicle is driven by a hydrogen fuel cell that delivers up to 900 W at 12 V and has a maximum speed of 32 km/h. The propulsion system is based on two DC motors via a gear mechanism. More information is available at www.paccar.ethz.ch.
- **Cookson – Smart materials for the Loop Economy.**[15] The London-based Cookson Group is an international materials science company that provides materials, processes and services to customers worldwide through its three divisions: ceramics, electronics and precious metals. Cookson developed a composite powder that can be pressed into any form and, when magnetised, becomes an extremely powerful permanent magnet. After use, this smart material can easily be demagnetised by grinding it back into a powder so that it can be reused. The manufacturer wants to rent the molecules in order to reap the future benefits from its smart material, as the 'free' reuse option is open to many actors (www.cooksongroup.co.uk). One such application could be Michelin's 'active wheel', presented in Section 1.2.5.3 smart engineering solutions.
- **Electronic paper.** The Japanese Toppan Forms Company started producing e-paper (electronic paper) with a thickness of about 200 microns in spring 2006, joining forces with the SiPix Imaging Inc. of the USA. With the SiPix production method, an embossing roller makes 31-micron-diameter indentations on the surface of a film. A liquid containing a fine powder is put into the indentations which are then covered by another film. When voltage is applied,

the powder moves and displays single-colour characters or still images. Toppan Forms expects to slash production costs for its e-paper by using this method. E-paper is one half of the systems solution discussed later in this chapter.

- **Meyer-Mayor – Producing sailcloth for champions.** The sailcloth that gives yachts – such as those used by the Swiss Alinghi team and its New Zealand rival in the America's Cup – their speed on down-wind runs is produced by Meyer-Mayor, a small Swiss company based in Neu St Johann. This spinnaker is an unbelievably tightly woven synthetic fabric weighing only 25 g/m^2. Standard white paper, by comparison, weighs 80 g/m^2. The cloth is tear-resistant, absorbs virtually no moisture and has characteristics in the wind making it ideal for racing yachts. Meyer-Mayor produces its spinnaker fabric exclusively for Contender, a Dutch sailcloth company. The sails weigh 30 g/m^2 and cost €22/m^2, or €800/kg.

Meyer-Mayor sails have a value-per-weight ratio of €800/kg.

- **SAMARIS – Ultra-performing fibre concrete.** A high strength fibre-reinforced concrete to repair and upgrade existing concrete structures was developed within the European Sustainable and Advanced Materials for Road Infrastructure (SAMARIS) research project by the Swiss Federal Institute of Technology in Lausanne. Part of a family of fibre composite materials developed by the Paris-based *Laboratoire central des ponts et chaussées* (LCPC), this ultra-compact cement is reinforced with short steel fibres that give it exceptional qualities compared to traditional concrete. The new material does not require compacting when applied and through its density does not absorb water, gases or chemicals, such as salt from de-icing in winter.
- **Designed performance sustainable concrete** is a new development that optimises cement input in concrete production. Instead of using traditional prescription-based concrete, this approach focuses on implementing existing environmental technologies instead of R&D. It is being promoted by the Brussels-based European Partners of the Environment (www.epe.be).
- **Micro fuel cells.** Hitachi Ltd, a Japanese electronics company, started commercialising the first micro fuel cell for portable electronic goods, such as PCs and mobile phones, in 2007. Micro fuel cells will replace the batteries and accumulators used today.

These devices, which have the potential to deliver more energy per volume weight than conventional batteries, are lighter, easier to use and eliminate the waste problem of end-of-life batteries.

- **Vacuum insulation panels.** The Fraunhofer Institute for Solar Energy Systems in Freiburg, Germany, has developed composite vacuum insulation panels (VIPs) with thermal conductivity ten times lower than common insulation materials, greatly reducing insulation thickness. Conventional insulation materials cannot fully prevent heat exchanges. The ideal solution is a vacuum as created in a thermo flask. The first prototype product is a practical composite thermal insulation system that is easy to handle on a building site. The panels come in three sizes and can be cut to shape in certain places. The project was supported by the German Ministry for Economy and Employment.

  Other applications for VIPs are windows and refrigerators. As the space between double windowpanes is less than a millimetre, both the windowpanes and window frames become much thinner than conventional-energy-saving window constructions, and the material input is equally reduced.

Other new fields of material sciences are thin-film photovoltaic (PV) solar cells, metallic glass, Borazon (an industrial diamond) and such intelligent materials as those designed with supercomputers at Switzerland's Federal Laboratories for Materials and Testing (EMPA). Thin-film PV solar cells are hundred times thinner than traditional solar cells and can be applied to glass, steel and plastic materials. Their technical efficiency is half that of traditional cells, so they need more surface; but as less material and energy is used in their production, the cost is lower and the (energetic and economic) depreciation periods shorter compared to crystalline PV cells.

Metallic glass, which was discovered in 1960 at the California Institute of Technology, has twice the strength of glass and four times the elasticity of steel. So far, the material has been produced mainly in laboratories, but start-up companies, such as the Swiss Advanced Metal Technology Company, want to mass-produce metallic glass for medical implants and surgical instruments. Other potential applications are parts for watches and small electronic goods.

Borazon is an industrial product made of boron and nitrogen and has abrasive properties similar to diamonds. Compared to other materials used in cutting and shaping tools, Borazon works at higher speeds and is more precise over longer time periods.

The world market for Borazon is estimated at an annual 16 tons with a value of US$30 million, or US$2000/kg.

The value-per-weight ratio of Borazon is US$2000 per kg.

For many smart materials, manufacturers must sell the material's performance in the context of the Functional Service Economy[16] if they want to profit fully from their innovation. This creates a chain reaction, as the manufacturer of the final product must rent its goods to the final customer in order to guarantee the return of the smart material to its producer. The same applies to e-paper (electronic paper), another smart systems solution that can thrive only within the Functional Service Economy.

In such cases, an initial high value-per-weight ratio is further boosted with each reuse. The more often and the more intensive a smart material is reused, the higher its value-per-weight ratio over its lifetime becomes.

1.2.2.4 Nanosciences and nanotechnologies

Chemists have for many decades made polymers, which are large molecules made up of nano-scale subunits. And for the past 20 years nanotechnologies have been used in computer chips and memory devices. Equally, nanoparticles have long existed in natural form, for instance in air pollution. Smokers produce nanoparticles, as do diesel engines, catalytic converters and wood-burning stoves.

But it was only at the end of the last century that scientific instruments enabling us to see and measure nano-sized particles were invented, starting with the scanning tunnelling microscope of Bednorz and Müller in 1986. These scientific advances gave a major boost to nanosciences and nanotechnologies, resulting in the creation of smart or 'functional nanotechnologies', such as the construction of nano-sized elements with desired characteristics,[17] allowing the exploitation of the nanodimension in medical and industrial applications for the benefit of all. But nanosciences also enabled us to see the existence of nanoparticles from all types of combustion processes, with an as yet unknown impact on human health, animals and the environment.

Nanosciences aim to understand and use matter on its smallest scale, namely, atoms. In 1959, US physicist Richard Feynman was the first to foresee the synthesis of any molecule through a designed manipulation of matter at atomic and molecular scale to construct materials with desired characteristics. The size of atoms, approximately a nanometre or one thousand millionth of a metre, has given the science its name.

In 1965, Richard Smalley, a US chemist, became the grandfather of nanotechnologies by discovering the so-called 'fullerenes' – molecules consisting of 60 carbon atoms – for which he received the 1996 Nobel Prize in Chemistry. Later on, it was discovered that these molecules also occur naturally in Russian coal mines.

Why do nanosciences enable quantum leaps in resource productivity? In nanosciences, properties differ significantly from those at a larger scale. Efficiency increases are exponential to the reduction in weight and size, as the ratio of volume to surface changes radically. This logic is inherent to the nanoscale[18] and therefore true for nanomechanics, nanochemistry, nanomedicine and other nanotechnologies. The smaller a 'product', the more efficient it is and the higher the sales price it commands – the very definition of the Performance Economy. The liability aspects of nanoparticles are discussed in Section 1.2.2.4.2.

Problematic for human health are ubiquitous nanoparticles, which are used in large quantities in several forms:

- ubiquitous in polluted air and water,
- in such consumer goods as food and cosmetics,
- integrated into durable goods, such as stain-repellent textiles, electronic products and automotive paints and
- functional particles in medical applications.

A 2004 report by the UK's Royal Society and Royal Academy of Engineering recommended that nanoparticle production be continued, that more formal research be undertaken and that nanoparticles be treated as 'new chemicals'. The domain of nanosciences has a long track record of successful examples related to the Performance Economy.[19] Super-fine particles are already being incorporated into a number of cosmetics and composite materials to improve their performance. The report therefore also recommended that the manufacturers' product test results be more widely publicised.

Nanoproducts, such as carbon nano-tubes (CNTs) made of fullerenes, and nano-structured surfaces are increasingly being developed. The former are part of research into intelligent components and systems, the latter make it possible to modify the properties of surfaces with a desired function – scratch-proof, dirt repellent, electrically conducting or anti-bacterial. These technologies are used in microelectronics, optics, power engineering, sensor systems, medicine and bioengineering. The vacuum insulation panels mentioned above are also based on nanotechnologies.

Nanocomponents, such as sensors and motors, can be used in nanorobotics and could change the way that medicines are distributed in the human body, enabling the targeting of drug delivery. CNTs are lighter and stronger than steel and also conduct electricity well. Methods are being developed to spin CNT into usable components, such as thin sheets made of trillions of individual CNTs. The resulting ultra-light material would weigh a few ounces per acre and could be used in medical and technical applications.

The resulting ultra-light material would weigh a few ounces per acre and could be used in medical and technical applications.

Products integrating nanoparticles available on the market include disk drives with nanometre layers to increase data storage, lipid (fat) globules for anti-cancer drug delivery, stain repellent and waterproof textiles, anti-fungal sprays and fabrics, novel coatings, paints and pigments.

Some of the ubiquitous nanoparticles in air pollution are the result of measures to save the environment in the 1970s, especially catalytic converters. Depending on vehicle speed and engine size, 0.07–2.0 microgram per kilometre of platinum is lost to the environment, adding up to several tons per annum worldwide. The potential toxicity of platinum nanoparticles was not researched before legislators ruled catalytic converters mandatory in many countries. Below are some of the pioneers and champions:

- **Applications of nanotechnologies.** Since the early 1990s, nanotechnologies have been successfully used to create non-stick surfaces in kitchen ovens and boiler chambers, making cleaning superfluous. These nanotech surfaces are rough, like the leaves of the lotus flower, which is why this surface is sometimes referred to as the 'lotus effect'. More sophisticated functional applications, however, are expected to be introduced into the market soon.
- **Pilkington**, a major UK glass manufacturer, has produced 'active' windowpanes that no longer need cleaning – a substantial cost advantage in the management of high-rise buildings. An invisible nanotech coating reacts with the sun's ultraviolet rays to dissolve

the deposits of organic compounds, which are then washed off by the next rainfall.

- **Amorphous carbon coatings.**[20] Plasma-enhanced chemical vapour deposition (PECVD) enables the application of thin film coatings on objects for decorative and functional purposes, such as watchcases and clockwork parts. These thin films are chemically inert, extremely hard and durable, which makes them ideal for 'tribological' applications to reduce the need for lubricating moving parts, to extend the service-life of critical components and to reduce the maintenance costs of machinery.

  Amorphous carbon is produced in an environment of organic gases in a low-pressure electrical discharge; the coatings are formed by condensation of the activated organic vapour. The only waste is carbon deposits on the inside walls of the machine. The cost of the applied coating depends on the geometry of the parts, and is highest – €40,000/g – for small applications.

> The cost of applied amorphous carbon coatings can reach €40,000/g of carbon.

- **Magnetic ferrofluids.** Ferrofluids are liquids that contain nanoparticles of iron, cobalt or nickel. Due to their high magnetic property, these particles can be attracted and directed with small magnets. Without the influence of magnets, ferrofluids behave like any fluid. Influenced by a magnet, they behave like a solid body, thus making them of high interest in medical applications and technical processes. In cancer treatment, magnetic ferrofluids can be used to transport medicine through the blood vessels to a tumour and then be fixed using magnets. Magnetic ferrofluids have left the domain of basic research and are now being used in many technical as well as medical applications.

  Ferrofluids are difficult to produce and must be designed specifically for each application. They are also costly. One milligram of Fe_2O_3, for instance, can cost US$100–500, or US$100,000–500,000/g. One litre of a custom-made ferrofluid can cost up to €15,000.

> The value-per-weight ratio of Fe_2O_3 can be as high as US$500,000/gram.

- **Memory devices.** From 1992 to 2003, resource productivity in the digital memory devices in Japan increased 10,000-fold, measured in mips (million instructions per second).[21] But technical progress and economies of scale in manufacturing reduces the value-per-weight ratio quickly. Smart products of the Performance Economy thus can rapidly become bulk products of the Industrial Economy and go out of production.

The value-per-weight ratio of a memory stick in 2008 was about €8000/kg.

1.2.2.4.1 Pioneers: Nano-structured micro-reactors and 'labs-on-a-chip' in chemistry

Chemical micro-reactors will be able to open new and safer production methods in future. Relative to their tiny volume, micro-reactors have a huge surface to absorb heat or free molecules produced in chemical reactions. As chain reactions in nano-structured micro-reactors are easier to control, substances considered too dangerous can be used. Mixing oxygen and hydrogen to produce water in space could be such an application; handling gaseous fluor in chemical reactions another. Many research centres have built and are using nano-structured micro-reactors. Novartis, a Swiss pharmaceutical company, already uses this technology in production processes. And the Swiss speciality chemical company Clariant has found another advantage of nano-molecules: a considerably higher purity and performance of colour pigments.

Lab-on-a-chip systems have a design similar to electronic chips, but with minute quantities of fluids circulating instead of electrons: nanocanals, valves and reaction chambers have replaced the transistors. A team from Stanford University and University of California in the US has succeeded in producing radioactive marked substances (fluorodeoxyglukoses, FDGs) used in positron emission tomography in a lab-on-a-chip. The traditional equipment needed to produce these substances easily fills a whole room.[22]

Due to the tiny size of nano-structured equipment, small quantities of chemicals can be safely produced where they are needed. This makes the transport of hazardous substances over longer distances superfluous and favours a regional economic development. Also, some nanoproducts such as CNTs cannot be transported without getting tangled up, or have a short life, such as fluor-18 used in FDGs. In both cases, they have to be manufactured locally at the place of their utilisation, thus favouring a decentralised economy.

Nano-structured microreactors, often a development of micro-structured technologies, raise new questions of intellectual property and patent protection. Before these issues are solved, few companies are prepared to talk publicly about their innovations in nano-structured microreactors. The following are examples of this new development:

- **DSM's micro-reactors to produce fine chemicals.** Chemicals are produced in batch or flow processes. If these chemical reactions produce large quantities of heat, their control can be difficult or, on an industrial scale, even become dangerous. In case of a problem, the reaction accelerates and the reactor can overheat and explode. Controlling the heat is easier in the case of small, thin tubes or large heat-absorbent surfaces. Micro-reactors function similarly to super-computers, which consist of thousands of parallel microprocessors. The DSM Fine Chemicals company has succeeded in building the first suitcase-size parallel reactor capable of treating 1300 kg of raw material. The resulting fine chemicals are of perfect quality, which was impossible until now. In addition, the process has a very high safety record as only few litres of chemicals are in the micro-reactor at any given time. If the process starts to overheat, the raw material input is replaced by water.

New products or processes in an early research phase give an indication of things to come, even if the lead time may be long and many developments may be abandoned later on. The following list highlights the broadness of the applications that are being researched in Japan: anti-cancer treatments, apple polyphenols, muscle stem cells, functional amino acid tablet, tumour growth inhibitors, artificial vision, adenovirus, pancreatic cell transplant, vitamin seaweed jelly, fat-control enzyme, laser surgery on brain tumours, anti-ageing chewing gum, gene-specific drug development, nano-tube capacitor, water-soluble starfullerene, tiny MEMS actuator, largest liquid crystal display (LCD) TV, faster supercomputer, sugar-powered fuel cell, acid typhoon, lightweight solar cell, animal waste power, obstacle sensor, super-conducting wire, highest-resolution SEM and high-tech chemicals.

Some future applications of nanosciences include: organic light emitting diodes (OLEDs) for displays, photovoltaic film that converts light into electricity, scratch-proof and self-cleaning coated windows, fabrics coated to resist stains and control temperature, intelligent clothing that measures pulse and respiration, light but very strong carbon nanotube (CNT) frames, hip joints made from biocompatible materials, nanoparticle paint to prevent corrosion, thermo-chromic glass to regulate light, magnetic layers for compact data memory, CNT fuel cells to power electronics and vehicles and nano-engineered cochlea implants. And this list is neither complete nor exhaustive!

> *One major obstacle in the development of nano- and biotechnologies is the structure of the present Industrial Economy: the net gains and value added lie at the end of the production process, in the marketing and commercialisation of goods. Cheap raw materials treated as commodities are transformed into high-value products by the value-added of manufacturing processes.*
>
> *Some of the smart solutions of the Performance Economy described above put this economic power and value structure on its head, as value added is now largely embedded in smart materials, which are situated at the beginning of the production process. The economic power is thus no longer the result of high-volume production processes.*

1.2.2.4.2 The liability of nanotechnologies

An issue of concern to insurance companies and policymakers is the liability of nanoparticles. A distinction between bulk and smart particles may provide the answer.

- Ubiquitous (bulk) particles, for example, in air pollution, which may pose a health threat, have no manufacturer and are in the realm of public health authorities.
- Smart nanoparticles used in functional nanotechnology applications are embedded in the goods they serve, with the possible exception of the production and disposal phase. Their production is already the manufacturer's responsibility and must follow occupational health and safety guidelines; contrarily, the goods' end-of-life phase, which often can be controlled only by the manufacturer, today is managed by waste managers.

The business models of the Functional Service Economy in Chapter 2 enable the economic actors – manufacturers, distributors and their insurers – to avoid liability claims following an uncontrolled release of functional nanoparticles during the disposal of the goods if they accept an extended performance responsibility over the full life cycle.

1.2.2.5 Convergence of science

Since its early days, science has been organised into disciplines. And even if the opportunities hidden in inter-, trans- and multi-disciplinary activities have been discussed for some time, any scientist eager to make an academic career is well advised to stick to his discipline.

The first example of the convergence of science may have been 'computer science'. This academic field exists in part thanks to IBM's insistence that it was not something that belonged to the physics, engineering or mathematical departments. Another one is 'space engineering'. Similarly to computer science, space engineering is emerging as a separate discipline with its own chair, such as the one created in 2009 at the University of Surrey, located in England's district of microsatellite businesses.

Yet most life- and nanosciences and bio- and nanotechnologies are genuinely interdisciplinary and have prompted collaboration between researchers in previously disparate areas to share knowledge, tools and techniques, from chemistry and physics to biology, medicine and engineering.

Nanotechnologies have also proved to be valuable tools to verify the validity of existing methods. Dialyse filters used for patients with kidney insufficiency are one example. Nanotechnology has allowed the verification of the proper functioning of these filters: the particles that pass through the filter have the size of a nanometre, which means that the filters have holes of the same size. Nanotechnology in this case acts as enabler, allowing the safe re-sterilisation and thus reuse of dialyse filters in hospitals.

Other new emerging sciences are inter- or multi-disciplinary by nature, such as biophysics and pharmanutricals, pharmacogenomics and pharmacogenetics. Other applications stem from looking at the human body as bioreactor, enabling self-healing through combinations of bio- and material sciences. Research to better understand the way nature functions has led to such new approaches in chemistry as polymerase chain reaction and DNA-templated chemistry.

Although biophysics has existed as a scientific discipline for some 50 years, it was only at the beginning of the third millennium that biologists and physicists met in California to discuss how they could merge their knowledge for their mutual benefit.

Nanoparticles can have several competing functions that may call for arbitration. Silver atoms, for instance, have been used in medicine as an antibiotic of last resort but are now being used to coat toddlers' toys to make them germ free. This could deprive medical doctors in hospitals of the ultimate weapon to fight infections in children.

Humankind is only at the beginning of the age of converging sciences. The above examples give an order of magnitude but cannot provide a complete or comprehensive picture of the hidden potential. Predictive medical diagnostics is typical for this development as it combines experts from medicine, molecular biology, biochemistry and life sciences. Many of these experts have degrees and experience in several of these fields.

1.2.3 Prevention strategies

Already part of the earliest stages of the knowledge economy, prevention is based on experience and expertise in risk management, which is a body of multi-disciplinary knowledge in itself. And prevention solutions work best if they are built on a socially and systemically integrated approach.

The value-per-weight ratio of prevention is summarised in the proverbial expression ‘An ounce of prevention is worth a pound of cure’, and as any amount divided by a small resource input results in a very high ratio, it is infinite in the case of any number divided by zero. Nevertheless, the economic productivity of prevention cannot be measured precisely, as it is difficult to know how many losses were prevented by any action taken.

In the Industrial Economy, prevention is counterproductive, as it reduces throughput such as expenses for repair and reconstruction work, resulting in a reduced monetary flow through the economy and thus negative growth.

In the Performance Economy, prevention has a high economic value to conserve stock. As accidents and disasters have a negative impact on people, the environment and physical assets, such as infrastructure, their prevention enables conserving economic and social values.

Among the pioneers of prevention are lighthouses, which illustrate innovation driven by the need to prevent economic losses. Lighthouses are among the oldest and most durable solutions to guide ships safely through dangerous waters.

With the development of commercial shipping, preventing shipwrecks became a growing economic concern. One solution to reduce the risk to an acceptable level was insurance, developed as a risk-sharing strategy of a pool of ship owners all facing the same risk: bankruptcy in case of a shipwreck.

Another solution was building lighthouses on or near hazardous rocks at sea level. This enabled ships to avoid the hazardous rocks and to continue their trip safely. It also deprived the inhabitants of nearby villages from their income as salvagers.

At the time, no technology existed to enable the ships to 'see' the rocks. But even if the technology had existed, the cost of equipping a certain number of rocks with lighthouses was, in the long term, cheaper and more reliable than to equip all ships with adequate technology. Lighthouses are thus a truly systemic solution that vastly improved the safety and economics of shipping (the system) without changing the design of ships (the product at risk)! Modern equivalents to lighthouses are, for instance, public tsunami warning systems.

Predictive medical diagnostics is an emerging example for the convergence of science as it combines experts from medicine, molecular biology, biochemistry and life sciences. Many of these experts have the educational background and an expertise in several of these fields (Golubnitschaja, Olga, 2009). In Europe, this field is coordinated by the 'European Association for Predictive, Preventive and Personalised Medicine' (www.epmanet.eu).

1.2.3.1 The key role of knowledge in prevention

The issue of prevention can be explained by giving an outlook for future treatments of the leading causes of human morbidity and mortality, which are cardiovascular and cancer diseases.

Predictive, preventive and personalised medicine play an essential role in **diabetes care**, as the increasing number of diabetics present a serious health-care challenge to most industrialised and developing countries. Overall, direct health-care costs of diabetes range from 2.5 per cent to 15 per cent of annual health-care budgets. (Worldwide, a patient dies of diabetes-related illness every ten seconds.) Given the high risk and prevalence of secondary complications as well as individual predisposition to target organ injury, diabetic pathology is one of the best examples for the application of predictive diagnosis combined with preventive measures and personalised treatment. The prevention of diabetes and its complications requires a well-coordinated multifaceted approach using broad multidisciplinary expertise.

Diabetes prevention programmes should combine:

- education,
- individualised nutrition as predictive diagnostic tools,

– novel molecular targets,
– non-invasive diagnostic approaches,
– targeted prevention of severe complications secondary to diabetes and
– personalised treatment of diabetics.

In fighting **breast cancer**, early and predictive diagnosis is crucial, because it is the most common cause of cancer death among women in both developed and developing countries, with an average incidence rate of one in ten women. Annually, breast cancer causes some 502,000 deaths worldwide. Advanced stages of breast cancer lead to the development of metastasis predominantly in the lymph nodes, bone, lung, skin, brain and liver. Early diagnosis has been demonstrated to be highly beneficial, enabling significantly enhanced therapy efficiency and possibly full recovery (Braun et al. 2009).

Mammography, ultrasound and magnetic resonance imaging (MRI) are techniques currently being used to diagnose breast cancer. But a major disadvantage of both mammography and ultrasound is the low resolution, which does not allow the crucial early diagnosis of breast cancer. Although MRI is currently the most sensitive diagnostic tool for breast imaging, its specificity is limited and its clinical application is relatively expensive, which makes it unsuitable for routine population screening. Furthermore, all three techniques have a limited success rate and can detect only developed solid tumours, the treatment of which is exorbitantly expensive and may reduce the patients' quality of life and life expectancy. Therefore, science is increasingly developing new methods that adapt treatment according to the patient, albeit at a high cost.

Early and predictive molecular diagnostics is one alternative route taken by scientists pursuing a new technology approach that allows disease prediction and even prevention. Among them is the promising approach of utilising blood proteomics technology in conjunction with molecular screening, establishing specific diagnostic markers and following up with *ex vivo* monitoring. The human differential blood proteome holds the promise of a revolution in epidemiologic screenings, disease diagnostics and therapeutic monitoring, provided that major challenges in proteomics and related disciplines can also be addressed in oncology. About 3000 protein products are normally present in human blood plasma; abundant scientific evidence from proteomics and other disciplines suggest that protein patterns and structures change in ways indicative of many – if not most – human diseases. This technology promises a broad impact, such as a quick and precise diagnostics and low costs for the evaluation procedure (10 times cheaper than MRI). This will allow broad population screening along with a prediction and even a prevention of the disease (Golubnitschaja 2009).[23]

The pioneers and champions of prevention include the following:

- **DuPont de Nemours**, the international chemical company with one of the best safety records, is selling its knowledge to other companies under the slogan of 'Safety Excellence – Business Excellence'. DuPont Safety Resources is a division of the Growth Platform 'Safety and Protection' (see also Section 1.2.1).
- **Professional cooperatives, innovation driven by peer pressure.** German industry is organised in craftsmen's cooperatives (*Handwerkskammern*) that are similar to and have the same political standing as the chambers of industry and commerce. Craftmen's compensation insurance in Germany is organised by professional groups (*Berufsgenossenschaften*), which cover accidents separately for each profession. Accidents must be reported to the insurance scheme and are investigated by peers. The lessons learned are communicated to all members of the group. If the workers or supervisors involved in the accident are at fault, their insurance premiums automatically go up.

  This system with a built-in incentive to reduce the number of accidents and the corresponding costs has worked as an excellent mechanism for prevention over a long time and across many technological changes, but it can be an obstacle to change in today's society.
- **Incident reporting systems, innovation driven by knowledge management.** The explosion that destroyed a chemical plant and most of the village of Flixborough in the 1950s was the wake-up call for risk management in the UK. As a result of the Flixborough accident, which claimed many lives, the British chemical industry installed a central 'incident-reporting office'.

  Incidents of a similar nature precede most disasters but do not necessarily lead to a disaster. As many of these incidents are due to human mistakes or negligence, the people involved fear punishment or are too embarrassed to talk. Reporting all incidents and accidents to a central incident-reporting office, which freely distributes the neutralised information to its members, helps chemical manufacturers to learn from these mistakes and prevent future accidents.

  John Kletz,[24] one of the early British experts in risk management, used to say that 'risk management is not another coat of paint'. Risk management demands fundamental changes in systems design. In the case of Flixborough, the batch process was changed to a flow process, reducing the volume of potentially explosive material within the chemical process from one tonne to one kilogram – and the risk by a factor 1000.

Similar incident-reporting systems have become common in areas such as civil and military aviation, both for near-misses and crew communication problems.

- **In-orbit anomaly reporting systems.** A proliferation of space debris and orbital debris has arisen over the last 50 years through collisions and deliberate explosions. At the same time, the number of operational satellites has been increasing every year. There is therefore a case to be made for loss prevention in space. This could be tackled with a secure database to centralise information on in-orbit anomalies, to which operators, manufacturers, insurers, brokers and space agencies could contribute and would have access. Some anomaly tracking tools already exist on a national basis, but space is a truly global affair and the problem should be solved on a global level.

1.2.3.2 The cost efficiency of loss prevention: Understanding the iceberg

Risk management is the art of weighing risks and chances, or uncertainties and opportunities, but also of balancing the costs of losses versus the costs of risk minimisation. The economic efficiency of prevention can be shown after each disaster! But traditional economists argue that the 'wasted' prevention costs in cases when nothing happened must also be considered.

Advanced industrial economists point out that, in order to make a judgement, the full costs of disasters must be taken into account! Society is relying increasingly on technology with less resilience, a higher built-in criticality and systems with little or no redundancy. Electricity grids, for instance, use overhead transmission lines that are vulnerable to weather influences. An ice storm that hit Quebec, Canada, in 1991 led to the collapse of the grid pylons, which shut off an all-electric Quebec and literally froze the economy for weeks. True to Murphy's Law, disaster always strikes when you expect it least and when it will create the greatest havoc.

To evaluate the economic efficiency of prevention solutions, the total costs and benefits thus must be known. The total costs of 'un-quality' accidents and disasters can be compared to an iceberg, of which only a small part is visible – typically the total amount of insured losses. Few studies exist on the economics of the 'Cost Iceberg' of accidents[25] and disasters, or the cost of 'un-quality'. An exception is the Six Sigma Iceberg that is part of General Electric's Six Sigma Programme, which neatly summarises the key benefits of prevention to a manufacturer: increased customer satisfaction, as well as a higher quality, lower costs and delivery on time!

- Traditional quality costs – above the water line – are easily identifiable and include inspection, warranty, rejects, scrap and rework.
- Hidden quality costs – below the water line – are difficult to measure and consist mostly of missed opportunities and inconveniences to customers, resulting in fewer sales, low customer satisfaction, overtime, late delivery and lost customer loyalty. But they also affect a manufacturer's operation through longer cycle times, changes in engineering orders, low employee morale, productivity and turnover.

Prevention is an optimisation over longer time spans and across specialisation! Take the issue of prevention through the interplay of risk engineering, insurance, disaster recovery and claims management when building a new factory. The most efficient solution would be a systems management approach that includes a disaster recovery plan in the new plant's design.

However, this contradicts the conventional wisdom of an optimisation of each subsequent step, from the plant's planning and construction to its operation and, in case of a loss to the rescue interventions, the loss adjustment and recovery operations. In this traditional approach, there would be little left to recover, independently of how good the recovery management operation was.

Prevention needs a systems' approach to reduce the criticality of complex technical systems! Take the near collapse of a bridge across the Rhine on the Gotthard motorway through the Swiss Alps. It buckled after a flood had swept away one of its pillars and was closed down for a long period. The problem could have been avoided by a modest increase of 1 per cent in the bridge's initial construction cost, either by reinforcing the concrete slab, or by setting the pillar's foundation 5 m deeper on solid rock. In planning the bridge, the engineers failed to measure the rock's deepness at the critical place. They based their judgement on historic hydraulic data, underestimating the potential effect of a major future flood on the bridge's stability.

The bridge's repair cost was equivalent to 150 per cent of the original construction cost. But the economic cost of the long-term interruption of what is the main North–South roadway through Europe was a multiple of these repair costs: longer and less efficient transport routes were necessary, the cost of which was borne by all. Preventing the near-catastrophe by deepening the foundations of the pillar on the rock face would have increased initial construction costs by only 1.5 per cent.

> The bridge's repair cost was equivalent to 150 per cent of the original construction cost. Prevention, by deepening the pillar foundations, would have increased initial construction costs by only 1.5 per cent – a factor of 100.

In 2001, the Gotthard motorway was blocked again for a long period after a head-on collision between two lorries in the main tunnel led to a catastrophic fire. The loss prevention worked with regard to the protection of human lives. A second auxiliary tunnel running in parallel and connected to the main tunnel with airlocks at regular distances enabled most people to run to safety and the emergency services to advance rapidly to the accident site. The severe heat damage to the structure, however, could not be prevented.

A similar lorry fire in the Mont Blanc road tunnel between France and Italy in the 1990s resulted in a high number of casualties. The absence of a second tunnel left victims no escape route other than the main tunnel. Firefighters gained access to the site only after the fire had burnt out.

In both cases, the cost of prevention is borne by the builder of the tunnel, while the costs of the iceberg are borne by a multitude of economic actors and individuals. Prevention thus requires a high degree of awareness and willingness to pay for the Common Good.

1.2.4 Sufficiency strategies

Sufficiency has many faces! The oldest may be the sufficiency of scarcity: 'Use it up, wear it out, make it do or do without!' was one of the maxims of the early European settlers in North America.

Another sufficiency is based on self-restraint, practised, for example, by the Amish people, most of whom settled in the Americas. Without expenses for agrochemicals, electricity, automobiles or tractors, great savings can be accumulated over longer periods. It is thus an economically, socially and environmentally profitable way of life, if the community accepts it as a quality of life and not as a punishment. In a culture-driven society, such as practised by the Amish people, sufficiency makes micro- and macroeconomic sense in the long term. The fact that it can pay in the long term by limiting oneself in the short term has been described in *The Strategy of Conflict* published in 1960 by Nobel Prize winner Thomas Schelling.

In an industrialised society, sufficiency solutions can mean turning a problem into an opportunity or a virtuous loop, in the sense of finding solutions that do away with unwanted environmental and social effects but without renouncing or reducing needs! Modern sufficiency strategies can be defined as enabling growth, namely, increased economic activity, with a substantial decrease in environmental impairment and social inequalities (Figure 1.1).

A major obstacle to the development of sufficiency solutions in the Industrial Economy is their economic impact, which is perceived as negative: sufficiency means less throughput and thus negative growth – hardly an economic incentive. Yet, already in the early 19th century, the liberal French economist Frédéric Bastiat (1801–50) wrote a famous petition (*Oeuvres économiques*) to explain this issue. In his petition, 'manufacturers of candles, lamps, candlesticks and street lamps and candle maintenance workers, as well as other businesses involved in lighting, complain to the members of Parliament about the disloyal competition from the Sun'. The petition goes on to demand a law to close all openings through which sunlight can penetrate into houses. 'For it is not the Sun that creates the demand for candles, coal, petroleum or wax, nor silver, iron, brass and crystal, to build candlesticks and lanterns, but industry. And industry then spreads wealth to its suppliers, which in turn will increasingly consume goods and spread wealth across the whole nation'.

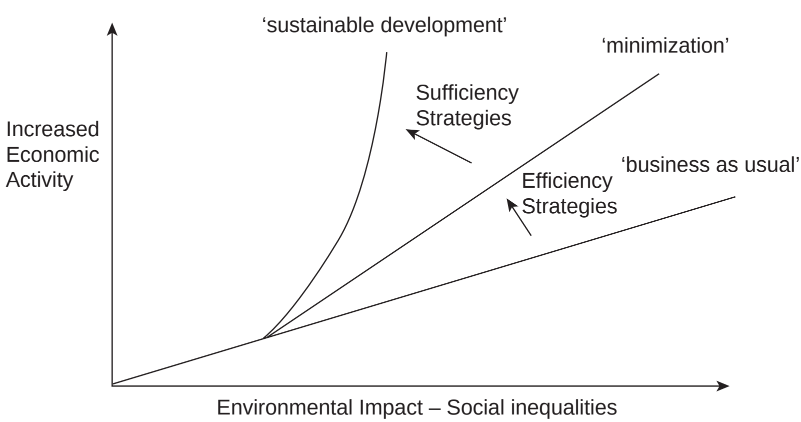

Figure 1.1 Shifting development paths towards sustainable development[26]

In the Functional Service Economy, by contrast, sufficiency solutions act as an economic driver, because the minimisation of resource inputs or efforts directly increases profits! Receiving the same amount of revenue for delivering the desired performance with fewer resources increases the competitiveness and profits of the supplier! Rising resource costs, such as oil or steel prices, will increase this profit advantage in the Performance Economy versus the Industrial Economy. Systems solutions can yet further increase this competitive advantage.

To judge the full impact of reductions in the resource consumption and related costs of sufficiency solutions, bear in mind where resources are used in the linear Industrial Economy (Table 1.3).

Sufficiency solutions have a triple economic benefit, as they:

- reduce the number of product life phases, and thus
- use fewer resources on the input side and
- create less emissions and waste on the output side.

In some cases, sufficiency even transforms costs into revenue.

1.2.4.1 Science, technology and knowledge-based sufficiency solutions

Historic sufficiency examples include anonymous ‘zero energy’ buildings in extreme climate zones, such as igloos built by the Inuit in Canada and underground habitats in the desert areas of Africa. Another example are brass containers to polish off food-poisoning bugs.[27]

Mutkas, the brass pots traditionally used to collect and store water in India, are ‘cleaning’ the water! Researchers found that bacteria such as *E. coli*, which are common in contaminated water sources in India, were killed by copper leaching into the water from the brass. The levels of copper are extremely low and safe, a fraction of the medically

Table 1.3 Resource inputs and losses during the life cycle of a product

Input costs	energy and material	energy and material	energy and material	energy and material	energy and material
main product life phases	***raw material extraction***	***manufacturing***	***distribution & marketing***	***utilisation & maintenance***	***waste collection & treatment***
Output costs	emissions and waste	emissions and waste	emissions and waste	emissions and waste	emissions and waste

recommended copper intake. However, the bacteria die after only one or two days, so villagers are urged to leave water in *mutkas* long enough and are discouraged from using earthenware or plastic containers.

Ploughing at night or lightless tilling is another anonymous historic sufficiency strategy. It reduces the amount of weeds by 90 per cent, as such natural plants as weeds need an impulse of light within a few minutes of reaching air to germinate. This method is historically well known and still used, for instance, by the Amish. As they use no herbicides but weeding by hand, lightless tilling saves them 90 per cent of work and time!

In the 1990s, a number of comparative field trials in many countries have shown the validity of lightless tilling to reduce herbicide use. But so far the method has had little success outside some small communities. Nevertheless, research continues into the phenomenon of photocontrol of weed germination.[28]

The hidden potential of lightless tilling could become of commercial interest in the Functional Service Economy selling integrated agricultural management services. If a performance manager gets paid a fixed fee for the performance or result achieved, savings in agrochemicals mean higher profit margins (see Section 2.2.2).

Similarly, the roof structures of most European cathedrals were built using beams made of chestnut trees. As woodworms hate the taste of chestnut wood, this has protected the roof timbers for centuries without chemical treatment against bugs.

There are also modern sufficiency examples by consumers.

- **Charging for plastic bags.** After supermarkets in Yamagata, Japan, started charging for plastic bags in May 2008, 90 per cent of shoppers carried their own reusable bags. By August 2008, 39 stores of nine supermarket chains in Yamagata had joined the initiative and 89 per cent of their customers shopped with their own bags. Other cities, including Nagoya in Aichi prefecture, have now started similar schemes. Nagoya hopes to reduce the volume of disposable plastic bags by 60 per cent, equivalent to 600 million bags weighing 4200 tonnes, which corresponds to 39,000 barrels of oil or 24,000 tonnes of CO_2.
- **Car-less inhabitants of Swiss cities.** The biggest Swiss city, Zurich, has a population of 400,000 and thanks to its excellent public transport network, 45 per cent of its households have no car. The Swiss capital Bern has a similar percentage of car-less households, while Basel leads with 55 per cent. In Geneva and Lausanne, the next towns by size, 35 per cent of households are car-less, while most

households in rural areas own a car. Nationwide, 19 per cent of Swiss households are car-less. However, only the urban elite are car-less by conviction; the other social groups – the elderly and low-income singles – cannot afford a car or cannot drive for health reasons. Interestingly, the percentage of the Swiss 'car-less by conviction' group has more than doubled from 15 per cent in 1994 to 32 per cent in 2009.

Switzerland has no mass car manufacturers – Rinspeed and Sbarro each produce around a hundred cars per year – and is the country where the car-sharing idea was born and is still thriving (Section 2.4.5.3). This, together with an excellent public transport network, can partly explain the high percentage of car-less households. In Germany, car-free districts have appeared in several major cities, and in the UK, the 'Autoholics Anonymous' has their own website.

But there are also failed sufficiency examples. Designed to lift and transport huge commercial loads over short and long distances, Cargolifter was the 21st century version of the Zeppelin of the 1930s. Like the Zeppelin, it boasted minimal energy consumption for both horizontal and vertical movements by exploiting the shape and uplift of the cargolifter balloon. With a length of 260 m and a diameter of 65 m, it was designed to fly a distance of 10,000 km at up to 125 km/h.

Goods weighing up to 160 tonnes with a maximum length of 50 metres could be lifted up and put into position from the hovering airship. Transporting a turbine from Germany to say a power station in India would no longer take two months, and there was no need to build access roads or railway. However, like so many other sufficiency solutions that are scientifically sound, it failed to win a viable position in the commercial markets and has disappeared.

The following are modern examples of sufficiency pioneers and champions. The wide variety of zero-energy houses by Japanese manufacturers seems to indicate an advanced industrialisation of the housing sector, a close link with high-tech companies as well as a strong competition between house-builders. The next step could be to integrate energy autonomous buildings into urban planning, in order to increase the resilience of cities – an idea that will be further explored in the section on smart systems in this chapter.

The following are modern knowledge-based examples of sufficiency pioneers:

- **Sekisui 'zero-energy cost' homes.** In 2003, Sekisui Chemical Company, a Japanese company with a strong position in the multi-storey residential building market, developed a steel-frame 'zero-energy house' based on airtight, highly insulated factory-produced panels for use in homes or multi-storey apartments. The system is completed with photovoltaic cells integrated into the panels, efficient warm-water production and a financing concept that offers lower interest rates for higher energy production ratios.

The commercial success took off only when the concept was called '*zero-utility cost house*', changing the marketing focus from the environment to the cost advantage for buyers. Sekisui, a profit-oriented enterprise, has shown that sufficiency solutions can be sold successfully in the marketplace. For more information, see www.sekisuiheim.com/english.

Higher profits could possibly be achieved in a next step by renting the houses for an all-inclusive rent, selling the function instead of selling the houses. As utility companies may not support this strategy – for them, zero-energy houses mean less turnover, less network utilisation, possibly overcapacity – they could also adopt this business model as a diversification strategy.

- **Sodis, producing solar drinking water.** In 1991, researchers at EAWAG, which is part of the Swiss Federal Institute of Technology in Zurich, had the idea to use free solar energy and disposable plastic bottles to disinfect water. On 25 April 2005, the Sodis project (solar water disinfection) received the Energy Globe's 2004 Special Prize during the 2005 world exhibition in Japan.

  The solution is simple: PET bottles filled with water are exposed to the sunlight, preferably on a tin roof, for six hours. Through the UV-A radiation and heating to 50°C, the biologic organisms in the water, such as bacteria and viruses, are killed or become inoffensive.

  As a third of the population of less-developed countries has no access to clean drinking water, polluted water is a major health risk. Sodis enables individuals in tropical countries to turn the available water into drinking water – without any expensive equipment!
- **Non-stick self-cleaning surfaces.** Early nanotechnologies from the beginning of the 1990s have been used to create non-stick surfaces in goods such as kitchen ovens and in boiler chambers, making cleaning superfluous; see also Section 1.2.2, 'Nanotechnologies'.
- **NASA's Centurion.** A lightweight, battery-powered, remote-piloted flying wing, 206 ft wide, first took to the air in late 1998. Designed to fly at 100,000 ft to monitor atmospheric changes, the Centurion was the first 'plane' that can stay in the air indefinitely, thanks to its storage of solar energy during the day. Unfortunately, after a number of successful flights, the Centurion crashed in 2004 on takeoff.

The Swiss scientist and adventurer Bertrand Piccard is now building a solar airplane, called the Solar Challenger, to fly around the world non-stop powered only by energy from photovoltaic cells on its wings.

- **Purists' sufficiency solutions.** 'I am not lazy but environmentally conscious'. This excuse for not mowing the lawn is environmentally valid, even if driven by laziness. And lawn mowing is directly linked to the sprinkling of lawns. No sprinkling means grass grows more slowly. So laziness is doubly green!
- **Sheep replace herbicides in vineyards.** The famous 'Listel Gris' vineyard in the French Camargue region was one of the first to use cereals – and sheep – to fight erosion. As the sandy soil, which is partly responsible for the tasty wine, is vulnerable to the winter mistral winds, cereals are sown after the autumn grape picking to prevent erosion. In March, some 5000 sheep are brought in to eat the cereal crop and to fertilise the soil with their manure for the next wine harvest. This approach saves the cost of herbicides and spraying, and is based on an edible and renewable resource: sheep.
- **Waterless urinals do away with water and water pipes.** Urine consists of relatively pure urea, a chemical used in processes and in products such as fertilisers. Traditional urinals use water to flush the urine into the sewer system, which limits the corrosive effects of urine but destroys its commercial value. Waterless urinals collect the urine in concentrated form for use in the chemical industry, substituting a collection service for the water and sewage piping, and substituting revenue for costs. See, for example, Urimat (www.urimat.com) or the US' Sloan Valve Company (www.sloanvalve.com), two waterless urinal manufacturers.

  A survey of 22 facilities using waterless urinals in Seattle, Washington, revealed that most were pleased with their non-flushing urinals. Enthusiasm for waterless urinals has waned over time, however, according to water conservation specialists with the Seattle Public Utilities. The problems can be traced to two factors: improper installation and maintenance! Installations with no slope will break down; similarly, inappropriate maintenance will lead to failure. Although an efficient water saver, this sanitary equipment requires maintenance staff willing to learn new procedures; otherwise conventional urinals may be a more satisfactory solution.
- **'Constructed wetlands', reed-based wastewater treatment plants.** Many small towns in industrialised countries use nature – natural and artificial substrates and wetland plants – to transform wastewater into

clean water. Teuffenthal, a Swiss village near Berne with 336 inhabitants, uses a reed field of 1130 m^2 instead of a biological–mechanical treatment plant with pumps and filters to clean its wastewater. The investment costs were €400,000, half that of a traditional plant, and annual operating costs of the reed-based installation are €1000, or 4 per cent of the operating costs of a technology-based plant. In addition, there is no sludge to be eliminated regularly and expensively. Instead, the soil resulting from nature's activity is removed about every 12 years.

> Annual operating costs of a Swiss reed-based installation are four per cent of the operating costs of a technology-based plant – or 25 times cheaper.

Constructed wetlands have been successfully used to treat municipal wastewater for decades. In many cases, these wetlands have started to be used in a cost-effective way in the reduction and treatment of industrial effluents. Several pilot projects were successfully completed by the Austrian Johanneum Research Company in Frohnleiten (www.joanneum.at/nts).

1.2.5 Systems solutions – Smart solutions

Systemic solutions are driven by the economic savings achieved by a systems operator, a manager of a fleet of goods or a group of economic actors involved in a system. Many systems solutions, therefore, work best in the Functional Service Economy described in Chapter 2. Among the incentives for systems solutions are:

- reversed incentives,
- symbioses,
- smart system solutions based on virtuous loops,
- smart engineering solutions and
- radical changes in framework conditions.

1.2.5.1 Reversed incentives

Reversed incentives drive many systems solutions to achieve the desired performance with less resource consumption yet without compromise on the desired result. The historic example of Chinese village doctors is still one of the best to explain reversed incentives. Some 2000 years ago every Chinese village had its own medical doctor, whose livelihood was paid by the villagers in good health; every villager who became ill was treated by the doctor free of charge. That way, everybody, including the doctor, was better off if they were healthy. There was little incentive to becoming ill or having an accident, as that would have been detrimental to one's own vital interests of survival; the risk of abuse or moral hazard was practically nil.

> *Most modern medical systems, by contrast, thrive on sick people. Many modern medical systems would be bankrupt if there were no or fewer patients, due to the high financial investments.*

Among the modern examples of reversed incentives are the following:

- **Promotion of firefighters.** Traditionally, firefighters in US cities were promoted due to their experience. Officers in districts with frequent, big fires – and hence solid experience – thus had a good chance for promotion. At the end of the 20th century, however, it was realised that the main task of firefighters is to prevent fires by visiting potentially hazardous sites and giving advice on how to reduce hazards. While fighting fires efficiently is still important, promotion is now primarily given to officers in districts with excellent prevention records.
- **Speno, selling the service of perfectly ground rails.** Speno International, with head office in Geneva, Switzerland, today is part of the Austrian Plasser–Theurer Group. In the 1960s, Speno developed a 'perfect-rail' service for railways and mining companies worldwide. Grinding the railheads prolongs the life of rails and reduces noise levels and maintenance costs of rolling stock. Railheads suffer a number of deformations through use, which cause increasing noise levels and vibrations in the rolling stock. Noise is a public nuisance in built-up areas; vibrations impose shorter maintenance intervals of the rolling stock and thus higher operating costs.

  The traditional solution was to replace worn rails with new ones, limiting railway operation temporarily and causing delays and higher risks through a two-way traffic on a single track. The service of *in situ* rail grinding entails running trains with computer-guided grinding machines at slow speed over the worn track, giving the railheads a perfect shape. The savings to the railway system determine the price of the service, not the costs incurred by the service provider.

The introduction of high-speed trains gave rail grinding a boost. The grinding of railheads guarantees a tolerance of 1/100 mm to the ideal profile, whereas new rails, a milling product, have a tolerance of 1/10 mm. As this is insufficient to operate high-speed trains, new rails also had to be ground, which is an additional business. Giving existing railheads a perfect shape through grinding is a service that sells guaranteed performance results with a minimum resource input! And the more efficient the technical solution is, the higher the profit of the solution provider. Rail grinding is a highly profitable service, whereas producing new rails is a commodity business with low profit margins.

- **Bad weather compensation in the solar industry.** Customers installing new solar power-generating systems in Japan can now receive compensation for lack of sunshine. The service was introduced in the Japanese solar industry by Takashima & Co. Ltd, which sells housing and construction materials as well as renewable energy systems. It developed the idea with Sompo Japan Insurance Inc. and made the service available to Takashima's new solar customers beginning in July 2005. The insurance compensates the owner of the solar system for bad weather. If global climate change leads to more sunshine, it will give the insurance higher profit margins. In the reverse case, it increases payouts – dealing with uncertainty is the core business of insurance.
- **Kyocera's medium-scale solar-power systems.** Kyocera Corporation, a Japanese manufacturer of electronic components and photovoltaic (PV) systems, in October 2005 launched 'Econoroots wide', a series of medium-scale PV power-generation systems (with a generating capacity of 10–13 kW) for such private facilities as day schools, gas stations and convenience stores.

  Compared to the traditional assembly of solar systems by an expert, the manufacturer now assumes the optimisation of all system components and guarantees its function for a given performance and cost. In return, a higher system efficiency provides Kyocera a higher profit margin on the panels. Kyocera enjoys a reputation for long-life maintenance-free products with its Ecosys laser printer series that may play in its favour.

1.2.5.1 Symbioses

Many systems solutions benefit the involved actors through their symbiotic nature. For instance, railways benefit from innovations to track maintenance by third parties and provide these entrepreneurs with work. In cases where this symbiotic benefit among producer, distributor and customer is lacking, systems solutions can fail in the market, as in the historic example of Ciba-Geigy's Taona Zina project (Section 2.4.2.6).

Inns are one of the oldest – and safest – solutions to food and lodgings for travellers in an unknown territory, selling a safe and comfortable place to sleep. The best-known historic example of an inn's social advantages are Chaucer's *Canterbury Tales*.

Hotels sell performance. They gain from sufficiency solutions, such as the reuse of towels: 'Help us to save the environment – reuse your towels as long as you stay with us' is such a solution. Many European guests are happy to oblige and waive their traditional right to fresh towels daily.

Yet this strategy also gives the hotel financial advantages, for example, fewer expenses for washing towels and a longer life for the towels and washing machines through less wear. Reusing towels is popular in Europe but less so in the US where customers expect a discount on their room rate for their cooperation. This does not apply to five-star hotels that are obliged to change towels every day or risk being downgraded to four stars.

Quality improvements benefit both the innkeeper through a higher income and the traveller through a more agreeable stay. Financial improvements benefit primarily the hotels as they increase their profit margin. Hotels are thus interested in efficiency solutions offered by facility management and water- and energy-saving contracting services. Modern examples of symbioses are:

- **Walking-talking bus.** The UK city of Liverpool started the walking-talking bus initiative in 2003 to encourage children to walk to school in large groups, entertained on the way by local poets, musicians and historians who take on the role of 'conductors'. The children have written numerous stories about exploring their community on foot, and the pilot of the initiative produced a road safety book and road safety games devised by the participants.

  Parents gain time as they do not have to drive their children to and from school, and they know their children are in safe hands. And the children enjoy the stories and company of the guest conductors and get some exercise. Traffic congestion and costs to all are reduced. In the UK, the 'school run' made up 18 per cent of car trips by urban residents in 2008. The walking-talking bus confronts the three threats of childhood: obesity, traffic jam and CO_2 emissions.

Walking bus programmes continue to crop up in European cities, most recently in Geneva, Switzerland, and Lecco, Italy, which have adopted the walking-talking bus under the name of '*pedibus*'. Lecco's walking bus was the first in Italy. In the USA, similar programmes were introduced in 2008 in Columbia, Missouri; Marin County, California; and Boulder, Colorado, as part of a national 'Safe Routes to School' campaign that provides state money to encourage students to walk or bike to school.

- **Accessibility – The sufficiency mode of mobility (the cargo tram).** Accessibility is a systems solution offered by sellers of goods and services. It means that goods and information are delivered to the customer, whereas mobility means that the customer moves to buy and transport goods or information.

  The replacement of public telephones by private telephones at home and ultimately by mobile phones is an example of the development of accessibility. Gas stations are a mobility solution. Electric cars refuelled at home are one of accessibility; the hydrogen society might provide an accessible 'gas station' at home (see Section 1.2.5.5).

  The information highways, such as Internet, enable customers to order most goods and services without moving. But most physical goods, such as food or furniture, still are delivered, boosting such delivery services as UPS and FedEx that not only distribute goods but also take them back efficiently. This has created a new business of reverse logistics in a two-way accessibility.

  Traditional services, such as tramways in urban areas, can also contribute to improved accessibility. In April 2003, public transport in the city of Zurich, Switzerland, introduced a cargo tram to collect used bulk goods from private households. As 45 per cent of Zurich's households are car-less, the disposal of large objects is more of a problem than delivery, which is normally done by the seller. The success of the cargo tram has led to the 2005 introduction of an e-tram that collects used electric and electronic goods from households.

  The Austrian capital Vienna also introduced a cargo tram in 2005 and the car manufacturer Daimler-Mercedes has implemented a tram service to deliver parts to its new downtown factory in Dresden, Germany.

  Most less-developed countries are still based on the mobility principle, including access to public administrations and Internet facilities. This takes time but also provides social interaction and communication. Public telephone booths, by contrast, have increasingly been replaced by private entrepreneurs renting out their mobile phones in the street.

- **Towns as resilient energy systems.** Some new buildings are designed as plus-energy building, or self-sufficient power stations. Originally, this approach was driven by environmental considerations but lately has been adopted by politicians, such as New York City Mayor Michael Bloomberg, and policymakers, such as the European Commission. The argument of Michael Bloomberg is that New York City prefers energy-autonomous buildings to increase its resilience in case of an electricity blackout, which creates general insecurity in the streets due to lack of lighting and emergency situations in the metro and buildings, shutting down safety-relevant systems and elevators as well as jeopardising critical hospital and computer centre equipment.

1.2.5.2 Smart systems solutions based on virtuous loops

Virtuous loops reinforce systems solutions and have the additional benefit of a built-in controlling mechanism. Some examples are given below.

- **Sainsbury's solar cooling lorry.** In the late 1990s, the UK supermarket group Sainsbury began using the sun to keep products cool. Instead of using diesel engines to power the refrigeration units on their delivery lorries, the trailer's 35 m^2 roof was covered with photovoltaic panels. The energy produced is enough to keep the temperature inside the unit down to 3°C, and both the noise and the emissions associated with diesel exhausts are totally eliminated. Data are monitored by the Sustainable Energy Research Group at Southampton University. This solution corresponds to a virtuous self-governed loop: the hotter the sun shines, the more energy is available to cool the lorry!
- **Unilever's solar-powered ice cream stalls.** At the 2004 Olympics in Athens, Greece, the UK food company Unilever tested five solar-powered ice cream cabinets topped with panels to convert sunlight into the electricity needed to keep the ice cream frozen. This solution can be adapted to power electric cooling fans and a number of other equipment during the hot season in most countries.
- **Remanufacturing a car engine**, a consumer-driven wealth or physical asset management model.[29] Employing innovative methods to ease multiple remanufacturing of the same component furthermore creates virtuous loops (see the example of Caterpillar in Chapter 3). The economic impact of remanufacturing a major component, such

as a car engine, is based on extending the life and investment of a car; this asset is re-valued.

Take a 1969 Jaguar XJ6 automobile that weighs 1640 kg. Remanufacturing its 220 kg engine necessitates new parts with a total weight of 20 kg (pistons, sleeves, valves, engine chains), plus 120 hours of manpower, and costs about €10,000. The value-per-weight ratio (€10,000 divided by 20 kg) is thus €500/kg, or about 23 times the ratio of an equivalent new car (€22/kg, €36,000 divided by 1640 kg).

The value-per-weight ratio of €500/kg is 23 times the ratio of an equivalent new car (€22/kg).

However, in the metrics of the Industrial Economy, remanufacturing a car engine is equivalent to one less car sold and hence a reduced sales volume at the point of sale as well as higher unit costs due to a reduced economy of scale. Governments promoting cash schemes to owners of 10-year-old cars in working order for scrapping them and buying a new one – France and Germany introduced schemes of this type in early 2009 to save their national car industries – thus miss the chance to increase the value-per-weight ratio of these existing assets, and to create local skilled jobs at the same time (see Chapter 3).

The above findings are true for most remanufacturing services and are of high economic interest for economic actors selling performance instead of goods, such as fleet managers of cars, aircraft or railway rolling stock. Remanufacturing as a profitable business model is further developed in Chapter 3.

1.2.5.3 Smart engineering solutions

Similarly to other smart solutions, smart engineering achieves the same value with a much lower input of material resources and thus achieves a much higher value-per-weight ratio of the economy.

An historic example of smart engineering solutions is the shift from parking tickets to handheld computers. At the end of the 20th century, Chicago's traffic cops averaged 12,000 citations every day, but the parking enforcement bureau succeeded in collecting only 10 per cent of the money due. At one point, unpaid parking fines totalled US$420 million, and the agency was years' behind entering tickets into its computer system. The Chicago authorities then contracted Electronic Data Systems Corp (EDS) of Plano, Texas, to revamp its operation. A specialist in building and operating computer networks, EDS began by giving Chicago's traffic cops handheld pen-based computers to log tickets directly into a central database. With the introduction of the new system, Chicago's ticket-collection rate jumped to 65 per cent and revenue doubled.

Smart engineering solutions have also been called 'Design for sustainability' (Stahel 2001). By rethinking a technical problem in a systems context and considering the best available technology, engineers can come up with staggering new solutions. The following are recent examples of such rethinks:

- **Plane Transport Systems (PTS)**, developed by Maffei, a German engineering company, in the late 1990s. The obvious solution to tow aircraft on the airport tarmac has been a tractor connected to the front wheel of the plane with a rod. However, the bigger the planes became, the heavier the tractors were; for to overcome friction in pulling and pushing, the tractor must be about a quarter of the weight of the aircraft. Before take-off, a jumbo jet weighs around 400 tons, so the biggest tractors put about 100 tons on the balance. In some cases, this weight was reached by building electric tractors with the lead batteries providing the ballast – a solution considered 'green' since there was no combustion engine.

  Maffei's plane transport systems, which are omnipresent at many airports today, are lean and mean. A PTS weighing ten tons will move a jumbo jet quickly even in wet conditions, and more safely because the PTS is fixed directly to the front wheel. So what about the physics issue of friction? Maffei's engineers realised that a quarter of the aircraft's weight rests on the front wheel. It is thus sufficient to produce a vehicle with a weight of only ten tons but capable of grabbing the front wheel and lifting it a few centimetres. The necessary ballast, 100 tons in the case of a jumbo jet, is now provided by the aircraft to be moved, not the tractor – a dematerialisation by a factor of ten compared to the traditional solution.
- **ICE 4,** the fourth generation of German high-speed trains, shows a similar breakthrough in engineering thinking. Ever since the invention of the steam engine, railway companies built engines, carriages and wagons and assembled them to form trains. And as trains grew longer, the engines had to be heavier or two engines had to be employed, either in front or at both ends to overcome the friction.

  A look at an ICE 4 train is striking: there are no engines! And yet the trains accelerate and brake very efficiently, even in wet conditions. In addition, passengers in the first carriage have a view similar to that of a bus: they can look out the front window! After 100 years, German railway engineers have integrated the change from steam to electric traction into the design of passenger trains. Similarly to the power tools used at home, the trains are now powered by a multitude of electric motors located on each bogie – the element integrating the axles and carrying the carriages. Wires distribute the electricity from the pantograph to all the motors, which are centrally controlled by the train conductor. The new ICE trains are much lighter because the biggest weight has been eliminated by a smart system design.

- **The pods of Queen Mary 2.** The new QM2 cruise ship is applying a similar design trick. Traditionally, ships used an engine and shaft to power one or several propellers; a rudder helped to steer the vessel on the high seas; and tug boats pushed it in the restricted harbour area. Contrarily, the new QM2 is electric! Even if the electricity is still produced by gas turbines and a big diesel engine, traction and steering are now done by pods at the rear end of the hull, linked to the vessel with electric cables. Each tear-shaped pod consists of an electric motor and a propeller and can swivel into any direction. Tug boats are now only on stand-by in the harbour, thanks to thrusters in the vessel's bow, also powered by electric motors.
- **Michelin's 'Active wheel'.** Most automobiles racing in energy-efficiency competitions are electric and use motors that are integrated into the wheel construction (see also the example of PAC-Car II in Section 1.2.2.3). The engineering revolution behind this design is similar to that of the ocean-going QM2 vessel. Traditionally, cars are built with an engine, a gear box, a drive shaft and a differential to drive two or four wheels. Brakes can be situated anywhere on the axle, often at the extremes. Suspensions consist of shock absorbers – which limit the design of the interior of the car – and other elements to absorb shocks.

  Michelin's active wheel integrates the brake, suspension and electric motor into the wheel construction, which still carries a rubber tyre. At the 2008 Paris motor show, the first car using Michelin's active wheel was presented to the press: the French Heuliez Will, which looks like an Opel Agila, with which it shares everything except the engine and drive train. The back wheels are battery-driven, stability is improved by electronic control of power to the two wheels. The second car using Michelin's active wheel will probably be the Venturi Volage, a four-wheel-drive sports car produced by the small French car manufacturer Venturi.

- **Intelligent lighting.** Lighting accounts for about one-fifth of the world's electricity consumption. Up to 50 per cent of this electricity could be saved by adopting high-efficiency light-emitting diode (LED) technology, which is already being marketed. It is also possible to add further improvements, such as sensing and actuation capabilities to LED so that they automatically adjust to natural light.
- **SkySails.** The utilisation of free-of-charge wind energy to move ocean-going vessels may not sound like a novel idea to sailing boat fans. But SkySails, a German start-up, has adapted the idea to modern ships and replaced the sails by kites. Large towing kites can reduce the heavy fuel-oil consumption of ship diesel engines, and thus reduce environmental pollution and operating costs. In 2007, MS Beluga SkySails, the first cargo ship with a SkySails propulsion, went into service for tests in order to raise the reliability and the degree of automatisation of the system to a level that customers expect in practical operation. At the 2006 Monaco Yacht Show, Rob Humphreys, a leading yacht designer, presented the layout of a SkySail super yacht: a 40-metre-long trimaran that with a good wind can reach a top speed of 20 knots using the new propulsion.
- **Honda micro co-generation units.** Co-generation units that produce electricity and heat simultaneously with a *high*-energy efficiency are state-of-the-art for large plants. In Japan, Honda made it available for home use by reducing the unit to the size of a household appliance. First introduced in 2003, this compact co-generation unit is now being used in over 50,000 Japanese households. The units generate electricity with a gas engine and utilise the exhaust heat to supply hot water, working with a total energy efficiency of 85,5 per cent. Honda began selling the system in the USA in 2006 under the name of 'Freewatt', in cooperation with the Clean Energy Company.
- **Ebara Ballard's residential fuel cell.** Japanese Ebara Corp. announced in June 2006 that it had completed the first prototype of a third-generation fuel cell stack for residential co-generation systems.

The common denominator of the above examples of smart engineering solutions may be the fact that the resulting goods do not look radically different from, and can be used in a similar way to, the goods they replace. In contrast to previous technological advances, the man in the street has hardly noticed that a breakthrough has been made.

1.3 Systems solutions through radical changes in framework conditions

Similarly to prevention solutions, systems solutions benefit both the public and economic actors. Innovators and explorers can therefore be in both the private and public sectors. Radical changes in the framework conditions, often imposed by governments, can promote systems solutions. As the short-term economics of these solutions can often be questioned, they need a solid cultural base and may therefore not be transferable to other cultures.

1.3.1 Radical changes by court order

Traditional democracies are based on a separation of the three powers: executive (government), legislative (parliament) and justice (courts). What power does a citizen have to force governments to adapt for the better? The following are examples of supreme courts giving citizens the possibility to force governments and the private sector to 'do the right thing'.

- **Delhi – Capital town with the cleanest air by order of the Supreme Court.** At the turn of the millennium, Delhi had the reputation of being the most polluted city in the world. Today, it rightly claims to be the capital city with the cleanest air worldwide. This change is credited to a decision by India's Supreme Court to impose the use of compressed natural gas (CNG), instead of diesel fuel, for health reasons. It is a direct result of the 'Public Interest Litigation' clause in the Indian Constitution of 1955, which gives every citizen the right to address a complaint directly to the Supreme Court in matters of public interest.

  In 1995, an Indian lawyer filed a case claiming that the health problems in Delhi were linked to the air pollution caused by diesel vehicles. In 1998, after a series of investigations and as a direct result of this complaint, the Supreme Court published a directive that specified that by April 2001 all buses, three-wheelers and taxis in use in Delhi had to be converted to CNG. In addition, the directive specified that 70 CNG refuelling stations had to be built in Delhi, and asked the local government to provide financial incentives for the conversion of existing vehicles.

  At the time (in 2001) CNG was already being used in neighbouring Pakistan in more than 500,000 vehicles (700,000 in 2004), most of which were automobiles. In 2004, Argentina boasted 1.4 million

CNG cars and total CNG vehicles in Japan exceeded 30,000 in 2006. Taxis in Tokyo and Dublin have been legally obliged to use compressed gas for decades. Italy leads European countries with 400,000 CNG vehicles. And the British Royal Household at Buckingham Palace converted its cars some years back, based on a decision by Her Majesty to set an example. Altogether, an estimated two million vehicles are using CNG worldwide.

But Delhi, with its 14 million-odd inhabitants, was the world's first capital city to change its bus fleet to CNG. Myanmar's capital, Rangoon, followed suit by converting its diesel buses in 2005.

CNG vehicles emit no fine particles and very small amounts of nitrogen oxides (NOx), carbon monoxide (CO) and hydrocarbons (HC). In addition, CO_2 emissions are 20–30 per cent lower than those of gasoline or diesel vehicles. CNG is a considerably cheaper energy source than gasoline, so customers are not hit hard financially. Yet, the Indian vehicle industry opposed the CNG directive, fearing that its global mass production would be jeopardised by the legislation. As little had changed by April 2002, the Supreme Court published a new directive that imposed a penalty on the local government for wasting the court's time as well as a daily fine of 1000 rupees (US$20) for each diesel bus still in circulation.

The local government then launched a programme to improve public transport and by 1 December 2002, the last diesel bus had disappeared from Delhi's roads. At the beginning of 2005, 10,300 CNG buses, 55,000 CNG three-wheeler taxis, 5000 CNG minibuses, 10,000 CNG taxis and 10,000 CNG cars were running on Delhi's roads. Since 2004, eight new cities along the CNG main pipeline have received a Supreme Court order to convert their diesel bus fleets to CNG, which is seen as the entry gate to establish a supply infrastructure and open up the car market to CNG.

The Japan Gas Association announced in 2006 that the total number of CNG vehicles in Japan exceeded 30,000 units. CNG vehicles have been on sale since the late 1980s and are gaining popularity. Forty per cent of CNG vehicles are trucks, about 30 per cent garbage trucks, buses or small cargo vans, the rest are cars. The reasons for this change are not known.

- **Cleaner air by order of the European Court of Justice.** In July 2008, the European Court of Justice, through its decision C-237/07, began paving a similar path to that ordered by the Indian Supreme Court. A lawyer in Munich, Germany, complained to the Bavarian courts about fine particles in the air repeatedly exceeding the legal limit. (EU legislation allows 35 days per annum above the legal limit before national governments must take action). According to the European Court's decision, citizens directly impaired by the threat of fine particles above the legal limit can demand member states to take rapid measures to reduce pollution levels. According to experts, this constitutes a subjective 'right for clean air' for citizens for the first time in Europe. The European Union (EU) is following India's lead – even if the EU would never accept this view. However, in contrast to the decision of the Supreme Court of India, the decision of the European Court of Justice has to respect the separation of each state's three governing branches and has no immediate effect.

1.3.2 Radical changes by new national legislation

Traditional democracies are based on a separation of the three powers: executive (government), legislative (parliament) and justice (courts). The following are examples of parliamentary decisions to force the private sector to 'do the right thing', a strategy that generally must be supported by subsidies or punishment.

- **Wind parks – Innovative legislation that made Germany the world leader.** In the 1990s, the German Government set fixed feed-in tariffs for wind energy, making it easier for German wind turbine manufacturers to attract investors because of the more predictable economic returns and lower costs. At the same time, the USA opted for tax credits, subsidies and tradable quota systems.

  While the USA had been the world's leading wind turbine producer in 1988, the German wind-power sector grew rapidly in the last decade of the 20th century and by 2003 accounted for 37 per cent of world installed capacity, compared with 16 per cent for the USA. Spain, Denmark and France have adopted similar support measures as Germany. In fact, the European Union today accounts for 80 per cent of the world stock of installed wind turbines.

  The German energy feed-in law (*Emeuerbare-Energien-Einspeise-Gesetz* – EEEG) changed the market in a fundamental way. Previously, manufacturers of wind turbines acted as entrepreneurs, negotiating bank loans, identifying suitable sites and leasing farmland at high cost to build windmills. Simultaneously, they had to fight environmentalists who mourned the loss of natural beauty, warned of the impact of the windmills on bird life and predicted a diminishing cow milk production.

Now, investment funds have taken on the full project management and hope to recover their investment within eight years. This is a manageable economic risk, as the technical risks are carried by the manufacturers. GE Wind, a General Electric division, for instance, guarantees a technical reliability of 98 per cent and offers a fixed-price contract for operation and maintenance over the first 12 years for its windmills.

By offering a deferred ownership instead of small land leases to the farmers, the investment funds cleared the psychological obstacles. After ten years, farmers become owners of the windmills on their land, thus giving them a future income and, more crucially, making them part of the future! The old ecological arguments are now regarded as phantom risks. This could lead to a fundamental change in the structure of electricity grids, described in Section 2.2.3.

By 2005, Germany became the world's leading manufacturer of wind turbines, with half of its production exported and 45,000 people employed in its windmill sector. But meanwhile, other countries have picked up the challenge, and GE Wind, through its acquisition of a major windmill producer, has become the leader. German manufacturers that have long profited from the government initiative have been hit by the current economic downturn and the resulting lack of venture capital.

However, as a result of the rapid growth, some areas in Northern Germany are now overcrowded with windmills, and opposition is rising. It is foreseeable that the only markets left for German windmill manufacturers are repowering existing windmills, offshore installations and exports.

By end-2007, over a dozen EU member states had introduced energy feed-in laws or other systems to promote renewable energies (www.feed-in-cooperation.org).

- **Vision Zero in Sweden – Systems prevention through legislation**. At present no one is in charge of road traffic as a system! Governments build and maintain the roads, investing money only in the infrastructure, provided these costs are lower than the health costs resulting from car accidents, which are frequent and costly, both socially and economically. Car manufacturers focus primarily on passenger safety, ignoring that half the casualties are pedestrians and cyclists. And most drivers certainly do not feel responsible for the system as a whole.

Vision Zero is an act passed by the Swedish Parliament in 1997 to increase road safety. It moved the responsibility for the road traffic system from the road users to road planners and builders.

Vision Zero is based on the idea that suppliers of the road system are responsible for its safety, and that citizens must obey the rules. It is built on two safety philosophies: that humans make mistakes (the system therefore must be fault-tolerant) and that the human body has critical limits. The system is thus designed to prevent people from being subjected to a crash speed that they cannot survive. This means that trees and other hazards along roads must be eliminated and traffic facing different directions physically separated, or else the speed of vehicles reduced. And cars should be built to start only after all passengers have fastened their safety belts, and when the driver is not under the influence of drugs or alcohol.

Vision Zero can claim an early success. By 2005, not one child had been killed on Swedish roads since its introduction in 1997. This was achieved by shifting the responsibility for child safety to the parents: no unaccompanied children on the roads and the mandatory use of back-facing child car seats.

1.3.3 Radical changes through people's power

Who is in charge of transport systems as part of a sustainable society? No country has ever made a cost/benefit analysis based on the three (economic, ecological and social) pillars of sustainability.

Switzerland, a country with 7.7 million inhabitants in 26 cantons located in the heart of Europe, is ruled by a unique political system of direct democracy and subsidiarity: decision-taking at the municipal or cantonal level has preference over federal rulings. The supreme power is the people. So-called people's initiatives that require 100,000 signatures can force a vote on any subject, either overruling decisions by parliament or the federal government, or proposing new legislation.

- **The Alps initiative – Systems progress driven by direct democracy.** During the 1980s many of the 50,000 inhabitants of Uri, a mountain valley in central Switzerland, complained about their miserable quality of life due to the noise and air pollution from the Gotthard motorway, a major European transport route linking Germany with Italy. In 1988, a committee of Uri citizens launched a people's initiative proposing a solution to this problem, which was supported by neighbouring populations but opposed by the federal government and all political parties. The initiative, which was handed to the federal government in 1989, proposed a new article in the Swiss constitution with three objectives: to protect the alpine regions against the negative impact of international transport, to transfer goods transport across Switzerland from the roads to the railways and to freeze the transport capacity of existing transit roads. An addendum stipulated that this transfer had to be done within a period of ten years after the acceptance of the initiative.

In an historic vote on 20 February 1994, 53 per cent of the Swiss populace accepted the 'Alps initiative', against the advice of the federal government and parliament and 19 out of 26 cantons decided to write the protection of the Alps into the Constitution. As a consequence, the Swiss Government decided in the same year to solve the issue of international goods transport through Switzerland by building two new railway tunnels. The first one through the Gotthard mountain group, from Lucerne to Chiasso with a length of 57 km, will become the longest tunnel in the world when commissioned in 2017. The other tunnel, through the Loetschberg and Simplon region, from Bern to Domodossola, became operational in 2007. The construction costs of these tunnels are financed by a sizeable road tax on lorries crossing the country.

In 1999, the Alps Initiative Committee convinced the European Parliament to introduce a similar levy on lorries transporting goods on European roads to provide an incentive to shift transport from the road to the railways. In 2009, Swiss Minister of Transport Moritz Leuenberger received the European Railway Award at a ceremony in Brussels and donated the prize money to the Alps Initiative Committee. Most Swiss politicians say that they would support the Alps initiative today if it came up for voting.

1.3.4 Radical changes through partnerships

Increasingly, radical changes come about by cooperation between different actors, typically public authorities and the private sector. Public-Private Partnerships (PPPs) are a defined form of progress driven by partnerships that has crystallized over the last ten years. (PPPs are covered separately in Section 2.4.3.3.) The following are some examples of different partnerships to achieve change.

- **The hydrogen society.** Hydrogen is the ultimate clean fuel. It is naturally available as a by-product of some chemical processes, such as oil refining, and can be produced by splitting water into oxygen and hydrogen, using for instance solar energy. Jeremy Rifkin and

> others have shown the opportunities and risks of a hydrogen society. Burning hydrogen in fuel cells will produce energy and, as sole emission, water. The introduction of hydrogen systems has now started to speed up, six years after Rifkin's 2002 book on the hydrogen economy.

French engineers have developed a hydrogen fuel-cell yacht that is propelled by splitting seawater with solar energy. Swiss engineers at the Federal Institute of Technology Zurich (ETHZ) have produced PAC-car-II, a hydrogen fuel-cell car that holds the world record for fuel consumption: 5500 km per litre, or 0.02 litres per 100 km. This car technology is comparable to the passage from transmission belts to power tools in factories a hundred years ago. The petrol engine's mechanical power train to the wheels is replaced by a hydrogen fuel cell, electric motors integrated into the wheels and wires linking the two.

The hydrogen fuel-cell PAC-car-II holds the world record for fuel consumption: 5500 km per litre, or 0.02 litres per 100 km.

In the first years of the 21st century, the German navy built four 212-class submarines (NATO code S 184) with a hybrid propulsion system. Using an electrochemical process based on fuel cell technology, oxygen and hydrogen are transformed into electricity and water, a process that makes the submarines independent of outside air and enables them to remain submerged for weeks, like nuclear-powered vessels. This is a near-perfect solution, as a submarine can split water to produce both oxygen for its crew and hydrogen for its propulsion. The system's reduced noise and thermal signature make the detection of these crafts by other ships more difficult. Further, an opportunity for technology transfer from the military to the public sector has been created.

In 2006, several leading car manufacturers produced a few hydrogen fuel-cell electric cars mainly to demonstrate the problem of a non-existing distribution system for hydrogen fuel. One of the main obstacles in any country is the necessary investment to build a hydrogen supply network, for without hydrogen supply, there can be no Hydrogen Economy. Countries lacking a developed distribution infrastructure for car fuels now have an incentive to directly build the hydrogen system of the future.

Other obstacles, such as stranded capital and technology lock-in at car manufacturers, are hardly ever mentioned. So, hydrogen fuel-cell electric cars are of interest only to countries with a large technology base, without a saturated car industry and a thirst for competitiveness. Where might a mass-produced hydrogen car – and the necessary hydrogen distribution network – be developed? China is the obvious answer.

The question, however, is can China develop a product that it cannot copy from the West? Yes, if more Chinese follow the path of Professor Wan Gang, appointed China's Minister of Science and Technology in May 2007. After receiving an engineering degree, he left China to earn a PhD at a German technical university. With his PhD, he found a job with a major German car manufacturer, where in the mid-1990s he was promoted to chief development engineer. In the late 1990s, he wrote to the Chinese Government to propose the development of a hydrogen fuel-cell car. As president of Tongji University at Shanghai, he has fulfilled his promise: the first mass-produced fuel-cell cars should be on the Chinese roads by 2012.

In 2008, politicians and manufacturers began to increasingly promote the hydrogen society, notably in Japan and in California in the USA. The following pioneers are presented in chronological order to give an idea of the race, and the partnerships involved, to become number one in the hydrogen society.

- **The first liquid hydrogen refuelling stations** opened at Ariake in Tokyo on 12 June 2007. It was the second in the Tokyo Bay area, the seventh in Japan. A part of the Hydrogen Refuelling Station Pilot Programme, sponsored by the Agency for Natural Resources and Energy of METI, it is the first station in Japan to provide both liquid and compressed hydrogen. The Ariake unit will also serve as the main refuelling station for a pilot project operating fuel-cell buses on regular routes that started in mid-2008.
- **The first US crossing for hydrogen cars** was completed on 25 August 2008 when hydrogen fuel cell cars from nine automakers arrived at the Los Angeles Coliseum after a 13-day cross-country trip that started from Portland, Maine. There are only 60 hydrogen stations in the USA, and only two are open to the public without prior arrangement. The cars had to be carried on flat bed trucks from Rolla, Missouri to Albuquerque, New Mexico, as there were no hydrogen stations on this route. One of the goals of the hydrogen road tour '08 was to demonstrate the need to build more hydrogen refuelling stations. The two hydrogen producers Linde and Air Products used their mobile hydrogen-making machines to refuel the cars several times in front of an interested public.

- **The world's largest 'hydrogen town' project** celebrated its foundation on 11 October 2008 with the first installation of a residential hydrogen fuel-cell system in Maebaru City, as part of the Fukuoka Prefecture's plan to realise an eco-friendly hydrogen-energy society. The project is run by the Fukuoka Strategy Conference for Hydrogen Energy, Japan's largest collaboration between industry, academia and local government, and is designed to undertake hydrogen-based research and development in the areas of production, transport, storage and application, in addition to promoting its activities and developing human resources in the field.

At the end of 2008, Nippon Oil Company and Seibu Gas Energy Company began installing 150 ENE FARM power-generation units, which are 1kW residential fuel-cell co-generation systems using hydrogen in liquefied petroleum gas (LPG). The system can generate up to about 60 per cent of the power consumption and 80 per cent of the hot water supply of a typical household.

- **The EU Fuel Cell and Hydrogen Joint Technology Initiative (JTI)**, a public-private venture founded by the European Commission and an association of European fuel-cell and hydrogen companies, was officially launched in October 2008. With a 2008–17 budget of €1 billion as part of the Seventh Framework Programme, the JTI plans to accelerate the development of fuel-cell and hydrogen technologies in Europe and ensure their commercialisation up to 2020. At its core, this initiative represents a partnership to implement a programme of R&D initiatives, completed by demonstration and support measures for the most promising applications. The JTI is the result of a six-year effort that began in October 2002 and led to the establishment of the industry-led European hydrogen and fuel cell technology platform in June 2003.

  The adoption of hydrogen technologies could reduce oil consumption in the EU road transport sector by 40 per cent and of carbon emissions by 50 per cent, by 2050. Despite the obvious benefits associated with these technologies, the European Commission believes the EU industrial sector still needs to be stimulated to make necessary investments.
- **Ballard's hydrogen fleet.** In early 2008 the fuel-cell technology company Ballard Power Systems joined with Daimler AG and the Ford Motor Company to form the Automotive Fuel Cell Cooperation Corporation. Using Ballard's Mark902 fuel cell, Daimler has 100 Mercedes-

Benz A-Class vehicles on the road worldwide, of which 60 in Germany, Japan, Singapore and the USA. The international shipping company UPS is currently delivering packages across the USA with a fleet of Mercedes-Benz Sprinter vans powered by Ballard fuel-cell technology (www.ballard.com).

The Honda Motor Company has begun leasing 200 FXC Clarity fuel-cell automobiles in Southern California and General Motors Corporation is testing 100 fuel-cell Chevy Equinox SUVs on the road.

- **EU parliament eases road for hydrogen cars.** Beginning September 2008, the European Union took a significant step towards the introduction of hydrogen-powered cars on European roads by calling for common criteria for this eco-friendly technology. The purpose of the proposal is to lay down harmonised technical provisions for the type-approval of hydrogen-powered vehicles. Currently there are no uniform requirements for hydrogen vehicles in Europe, posing marketing problems for manufacturers. With the adoption of Europe-wide criteria, the European Union can establish itself ahead of global research and ensure investment security for market access of this future technology (www.ec.europa.eu/enterprise/automotive).
- **The first hybrid hydrogen power station**, which was inaugurated on 23 April 2009, combines biogas, wind power and hydrogen to produce electricity. The Enertrag Company plant in Penzlau, Brandenburg, cost €21 million to build and will supply electricity to 2000 households and heat to 300 homes in winter. Hydrogen is produced when there is an oversupply of wind power.
- **Professor Wan Gang**, China's science minister who has developed prototypes for fuel-cell cars, wants to see fuel-cell-powered electric cars on China's roads. Professor Gang developed the prototype while president of Shanghai's Tongji University, one of the foremost technical institutions in China founded in 1907. He hopes that in 2012, Shanghai will start producing 10,000 such cars a year, in a first step towards emission-free traffic in China.

The above examples of CNGs in India, wind parks in Germany, Vision Zero in Sweden and Alptransit in Switzerland, have all achieved their objective. But only Germany's feed-in tariffs for renewable energies have been copied by the political authorities of other countries, despite the fact that they lead to higher electricity costs for consumers. What are the missing incentives or drivers to make change spread?

1.4 Change drivers

The previous sections illustrate performance as a driver of wealth creation and reduced resource consumption and only sketch the potential of innovation in the fields of science and knowledge, loss prevention, sufficiency and systems solutions. Nevertheless, they allow drawing some conclusions.

A number of existing applications from science and technology, such as a nano-polishing of bearings that will multiply their initial service-life, or smart materials that can easily be reused, are neither of practical nor economic interest in the mass production of disposable goods in the present Industrial Economy. A shift to the Functional Service Economy sketched out in Chapter 2 will, however, provide markets for these innovations.

1.4.1 Daring

As science thrives on innovation and creativity, it is fruitless to plan its further development in detail. Framework conditions to foster education and discovery, research and innovation will produce most of the future winners! Individual freedom and competition creating more dynamic research environments in life, nano- and material sciences could well be the hallmarks of the most successful companies and nations! For this reason, a 2001 report to the European Commission suggested that 10 per cent of total research money be spent on 'crazy ideas' with a high potential but for which no cost-benefit estimation was possible.[30]

Leading research centres normally act in symbioses with industrial partners around them. CERN, the European Nuclear Research Centre in Geneva, works with thousands of subcontractors, and spins its ideas off into the economy. In the last five years, CERN was at the origin of 125 technology transfers, 12 new companies and a number of industrial projects. Many universities have a similar role as incubators for innovative ideas.

Daring to exploit emerging opportunities is helped by a public belief in the future. Not so long ago, the general view was that 'science builds the roads to the future; science blows away the rocks, eliminates the old walls and obstacles and brings light and air into people's living rooms'.[31]

The perforation of Switzerland's Gotthard railway tunnel in 1880 was described in the media 'with euphoric feeling about the tunnel, a belief in science and pathos', despite the fact that it had been achieved with a high fatality rate including the death of its builder, engineer-entrepreneur Louis Favre in 1879, aged 53.

Today, many public discussions in Europe focus on potential risks of new sciences, not on opportunities, whereas in countries outside Europe the view is optimistic. This cultural divide could turn into a competitive advantage for the optimists and a disadvantage for Continental Europe. A better application of the knowledge on prevention and sufficiency solutions could help to reduce fears.

1.4.2 Environmental impact as facilitator

Many traditional chemical production processes, for instance in textile manufacturing and washing, can be replaced with processes based on microorganisms or enzymes, which use less energy to run and are based on renewable instead of fossil resources. In addition, emissions to the environment are reduced and substances have a lower toxicity. The economic advantages arise from a reduced need for safety technology and a higher yield in resource use.

Using coldzymes in clothes washing shifts the balance in an overall energy analysis. The biggest energy consumption is now in the production of detergents, no longer the washing process itself. A high energy efficiency in the utilisation phase thus reverses traditional thinking and underlines the need for an increased systems optimisation.

1.4.3 Social sciences as facilitator

Social sciences could take on new roles: as facilitator for systems innovation and systems solutions and as mediator between the knowledge economy, communities and the common good inherent to sustainability.

Humanities and social sciences share one objective with systems solutions: they both place the Common Good as their main beneficiary. For instance, rail transport – a systems solution – takes up less land and produces less CO_2 per passenger mile than road traffic, but road traffic gives the individual more freedom. And economic actors in an Industrial Economy profit more from individual solutions with a high resource throughput than from knowledge-intensive services. The invisible hand of the Industrial Economy market can therefore not be expected to promote systems solutions.

By contrast, the Functional Service Economy has always sold a mix of products and services. One example is airlines, companies that sell air transport but are increasingly focusing on ticketing and organisational work and outsourcing the 'flying' to operational leasing companies under 'wet lease' contracts that include aircraft, fuel and crew management.

As the Common Good profits primarily communities and nation states, many successful systems solutions have been and will be initiated by government authorities. For cultural reasons, however, the examples in Section 1.3 may be difficult to transfer to other regions:

- Vision Zero in Sweden, legislated by a Swedish parliamentary decree, would lead to a revolution in Germany.
- The CNG conversion of Delhi's transport fleet ordered by the Supreme Court of India and made possible by the Indian Constitution would be unthinkable in other parliamentary democracies.
- The Swiss Alps initiative may remain unique because in most democracies the people cannot overrule their governments by imposing legislation that political parties oppose.
- The hydrogen society, however, has a better chance of succeeding because it creates new commercial markets, promotes technologic innovation and R&D, and eliminates the potential threat of CO_2 emissions.

In successful cases, the public sector has exploited known opportunities of systems solutions to benefit primarily the Common Good, which otherwise would not have been initiated by the private sector. In cases where the benefits are more specific, economic actors have taken – or refused to take – the lead. Known opportunities of this type of systems solution are:

- **Coldzymes** (for commercial laundries and households). This European Union research project was successful but commercialisation was slow; due to hidden obstacles, Coldzymes have taken more than ten years to arrive in the shops.
- **Energy farmers** in Austria, southern Germany and the UK succeeded in realising their project only with the help of understanding politicians. In the regions of energy farmers, gas companies quickly built new gas pipelines to the villages concerned and pushed at political level, unsuccessfully, for 'a duty to connect' rule for all buildings. Politicians thwarted this move through new legislation and land use laws adapted to the new solution.
- **Rent-a-wash**. The leasing of household washing machines was withdrawn from the Swedish market as it would have shifted control from the white goods manufacturer to the electric utility company.

- **Construction limitations** proposed along Thai beaches after the 2004 tsunami were not accepted by the local economic actors and the population making a living from tourism.

In the unsuccessful cases, manufacturers either ignored the new solution or took corrective action to defend the existing status quo. Rent-a-wash could have succeeded if the white goods producer had obtained control over the electricity utility.

Social sciences could find answers to the questions of when and how to promote sufficiency and systems solutions, which are at the centre of the triangle of the knowledge economy, sustainability and communities. But some economic questions remain: radical changes in the framework conditions, often imposed by governments, can promote systems solutions with questionable short-term economic impacts, such as higher electricity prices for consumers in the case of the German electricity feed-in tariffs.

A revisit of 'the Failure of the Commons' could also bring light into the traditional confrontation between the wishes of communities for quality of public life (sustainability) and the search for personal quality of life (comfort and own benefits), complemented with the new role of gatekeepers of new technologies in the market.

Coldzymes is an ideal virtuous loop as it reduces energy consumption in washing clothes by 90 per cent, making private households benefit from drastically lower energy costs. As washing is ruled by a combination of heat, detergents, mechanical action and time, Coldzymes greatly improve working conditions in commercial laundries by lowering temperatures in summer, while the lower energy costs for air conditioning and washing processes partly offset a possible cost increase due to longer washing cycles. But enzyme producers have huge investments in marketing and production of existing detergents; should they endanger those investments for the benefit of the Common Good (including energy as a potentially scarce resource) and the finances of private households?

In the Functional Service Economy, by contrast, sufficiency solutions such as Coldzymes act as an economic driver, because the minimisation of resource inputs or efforts directly increases profits! Receiving the same amount of revenue for delivering the desired performance with fewer resources increases the competitiveness and profits of the supplier! Rising resource costs, such as oil or steel prices, will increase this profit advantage in the Performance Economy versus the Industrial Economy. Systems solutions can yet further increase this competitive advantage.

To judge the full impact of reductions in the resource consumption and related costs of sufficiency solutions, bear in mind where resources are used in the linear Industrial Economy (Table 1.3).

1.5 How to overcome obstacles

Planned economies and framework conditions restricting discovery and innovation could prove to be the worst obstacles to future development, as creativity cannot be planned. A focus on collective interests and social justice frustrates research efforts and may convince young researchers and entrepreneurs to emigrate. One reason for this is that thinking ideas through to the end is difficult and more common in Asia than Europe. Yet, there could be hidden advantages for the Common Good that are unimaginable at the start, witness some historic examples:

The scientific advances of the 19th century led to the development of typewriters, automobiles and railways, X-ray imaging, electricity, wireless telecommunication, vertical elevators and chemical film photography. Their value-per-weight ratios have since been continuously improved. Electric power then led to the invention of elevators, which in turn enabled building tall buildings, which greatly reduced the consumption of land and changed the face of many cities.

The same is true for the scientific advances of the 20th century that led to polymers and electronics, nuclear physics, aircraft, computers, radar, television, space travel and deep-sea submarines.

All these past achievements were based on a belief that science was the solution, not the problem. Has this belief changed?

In Continental Europe, many new fields of science, such as bio- and nanotechnology, seem to frighten people partly because of their efficiency and invisibility! Yet this efficiency – namely, the smaller a 'product', the more efficient – is the very definition of the Performance Economy. But it contradicts the past experience of the Industrial Economy that bigger is better.

One major obstacle in the development of nano- and bio-technologies is the structure of the present Industrial Economy: the net gains and value added lie at the end of the production process, in the marketing and commercialisation of goods. Cheap raw materials treated as commodities are transformed into high-value products by the value-added of manufacturing processes.

> *Some of the smart solutions of the Performance Economy described in this chapter put this economic power and value structure on its head, as value added is now largely embedded in smart materials and smart solutions, and no longer the result of high-volume production processes.*

For instance, little information exists on the effect of nanoparticles on human health or on species other than humans. An acceleration of low-risk applications of nanotechnologies could be achieved by a shift to the Functional Service Economy, where companies accept an extended product responsibility over the full life cycle of their products, privatising the cost of risk instead of legislating it. Applying the principle of the insurability of risks as a natural borderline between the market and nation states will speed up the commercialisation of scientific and technologic progress and select the insurable (low-risk) solutions (see Section 1.5.1).

Most future applications of the new discoveries and innovations of the Performance Economy will result from research! Balancing opportunities and uncertainty thus becomes a responsibility for countries in the 21st century. The public acceptance of progress with free market safety nets is the answer. Viewing science as the problem or the solution is a cultural issue that must be decided by society, as the choice will determine a country's future sustainable competitiveness. Research into understanding the cultural issues of chances and risks in a sustainable society could certainly help.

1.5.1 Insurance as enabler of technology

Within the limits of the insurability of risks, insurance has a role to play as an enabler of technological and scientific progress and as a free market safety net for mistakes.

To improve the economic competitiveness of nations, insurance holds an under-exploited key tool: the 'insurability of risks'. Insuring new technologies speeds up their transfer to the marketplace and guarantees both a fair pricing of the potential emerging risks and an internalisation of the costs of risk by the economic actors. In the quest for a sustainable and competitive economy, insurability could be a major driver of progress.

The 'insurability of risks' can be defined as the 'natural borderline' between the market economy and nation states. Risks that can be insured need not be regulated; uninsurable risks, however, must be dealt with by nation states. Insurability is also a filter between technological innovation and sustainable development, as shown in the following Figure 1.2:

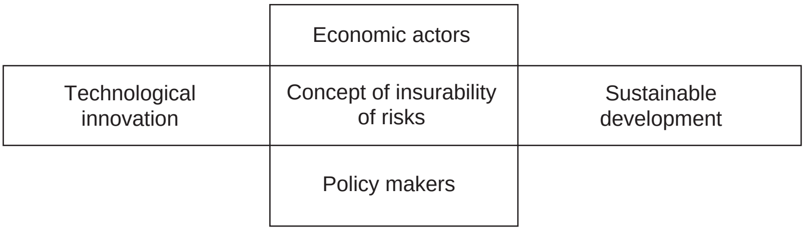

Figure 1.2 Insurability as a natural borderline between the market economy and legislation

A number of examples illustrate the range of circumstances in which different actors influence technological innovation. They fall into three groups:

- **Economic actors** that maximise return on investment by taking measures to prevent losses or reduce risks for economic **reasons or as good corporate citizens**,
- **Insurance, which influences technological innovation both by promoting it and by steering it away from high risk**/low opportunity directions, through adequate risk premiums and
- **Nation states** that promote technological innovation by financing specific projects, but also by hindering innovations through the subsidy of existing technology (diesel fuel, for example) or the prohibition of technological progress through legislation (such as GMOs in the European Union).

The objective of loss minimisation is the common principle of these examples and also the link with sustainable development: loss prevention is a prevention of social hardship, of wasted resources and of economic losses. Promoting technological innovation, which enables economic progress without losses in social and natural capital, seems an appropriate objective for our times, and insurance has a key role to play in it.

However, legislators and insurance companies have to act in a coordinated way. Buildings in flood plains cannot be insured, and building and land use laws should therefore prohibit these constructions.

Yet, not all risks that are insurable will be insured. Many car drivers prefer to save money by not having insurance (75 per cent of drivers consider their skills to be above average). And pharmaceutical companies sometimes prefer alternatives to insuring insurable risks for similar reasons:

> *Changes in the product liability insurance market for originator pharmaceutical products have made purchase of such policies uneconomic. For certain pharmaceutical substances, coverage cannot be obtained at all. To cope with this change in market dynamics, Novartis has established provisions for the product liability risks of the group. From 1 January, 2006, these provisions … provide the sole means for affirmatively managing the product liability risks of the Novartis Pharmaceuticals Division. Product liability insurance coverage for all other divisions … continues to be acquired from third parties.*

1.5.2 Regionalisation of the economy

The Performance Economy imposes changes in the belief structure of the mainstream economy. Some innovative components, such as carbon nano-tubes (CNTs) cannot be stored or transported because they cannot be separated if intermingled. As they need to be produced at the place of demand, their production processes will be regionalised.

A similar decentralisation revolution will happen through the introduction of nanostructured micro-reactors in the field of fine chemicals. Intelligent parallel working micro-reactors will take the place of large centralised reactors in the chemical industry. Fine chemicals no longer need to be produced at few sites in the world and then shipped to the user but can be produced in the quantities that are needed and where they are needed. This might lead to a spreading of the 'selling performance' concept detailed in Chapter 2, already common among paint manufacturers, to other parts of the chemical industry.

In some medical applications, nanostructured microreactors will enable a decentralised production of short-lived tracer elements, eliminating the present need to travel to central hospitals for most patients.

Regionalisation of the economy will also grow through the reindustrialisation of regions linked to an economic reorientation towards the management of existing physical assets (the patrimony). Many activities of the Lake and the Loop Economy of Chapter 3 are best done locally, where the clients and the goods are located.

Furthermore, concepts such as Jeremy Rifkin's Hydrogen Economy may well lead to a regionalisation of the energy production sector and change the structure and function of the electricity grid.

The quest for safety through energy autarky by politicians (explained in Section 1.2.5.2) is another driver for a regionalised economy. The New York City government, for instance, wants new buildings to rely on decentralised own energy production in order to reduce the impact of power cuts on security, safety and society.

A further major advantage of a regional economy is that it increases resilience against such disruptive events as natural disasters, pandemics and terrorism. The Performance Economy could thus lead to competition between regions, complementing today's competition between global corporations.

1.6 How to measure it!

The objectives of The Performance Economy are summarised in Figure 1.3. A considerably higher value-per-weight ratio follows from the consequence of achieving simultaneously higher wealth and lower resource consumption.

The new metric of sustainable economic productivity in the Performance Economy is 'economic value achieved per unit of resource consumed', or

VALUE PER WEIGHT, expressed in **€ per kg**.[32]

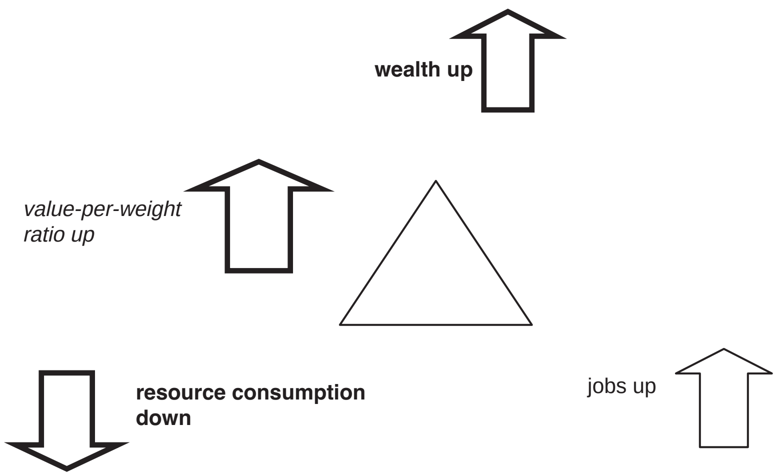

Figure 1.3 The objectives and metrics of Producing Performance in Chapter 1

Private consumers can calculate this metric for physical or material goods at the point of sale, as price and weight are known. The same goes for procurement managers in companies and public administrations; their concept of 'green procurement' will be simplified with the new metric.

Services are often based on a high initial material input. A taxi driver or a hotel cannot function without a car or a building. But their value-per-weight ratio can be improved by making more intensive or longer use of the initial input, creating additional units of service-life without additional resource consumption. A Performance Economy is competitive *and* sustainable because it greatly improves the ratio between the key factors: economic growth and corporate revenue on one side, and resource consumption on the other.

Wealth creation with less resource consumption is the main objective of the Performance Economy.[33] Instead of the purely monetary exchange value at the point of sale, which is the central notion of value of the Industrial Economy (expressed as annual turnover and GNP), companies and countries now have a composite indicator – the value-per-weight ratio – to determine their sustainable competitiveness and follow its evolution (Figure 1.3)!

Such examples as rail grinding and remanufacturing used combustion engines that will be shown in Chapter 3 demonstrate that service strategies to extend the product-life of physical goods are one key strategy in moving the Industrial Economy towards the objectives of the Performance Economy in cases where scientific or engineering innovation cannot propose a radically superior solution.

The new value-per-weight metric thus provides a benchmark, enabling each economic actor to identify its position and provide the laggards with reasons to search for alternatives with a higher value-per-weight ratio.

2
Selling Performance[1]

Why the shift? How it works! How to measure it!

2.1 Why the shift to selling performance in the Functional Service Economy?

The Functional Service Economy has several distinguishing characteristics:

- It internalises risks, and the costs of risk and of waste, over the full life cycle of products and systems by accepting full responsibility for performance – a strategy of caring. With this internalisation of all costs, the economic actors produce sustainable profits in a low-carbon resource-efficient economy.
- It gives incentives to integrate the 'Factor Time' into the economy through an extended performance responsibility.
- It is based on selling performance (results, utilisation), instead of selling goods.
- It accepts the challenge that private investment is needed to achieve public development objectives and is crucial to boost growth and prosperity.[2]

The Functional Service Economy incorporates many of the systems solutions in Chapter 1, as its economic actors can profitably exploit sufficiency solutions as well as loss and waste prevention opportunities. The Functional Service Economy also profits from an extended service-life of goods by economically exploiting the business opportunities of maintaining performance over time described in Chapter 3.

A 'cradle-to-cradle' approach (Stahel 1981), with a focus on maximising utilisation value and an open time perspective, enables entrepreneurs to exploit future opportunities by building resilience and redundancy into their business models:

- For consumption goods, such as chemicals and energy, an integrated life cycle management gives manufacturers incentives to strive for higher competitiveness by minimising costs and resource inputs, as compared to selling the goods. (In the case of packaged food and pharmaceuticals, manufacturers already carry a producer liability for the performance of their goods; witness the Nestlé powder milk and Perrier benzole trace cases.)
- For catalytic goods, which are contaminated but not consumed during use, an integrated 'rent-a-molecule' service enables economic actors to create revenue without resource consumption. (Smart materials of the Performance Economy will increase the volume and scope of these opportunities.)
- For durable goods, a life cycle management approach gives manufacturers incentives to design product systems built on a modular design using standardised components that can be commercialised through operational leasing and periodically adapted to changes in technology and in demand throughout their service-life. (Infrastructures and other 'public services' will increasingly benefit from Private Finance Initiatives (PFIs), a business model of selling performance, which includes private-sector financing and risk transfer and helps to prevent public debt from rising indefinitely.)
- For all goods, accepting a full life-cycle responsibility means that today's products are the resources of tomorrow at yesterday's resource prices.

The economic actors of the Functional Service Economy draw the biggest profit from a system optimisation over longer periods of time, which demands a redefinition of quality as shown in Figure 2.1.

Nation states can reward entrepreneurs through both incentives and appropriate framework conditions, and by demanding an extended performance responsibility in all public procurement contracts. In addition, governments can exploit new business models, such as Private Finance Initiatives (PFIs) and Performance-Based Logistics (PBLs) as powerful strategies of the Functional Service Economy to prevent public debt from rising further, and enable additional economic actors, such as banks and insurance companies, to contribute

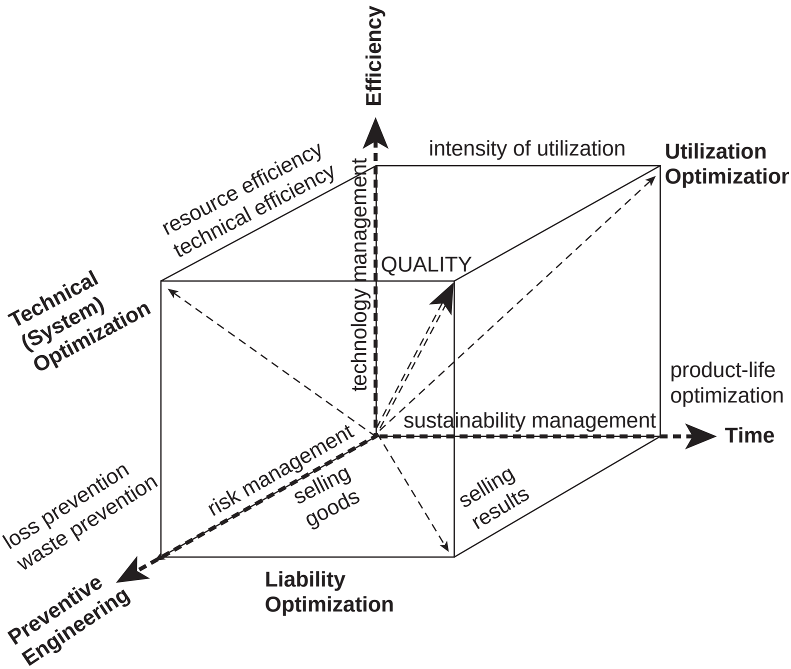

Figure 2.1 The Quality Cube: Quality defined as product system optimisation over longer periods

their expertise and skills to the (formerly nationalised) infrastructure sector. Some Public-Private Partnerships (PPPs) have a similar function.

Business models with an Extended Performance Responsibility (EPeR) may become a precondition to commercialise goods with embodied smart nanotechnologies in order to prevent a release of nanoparticles into the environment in the end-of-life phase of the goods, Similarly, EPeR may become a precondition for the use of smart materials on a rent-a-molecule basis.

2.1.1 The 'Factor Time'

The Functional Service Economy introduces 'time' into the existing concept of technical efficiency optimisation, defining new business models based on quality as achieving the best technical system performance and utilisation performance, while minimising potential liabilities over longer periods of time.

The new definition of quality further enables economic actors to maximise their profit by exploiting opportunities from the Lake and the Loop Economy, such as long-life maintenance-free components and better use of their regional service activities.

> *In contrast, the Industrial Economy optimises production up to the point of sale. Its optimisation concerns mainly the 'Efficiency' dimension in Figure 2.1. The long term therefore has a very limited meaning in the Industrial Economy, its objective being to shorten the lap of time to the next sale.*

Excluded from the Functional Service Economy is financial leasing if it constitutes a deferred payment, and short-term operational leasing contracts with a sale of the goods at the end of the contract. Both models provide no incentive to influence product design in the sense of improving the performance along the two new axes – 'Preventive Engineering' and 'Time' – of the Quality Cube (Figure 2.1).

2.1.1.1 The Factor Time concerns both supply and demand

Xerox, with headquarters in Rochester, NY, has been selling customer satisfaction since the 1980s against a fixed fee for each photocopy made and is one of the pioneers of selling performance instead of goods. Xerox's history shows that the Functional Service Economy is not a guarantee for success; a constant adaptation of the initial business model as well as of the hardware and software to changes in technology and customer demand is a necessity. But these risks are carried exclusively by the supplier (see Section 2.4.1.3).

The 'Green Lease' concept of the US-based Interface Corporation (the world's largest manufacturer of modular carpet and carpet tiles) guarantees the service of a perfect carpet over 20 years within the framework of the Functional Service Economy. This performance concept includes maintenance and component exchange (carpet tiles) for an annual rent over the duration of the lease. The company's 'Green Lease' so far has achieved a low market penetration. Many facility managers seem to prefer negotiating with a number of independent services contractors, while others prefer a high initial payment rather than small rental fees over a 20-year period (See details in Section 2.4.2.1).

These obstacles are similar to those encountered by Xerox when selling customer satisfaction at a fixed rate per photocopy. One argument brought forward by managers against Xerox's all-inclusive business model was the capability built up in their own procurement departments to find the cheapest toner cartridges, which would become redundant.

2.1.2 The case for internalising the costs of risk and of waste

The different degrees of internalising the costs of liability from risk and waste are shown in the following Figures 2.2 and 2.3, opposing two business models of the Industrial Economy – outright sales by manufacturers and rental by third-party operators – with those of the Functional Service Economy – selling system utilisation and selling customer satisfaction.

Figure 2.2 shows the shift from the Industrial Economy – where the producer sells goods and externalises risk and liability for quality and

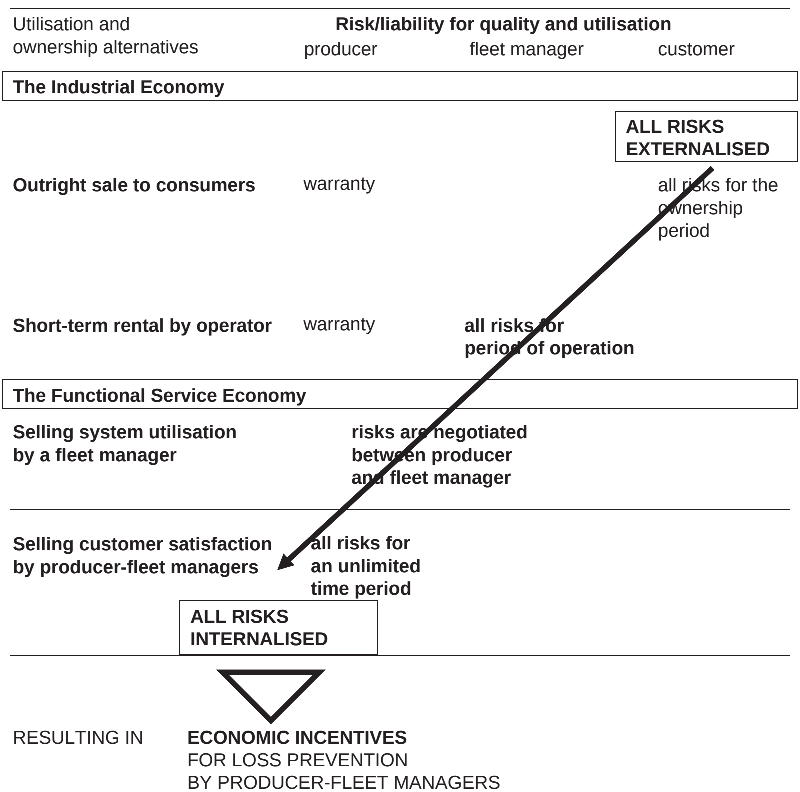

Figure 2.2 In shifting from the Industrial Economy to the Functional Service Economy, the cost of risk shifts from the consumer to the producer

utilisation to the customer – to the Service Economy – where the producer sells system utilisation and internalises these risks and their costs.

Figure 2.3 shows the same shift for waste costs and liability from the Industrial Economy – where the producer externalises all waste costs and liabilities to the taxpayer and state – to the Service Economy – where the seller of system utilisation internalises these risks and liabilities and their costs.

Figure 2.4 summarises the different degrees of internalisation of the liability for costs of risk and waste in the Industrial and the Functional Service Economies, and shows the economic incentives for loss *and* waste prevention for producer-fleet managers in the Functional Service Economy.

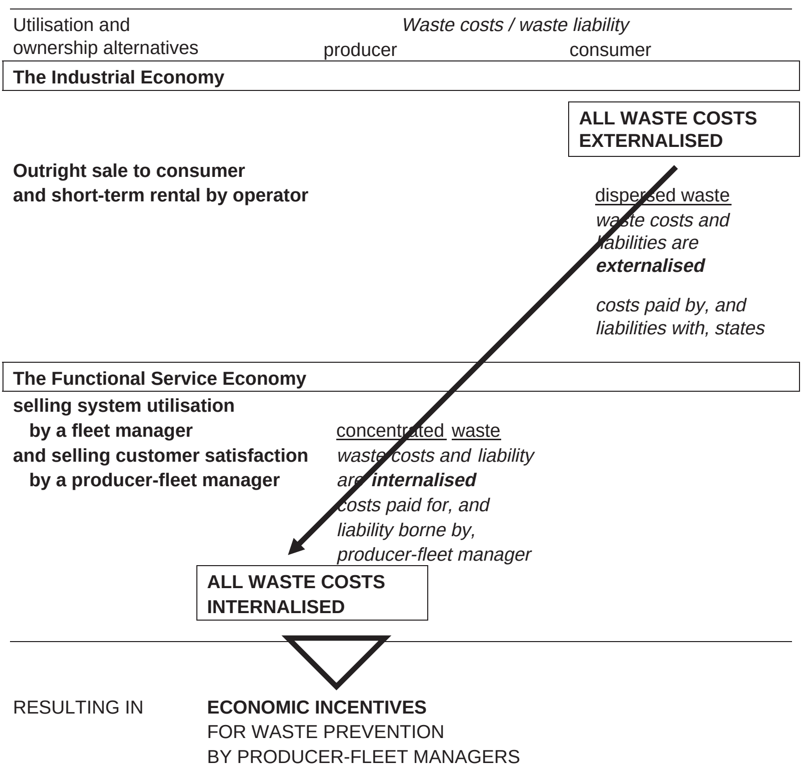

Figure 2.3 In shifting from the Industrial Economy to the Functional Service Economy, the cost of waste shifts from the state to the producer

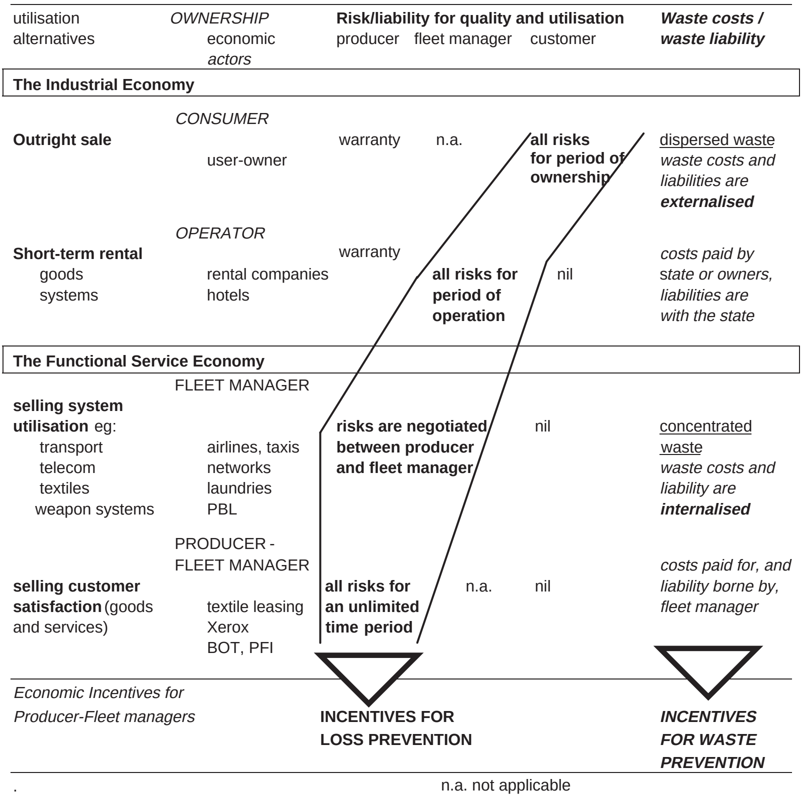

Figure 2.4 The liability costs for utilisation and waste in different business models[3]

All economic actors seek to reduce costs in order to be more competitive. One approach is to transfer (externalise) costs for liability, risk and waste disposal to third parties by selling the goods. Yet, this constitutes a vicious loop, as it also eliminates economic incentives to prevent or minimise these costs. As a result, the cost factors and economic incentives for prevention differ greatly among the different business models, as summarised in Figure 2.4.

2.1.3 Incentives for integrating 'Factor Time' into the economy via extended performance responsibility

Ownership includes risk ownership! Economic incentives for loss prevention work best if the *costs for risks and liabilities during utilisation* are internalised by the manufacturers and other economic actors involved.

This is the case only for the business models of the Functional Service Economy, in the lower half of Figures 2.2, 2.3 and 2.4.

Similarly, economic incentives for waste prevention have an impact only if the *costs for wastes* at the end of the good's life are borne by the economic actors involved. Again, this is the case only for the business models of selling system utilisation and customer satisfaction in the Functional Service Economy.

> *The economic actors of the Industrial Economy – the upper half of the three figures – profit from delegating the responsibility for utilisation to the buyer-owner-user of their products, and for the end-of-life to the state or third parties. They have neither an incentive nor an obligation to take on any responsibility beyond the point of sale; the costs of risk and waste are carried by the consumers and taxpayers.*

The Functional Service Economy is thus characterised by an Extended Performance Responsibility that is reflected by a corresponding shift in the revenue structure from goods to services. Among the pioneers of the Service Economy is General Electric, which since the 1990s has earned 75 per cent of its revenue from the sale of services and only 25 per cent from product sales!

This business model is also referred to as 'the Functional Economy'[4] because its economic focus is on the function (or performance) of goods; fashion and other emotional factors – 'e-factors' – are not driving the Functional Economy. However, e-factors can be integrated through contracts enabling customers to change goods frequently. The short-term rental of goods and equipment from a fleet manager allows constant changes and the testing of, for instance, sports equipment, cars, mobile phones and other consumer goods. Long-term corporate fleet leasing contracts for cars, lorries and aircraft can also provide this flexibility to each individual manager-user.

The business model of selling performance in the Functional Service Economy is currently used in several distinct market segments ruled by different driving factors:

- **B2B (Business to Business) Performance Services** are offering customers better tailor-made solutions for their needs. Demand for Performance Services is driven by economic pressure on the buyer to choose the most advantageous solution, and is characterised by a manufacturer relationship directly with the customer (Section 2.4.1).

- **B2B Management Services** in the B2B markets include facility management; textile leasing and chemical, energy and agricultural management services. The most visible B2B management services today are all-inclusive operational leasing contracts, which can be for cranes, public toilets or textiles or for facility management of buildings and industrial plants (Section 2.4.2).
- **B2G (Business to Government) markets** are probably the largest domain for selling performance (Section 2.4.3). Its main segments are:
  - **BOT, BOO and PFI** – Build-Operate-Transfer, Build-Own-Operate and Private Finance Initiatives are private-sector vehicles to finance, own and operate public infrastructures. They are driven by a shortage of public funds to finance necessary infrastructure projects and by manufacturers that want to break out of volatile production cycles.
  - **PPP** – Private-Public Partnerships are cooperation agreements where governments typically pay for the initial research and development phase before handing a project to the business sector for exploitation. The European global positioning system (GPS) is an example of such a PPP that failed.
  - **PBL** – Performance-Based Logistics is the defence industry's version of buying performance, enabling ministries of defence to avoid future problems in the operation and maintenance of defence equipment, such as the unavailability of service parts for out-of-production weapon systems, and puts a fixed cost on the future performance of equipment.
- **G-MS** – Generic Performance-Based Management Services, offered to both corporate clients and individuals, are among the oldest examples of selling performance instead of goods. They include urban transport, railways, toll motorways, bridges and tunnels as well as airlines, shipping lines, hotels, the post office and similar public services. In the past, selling Generic Performance-Based Management Services to consumers are largely concentrated in rental apartments, 'cascadable toys' such as sports equipment and cars, and special goods such as single-use cameras and costumes. New trends of G-MS exclusively addressing consumers (B2C) include the short-term rental of expensive goods – such as exclusive name-brand ladies handbags – where fashion and social status dominate over function (Section 2.4.4).

The business models of the Functional Service Economy are driven by supply-side innovation, demand-side needs and competition from economic actors of the Lake and the Loop Economy in Chapter 3. Big differences exist between business and private clients. The same goods – such as cars, tyres and computers – are sold to businesses as investment goods in the Functional Service Economy (internalising costs of risks and liabilities), and sold as consumer goods to individuals under the rules of the Industrial Economy (transfer of ownership and costs of risks and waste to the consumer).

Selling performance and customer satisfaction in markets of long-life goods help suppliers to mitigate market volatility. Take European real estate as an example. An average life expectancy of 50 years for buildings means that the new construction market in an average year is equivalent to 2 per cent of the building stock, and subject to economic cycles of boom and bust. The volumes of repair and maintenance activities, however, vary much less from one year to the next: annual repair and maintenance are required for most buildings, infrastructure and technical systems, even if budgets are tight. The yearly operation and management (O&M) costs of a motorway correspond to 5 per cent of the initial construction cost; after 20 years, a motorway's O&M expenses will thus equal investment costs.

The bidding for control of the French state-owned toll motorways in December 2005 has shown a high interest of construction, operator and investment companies to become owner-operators of toll motorways. Among the bidders were the motorway operators Citra (Spain) and Autostrade (Italy), the construction companies Vinci (France) and Abertis Infraestructuras (Spain) as well as the financial services firms Ontario Teachers' Pension Plan, Borealis, Caisse des Dépôts, Axa, CDC and the finance holding of the Peugeot family, FFP (all French). The sales price of the toll motorways was much higher than expected, and shows the interest of private-public corporations to finance and operate private infrastructure projects. A similar development can be observed for long-term operation and management contracts for airports, commercial parking lots, street furniture and even public toilets.

2.1.4 Selling performance versus the sale of goods

The key differences between the two business models, selling performance in the Functional Service Economy and selling products in the Industrial Economy, are summarised in Table 2.1. In Paul Hawken's book *Natural Capitalism*, Walter Stahel is given credit as inventor of the concept of selling results instead of selling goods.

Other key advantages of selling performance are a guaranteed future supply of resources to the economy and a national resource autarky.

Table 2.1 Selling performance versus selling products

Sale of performance in the FUNCTIONAL SERVICE ECONOMY	Sale of products in the INDUSTRIAL ECONOMY
The object of the sale is performance, customer satisfaction, the result	*The object of the sale is a product*
The liability of the provider is for quality of performance or usefulness	The liability of the seller is for manufacturing quality only (defects)
Buyer requires no capital up front	Buyer needs capital to buy goods
Payment is due pro rata if and when the performance is delivered ('no fun no money' principle)	Payment is due at the transfer of property rights ('as is where is' principle)
Performance has to be produced *in situ* through services, around-the-clock, no storage or exchange possible	Products can be produced centrally/ globally and stored, resold or exchanged
Property rights and liability remain with the manufacturer/fleet manager, leading to caring and sharing approaches	Property rights and liability are transferred to buyer, leading to manufacturer's attitude of 'out of sight, out of mind'
Advantages for the user:[1] • high flexibility in utilisation • little own knowledge necessary • cost guarantee per unit of performance • zero risk • status symbol as when bought	Advantages for buyer: • right to possible increase in value • status value as when buying performance
Advantages for the OEM/fleet manager: guaranteed access to its own resources and materials, at a known resource cost, and choice of optimal reuse strategy	Disadvantage for manufacturer: no control over goods and the inherent material and embodied energy pool after the sale
Disadvantages for user: • no right to possible increases in value	Disadvantages for buyer: • zero flexibility in utilisation • own knowledge necessary, such as a driver's licence • no cost guarantee • full risk for utilisation and disposal
Marketing focus: customer service and long-term customer relationship	Marketing focus: publicity, sponsoring to trigger spontaneous purchases
Central notion of economic value: UTILISATION VALUE constantly high over long-term utilisation period	Central notion of economic value: EXCHANGE VALUE high at the point of sale

[1]Main drivers of the Functional Service Economy.

These macroeconomic advantages are also valid on a microeconomic level for corporations. In future, the main advantage for providers or sellers of performance of physical goods, such as manufacturers or fleet managers, may well be guaranteed future access to resources at a known cost, as owner-manager of the assets.

As shown in Chapter 3, 80 per cent of the energy used in manufacturing physical goods is embodied in the goods' structural parts, 20 per cent in secondary elements and technical equipment. As a result, high energy and/or material prices, or a shortage of energy and/or certain materials, substantially increase the competitiveness of service-life extension options versus the manufacturing of new substitute goods.

The continued ownership of goods in the Functional Service Economy and the assured take-back place the performance provider in the driver's seat, similar to the economic actors in the Lake Economy of Chapter 3. The performance provider can choose the optimal timing strategy at the end of each service-life, according to actual market conditions: reuse or remarket the goods or components, or recycle the components in order to recover the molecules. The performance provider thus becomes a full asset manager with long-term options at no additional cost and with a substantially reduced vulnerability on the availability and cost of future energy and material resources.

For nation states with few or no natural resources, the Functional Service Economy promises a higher degree of autarky for raw materials and energy on a national level.

In the case of dissipative applications of such rare materials as iridium, gold and platinum, reuse of components may be the cheapest strategy. Today, these materials are mainly contained in lighting, catalytic converters and electronic goods, with no recovery option.

2.2 Selling performance in the Functional Service Economy: How it works!

2.2.1 The origins of the Service Economy

The origins of the Service Economy were to make the most of technological applications in the market. This means that the growth of service functions in producing wealth is the direct consequence of the development of production technology throughout the Industrial Revolution.

Up to the early 20th century, changes in technologies and production processes resulted mostly from improving practices on the spot and through work experience, in short from 'learning by doing'. Very rarely were such changes or improvements the outcome of a specifically financed research programme inside the company or contracted outside. The professionalisation of research only started during the 1920s, reflecting the growing complexity of new technologies and the need to carefully plan their development and manage their achievements.

The maintenance and storage of incoming raw materials and storage of finished products have always been part of even the most simple production processes. But the growing specialisation of production units, an increasingly complex and advanced technology as well as better protection of more sophisticated products against damages over longer transport distances are contributing to a continuous rise in the cost of organising such functions. As a result, the pure and relative costs of production are decreasing.

An increasing economy of scale to lower unit costs in manufacturing has meant the distribution of products to a larger number of people in countries further from the point of production. This has required the organisation and operation of complex marketing functions without which the product simply cannot reach most potential consumers. The financial activities and insurance functions linked to the performance of production and distribution become essential and ultimately indispensable. When investments for one 'machine', such as a nuclear power plant or an oil rig routinely are over US$1bn, an adequate functioning of all financial and insurance institutions becomes crucial. A variety of liberal professions – doctors, lawyers, market researchers, economists, consulting engineers – are needed to perform a large number of professional services, either within or attached to the production complex. In addition, mass education and health-for-all programmes have been among the rapidly expanding service functions throughout the Industrial Revolution.

The growth in services is thus the result of the specific successive evolution of the production process itself. Technological advances, which made production processes more efficient, have introduced numerous new services at all phases of the transformation processes. During the last quarter of the 20th century, the majority of functions performed – of jobs done – in manufacturing and in agriculture concerned service activities: the Service Economy has arrived.

All these services are essential in planning, accompanying and supporting production not only up to the point of sale but also afterwards by assuring product performance during utilisation. Yet, there is another important service that the maturing Industrial revolution has finally put in evidence: the management of waste, or the Loop Economy of Molecules.

The growth of services, such as insurance, even in periods of declining economic activity, is inherent to the modern production system, which in turn depends on insurance and other services as key tools to guarantee its proper functioning. At an advanced level of production, where risks and vulnerabilities are highly concentrated, insurance has become a fundamental precondition for investment. Similarly, social security, public security, health and life insurance have now achieved the status of a primary goods in industrialised countries.[5]

2.2.2 From the Service Economy[6] to the Functional Service Economy

The growing telecommunication, banking, financial, maintenance and engineering services now offered are not simply a new kind of 'production', an extension of what has happened in the textile, iron and steel and chemical industries. Selling a shirt (once, in a given moment of time) is a different business from textile leasing, i.e., fulfilling a maintenance contract over an extended period, during which the seller remains contractually responsible to the buyer for the product's performance. We switch from an Industrial Revolution mentality to a Service Economy mentality when we add to a shirt's production costs the maintenance costs (washing and possibly repairing) during its life, plus the costs of its disposal and replacement. Then we appreciate the shirt's value in terms of its actual utilisation.

The more complex a product, the higher is the cost of learning how to use it and the more important is the assurance of its usefulness. In the Functional Service Economy, people are not buying a product, they are buying functioning systems and system functioning over time as a permanent service!

The same concept can be found in the health sector. Health Maintenance Organisations (HMOs) combine various elements: incentives to doctors to produce healthy patients rather than major consumers of drugs and hospital services; generalists integrating the collaboration of specialists; use of new technologies to record a patients' medical history and reduce social health expenses. The good functioning of HMOs provides better treatment for patients and cost reductions in the health sector, because the target is an optimal system-operation. The value of HMOs is not identified with the amount of money spent on drugs or hospitalisation. Money is more efficiently spent because the economic value has shifted to performance and results (of increasing health) rather than a pure 'industrial' vision (equating more drug consumption with an increase in health and wealth).

For many market needs, the Functional Service and the Industrial Economies both offer competing solutions. Differences in framework conditions between countries therefore have a heavy hand in guiding the markets in their obligation to internalise the costs of risk and liability.

In global markets, small players prefer the business model of the Industrial Economy, which limits liabilities in time and space through its out-of-sight out-of-mind approach. A small producer in China can sell goods anywhere in the world, but it is difficult to imagine its selling performance in Europe or the US to local customers without local partners and third-party guarantees. This is why legislation imposing Extended Performance Responsibility (EPeR) can lead to integrated solutions with local economic actors. Today, there are few consumer protection policies that impose a manufacturer's product liability beyond a short sales warranty; consequently, insurance cover for an extended performance responsibility is offered but seldom bought by manufacturers.

This trend can be countered by a redefinition of national framework conditions to reward extended performance responsibility, cradle to cradle. This will speed up the change from a throughput-driven Industrial Economy to a responsibility-accepting Performance Economy, and from a product to a system focus.

By guaranteeing, and getting paid for, customer satisfaction over the full utilisation period, manufacturers-*cum*-fleet managers develop a strong self-interest to reduce risks during utilisation, for instance by designing products and systems that are safe against abuse, misuse and theft, leading towards fail-safe and fool-proof solutions.

2.2.3 From the supply chain to the performance chain

The Functional Service Economy has many objectives in common with the Lake and the Loop Economy described in Chapter 3. In both cases, the vision is of an economic optimisation over an open-ended service-life. But the Functional Service Economy is not limited to durable goods and incorporates an extended performance responsibility.

In the Functional Service Economy, the 'Factor Time' as well as sufficiency solutions become new factors in competitiveness. Exploiting these opportunities demands an understanding of which corporate strategy and which business model can be the most successful for each product group, and a cognisance of the governing factors and social impacts.

The satellite sector is a prime example of selling performance by a number of independent but interlinked economic actors, each guaranteeing the performance of its products or services. Satellite manufacturers produce a product that, once in orbit, can be corrected or maintained only by software commands. The launch company guarantees that the satellite is placed in the right position and orbit, while the satellite operator sells the functioning of the satellite over ten or more years.

Performance guarantees in the satellite business have a cost that can be determined precisely: the cost of insurance! Premiums vary according to the track record of the economic actors; their cost is the second expense item of satellite operators after financial depreciation costs. Satellite manufacturers, despite the fact that they sell their wares primarily to satellite operators, have a business model that is characteristic of the Performance Economy. The core goals of Lockheed Martin, for instance, aim for reliability and long life to support customers well beyond design life. Its main A2100 bus satellites have a basic identical structure and modular design, which comprises only flight-proven standard components with an extensive heritage or track record.

2.3 The structure of the economy selling performance

Table 2.2 shows the links between corporate strategies, product groups, business models and the three factors: science, Extended Performance Responsibility (EPeR) and job-creation potential.

The main corporate strategies and inherent business models of the Performance Economy are:

- **Strategy S1**: selling prevention – knowledge-based solutions founded on science but also experience and know-how. It is open mainly to companies with a corresponding track record, 'selling the talk', such as DuPont in Chapter 1.
- **Strategy S2**: manufacturers selling performance, services or results – many examples in this chapter are based on EPeR in combination with science. It follows a vertically integrated business model that enables manufacturers to control the entire value chain and reach down to their customers.
- **Strategy S3**: fleet managers with a loop responsibility – are most successful with a business model from a closed Loop Economy, witness single-use cameras by Fuji and Kodak and products with return incentives (such as deposits). A key capability here is efficient reverse logistics.

Table 2.2 Key business strategies of the Functional Service Economy

Corporate Strategies and product groups	S1 prevention strategies	S2 manufacuturers selling performance, services or results	S3 manufacturers fleet managers with loop responsibility	S4 fleet managers with maintenance & operation responsibility	R independent remanufacturers
	SCIENCE				
consumption goods (fuel) dissipative goods (paint)	knowledge -based solutions	vertical integration			
catalytic goods (engine oil, solvents)			an economy in closed loops		
durable mobile goods (cars) durable immobile goods (buildings)				utilisation optimisation	product-life extension
		EPeR Extended Performance Responsibility			**JOBS** job creation potential

- **Strategy S4:** fleet managers with maintenance and operation responsibility, such as facility managers – best use a business model focused on use optimisation for durable goods and systems.
- **Strategy R**: (independent) remanufacturers – draw their profits from extending the product-life of durable goods; examples are given in Chapter 3.

The main product groups of the Performance Economy are:

- **Consumption goods** – such as energy, water and food – that disappear through their application. This includes convenience foods, pharmaceuticals and other edible products, including bottled water and alcoholic beverages. Manufacturers of these goods carry an extended responsibility for the performance of their goods. Strategies available are S1 and S2, and the drivers are life sciences and material sciences. Unsatisfied customers can take legal action, especially in countries that allow class action suits.
- **Dissipative goods** that continue to exist after application to a 'carrier' good but are not recoverable, for example, paints, varnishes, cement and platinum (catalytic converters). Problems arising during use or at the end-of-life can fall back on the original manufacturer. Witness the litigation concerning the waste management of leaded paints and asbestos insulation. Strategies available are S1 and S2, with drivers again being life sciences and material sciences.
- **Catalytic goods** – for example, filters, solvents, engine oil and gravel on flat roofs – that are not consumed in applications but lose their purity or efficiency. The impurities 'polluting' the catalytic goods can contain valuable information on the 'carrier equipment'; in the case of engine oil, on the qualitative state-of-the-art of the engine components. Strategies available are S1, S2 and S3.
- **Durable mobile goods** – such as automobiles and computers – that offer the opportunity to exploit all available strategies and business models. A key capability is reverse logistics; drivers are such tools as Design for Environment, called Eco-Design in Europe.
- **Durable immobile goods** – for example, buildings and infrastructure – that again offer the opportunity to exploit all available strategies and business models. A key capability is to be able to intervene quickly on site.

The three key functions of the Performance Economy are:

- **Science** as the key to strategies S1 and S2 can be applied to all product groups. Science as a driver is explained in Chapter 1.

- **EPeR** – is the result of strategy S2, where manufacturers sell performance instead of goods. Insurance is a precondition for activities in this field, enabling companies to advance into new fields of science. EPeR as a driver is dealt with in the following sections.
- **Jobs** – a result of fleet management and remanufacturing activities; Strategies S3, S4 and R concern catalytic goods and both mobile and immobile durable goods. The job-creation potential is described in Chapter 3.

2.4 Markets and economic actors selling performance

Systemic and systems solutions thrive in the Functional Service Economy. Understanding the opportunities and vulnerabilities of systems solutions and networks then becomes a key capability of successful economic actors in the Functional Service Economy (Table 2.3).

The Functional Service Economy, which optimises the use or function of goods and services, focuses on the management of existing wealth in the form of goods, knowledge and natural capital. The economic objective of the Functional Service Economy is to create the highest possible use value for the longest possible time while consuming as few material resources and energy as possible. The aim is thus to achieve a higher competitiveness and increased corporate revenues, measured in the value-per-weight ratio (see Chapter 1).

As most networks are long-term investments, users and systems operators share responsibility for many systems and network solutions.

For both public and toll *motorways*, the state provides the framework (speed limits) and emergency interventions (fire brigade and rescue). The main risk for operators of toll motorways is financial: insufficient revenue due to low volumes of traffic and liability for accidents due to unsafe design.

Railway networks are fully controlled by the railway itself. It is impossible to optimise separately the different parts (tracks, rolling stock, energy supply, signalling, safety), as the example of Railtrack in the UK has shown: railways have to internalise all costs of safety and liability as well as costs of risk and waste. Short-term savings on one component (track) push up its share price but ruin the system.

Airlines and shipping lines are unique in that they have to provide food and lodgings for passengers in the performance chain and are held responsible until the passengers have reached their destination. Captains are in charge of individual vessels both on sea and in the air. As seaways and airways over the high seas are not under state control,

Table 2.3 Opportunities and risks for systems and network operators

Actors	Motorway operators	Railway operators	Airlines	Shipping lines	Electric utility	Hotels	Smart white goods operators
Responsibility for							
Safe paths	Operator	Railway	(Air control)	?	Utility	–	–
Safe harbours	Operator	Railway	Airport	Harbour	–	Hotel	–
Fuel/energy supply	Driver	Railway	Captain (airline or wet lease)	Captain, shipping company	–	Hotel	Utility company
Reservations, billing	Driver	Railway	Airline	Shipping company	Utility	Hotel	Utility company
Emergency services	State	Railway	State/Airport	Other ships	?	State	–
Safety in operation	?	Railway	Airline or wet lease	Captain, owner	Utility	Hotel	OEM/fm[1]

[1]OEM/fm: Original Equipment Manufacturer cum fleet manager.

an active interaction between ship and aircraft captains operating in the same region is necessary. Pirates operating in international waters can create havoc to the safety of shipping, as they recently did off the coast of Somalia. In early 2009, the ship owners' countries took steps to guarantee shipping safety by building a military presence and organising convoys in the area. Operational responsibilities can be outsourced by airlines and shipping lines through 'wet leases' (operational leasing of aircraft, crew and fuel) and ship charter contracts. They can then focus on organisational issues in direct contact with the customers, such as timetables, pricing, ticketing and marketing.

Electric utilities are networks with a monopoly character. They give no guarantee for the uninterrupted availability of electricity. Power cuts entail higher overall costs for clients that depend on an uninterrupted supply and must pay for stand-alone diesel-power generators, batteries or fuel cells. This potentially leads to a role change. If local and regional back-up systems turn into electricity suppliers, the network becomes a two-way electricity distributor and the utility companies a place of storage. Such a trend has started in European countries with the enactment of energy feed-in laws for electricity from renewable sources. Jeremy Rifkin predicts that this will be the future norm in his vision of a Hydrogen Economy.

Hotels are in charge of all potential risks except for safe access and emergency services, which are normally provided by municipal fire brigades.

Smart white goods create a clash of interests when the Functional Service Economy extends to private households. In the case of washing machines, manufacturers can supply the hardware and the maintenance services, but the billing is governed by the smart electricity meters of the electric utility that collects the data. This puts the utility in the driver seat; the manufacturer can no longer reach down to the customer and is now at the mercy of the electricity company, which can decide to run the show alone by buying cheaper white goods elsewhere and assume the fleet manager's O&M role. White goods manufacturers can therefore not be expected to offer concepts, such as 'rent-a-wash', if they have no control over the smart meters.

In the case of smart fridges, the content supplier is in the driver seat, not the manufacturer. Smart fridges can be compared to vending machines, which are owned, operated and refilled by the content provider, such as Nestlé or Coca-Cola. Vending machines are 'tools', typical equipment that are regularly remanufactured. A new example of 'content overtaking product' will probably become e-paper (see Section 2.3.4).

As described earlier, the Functional Service Economy can be broken down into several main groups:

- Performance Services in Business-to-Business (B2B) markets (Section 2.4.1),
- Performance Management Services in B2B markets (Section 2.4.2),
- Performance Services in Business-to-Government (B2G) markets, including PBL, PFI, PPP (Section 2.4.3),
- Performance Services in Business-to-Consumer (B2C) markets (Section 2.4.4),
- G-MS, Generic Performance-Based Management Services offered to both corporate and individual clients (Section 2.4.5).

Understanding the difference between 'tools' and 'toys' is key to successfully conquering the B2B and B2C markets. Up to now, corporate and individual clients have functioned differently with regard to monetary incentives and emotional factors. But there are signs that these borders are shifting, and in some cases may even disappear.

Tools are production or investment goods used by economic actors to make money. Tools are influenced by the needs of efficiency in both economic and productive terms. In contrast to consumer goods (toys), fashion plays a minor part; performance and results are what is expected from tools, similar to what is expected from workhorses.

Toys are goods for amusement, not to earn money. Some toys are influenced by the e-factor,[7] such as teddy bears and antique automobiles. But more often they are influenced by fashion's 'bigger-better-faster-cleaner' syndrome in the minds of both consumers and marketers! Toys are similar to Lipizzaner and race horses: it is the show that counts, not long-term efficiency.

This difference is also present in insurance contracts. Tools, such as buildings and production equipment – for example, machine tools – are normally insured for their replacement value independent of their age. If not damaged beyond repair, insurance companies will normally pay for tools to be repaired. Toys are insured for their depreciated value, based on taxation periods. A seven-year-old car, for instance, is fully written off. In case of an accident, the owner will have to invest his own money in repairs or buy a new car.

Few durable goods are produced in twin versions of 'tools' and 'toys'. Washing machines are a rare example. The semi-commercial washing machines used in laundromats are household equipment specifically designed and produced for intensive simplified use. The main differences between a household and a semi-commercial washing machine are

- the technical life (3000 versus 30,000 wash cycles),
- the number of programmes (99 versus a few basic programmes),
- their complexity (stand-alone with an integrated electric water heater versus hot water from a central source), and
- the presence or absence of a few elements that can lead to a breakdown (semi-commercial machines have no timer nor filter).

Both have a service-life of 10–20 years. Semi-commercial machines are tools that have to maximise profits for their owners and are remanufactured. Household machines are toys that are subject to fashion and are often replaced long before the end of their technical life.

This translates into significant differences in material and energy consumption. The semi-commercial machine used in laundromats are very resource efficient, with a material input per wash cycle 90 per cent smaller than household washing machines – a 10-fold higher material efficiency. Further, it reuses the hot clean water from the final rinsing for the initial wash cycle of the next client – reducing overall water and energy consumption.

Tools and toys are also culturally different as to time and money. While economic actors must work efficiently and productively, consumers are not under the same obligation. The more leisure time consumers have, the less efficient they tend to be, preferring time-consuming window-shopping rather than the 'too efficient' Internet shopping! Smart fridges, for instance, take away the burden of shopping but also the excuse for possibly discovering new goods while shopping. This could be one reason why some European countries like Germany and France, with a culture of a 35-hour workweek and an annual six-week holiday, lag behind the USA and Japan in many domains of the Functional Service Economy.

The following sections again highlight pioneers and champions. As noted earlier, 'pioneers' are explorers leading the way but are often not the most successful companies in the longer term; and 'champions' are the successful exploiters of an idea. The first section shows companies that exploit the inherent performance of novel materials or innovative processes and technologies, a strong link to strategies described in Chapter 1. The other sections show companies taking a new management approach in applying the business models of the Functional Service Economy.

2.4.1 Performance services in Business-to-Business (B2B) markets

The following B2B examples of performance services – with the characteristic of 'tools to make money for the customer' – are grouped according to their driver's science, sufficiency and efficiency:

- Science-based performance services (Section 2.4.1.1),
- Sufficiency-driven performance services (Section 2.4.1.2) and
- Efficiency-driven performance services (Section 2.4.1.3).

2.4.1.1 Science-based performances services

The following examples cover catalytic goods such as smart materials, RFID chips, micro fuel cells and reprogrammable e-paper, and selling performance of such durable goods as jet turbines.

- **Cookson's 'rent-a-molecule' of smart materials.** The UK's Cookson Group developed a composite powder that can be pressed into any form and, when magnetised, becomes an extremely powerful permanent magnet. The two characteristics, easy shaping and magnetisation on demand, make it an ideal material for use as a rotor in small electric motors. One possible application is in future automobiles using small electric motors integrated in each wheel, such as Michelin's active wheel, combined with a central source of electricity. Electric cables replace the propeller shaft and drain train (Section 1.2.5.3).

  After use, this smart material can easily be demagnetised by grinding it back into a powder and then remixed for its next use, an opportunity open for many economic actors. To benefit from the successive life cycles of its smart materials, the manufacturer has to retain ownership by, for example, leasing the material to component manufacturers with a return guarantee – a business model called 'rent-a-molecule'. In this case, the strategy of selling performance in the Functional Service Economy must be imposed on all levels from material to product. Otherwise, there is no guarantee that the smart material is returned to its manufacturer at the end of the product's life.

  In the absence of this option – cars are still goods sold in the Industrial Economy – the smart material has not been commercialised.

- **E-paper and content, a systemic solution.** E-books, or books on a screen, were seen as a future market in the early 21st century. When finished with an e-book, the reader simply changes the chip and goes on to the next book on the ***same*** e-paper. Yet, marketers underestimated the importance to readers of touching the paper, the possibility of making notes on the margins and keeping a book after it has been read. In early 2009, Sony launched its PRS-505, a new reader for electronic books that can store 160 e-books, which is being sold through European bookstores. Compared to the Sony-bookman, which was launched in 1992 without great success, the PRS-505 boasts a higher screen quality and better energy management; it uses energy only to turn pages and one battery charge is sufficient to read 6800 pages.

  In February 2009, Amazon launched a new e-book reader – Kindle2 – for its US customers. The new reader weighs 300 grams, can store 1500 books and the battery power can last up to two weeks. Kindle2's novelty is that it can transform e-books into audiobooks.

  E-books could also work well for such short-term applications as newspapers, especially on airplanes. As newspapers are often outdated by the time they are distributed in an aircraft, news on e-paper would be a perfect solution as it can be updated electronically at any time during the flight. At each stop, airline staff simply collect and update the e-paper and then redistribute it on the next flight. Marketers now estimate that by 2015, 25 per cent of all newspapers will be on e-paper.

  An estimated 230,000 e-books, in addition to a number of mainly US journals and newspapers, are currently available for download.

  E-paper is an asymmetrical systemic solution. The main cost factor is the e-paper, but the profit goes to the content or information provider. The system thus needs to be designed as a win-win situation; otherwise the same actor must provide both the e-paper and the content. There are similarities to the 'rent-a-wash' strategy of the white goods' example below.
- **Radio Frequency Identification (RFID) chips.** In logistic chains, RFID chips are destined to become the successors of the bar codes that consist of a single number and thus have a limited information capacity, and must be scanned manually with an infrared reader.

  RFID chips can do away with manual work, as one chip on a pallet automatically gives all the data on the quantity and quality of the goods when passing an electronic gate in distribution, while another chip on the product performs the same trick when passing the supermarket checkout counter. However, problems arise when RFID chips are fixed on metal goods without proper insulation, when there is more than one chip affixed to the goods or when the information on the chip does not correspond with the quantity or quality of the goods.

Furthermore, as manufacturers, distributors and logistics managers need free access to the RFID's information in order to share both costs and benefits, the electronic hardware and software systems involved must be compatible with the security system to exclude unauthorised persons from accessing and exploiting the data. The RFID's end-of-life liability also must be solved in order to prevent dissipative electronic nano-waste from entering the municipal waste streams.

RFID chips have also found applications to speed up maintenance activities and transport networks. For example, the German railways have equipped such critical components as wheel sets with RFID chips. By using a scanner linked to the central data bank, the railway's maintenance engineers can immediately see the maintenance record of a component and decide if any, and what, action is needed.

In 1997, Hong Kong introduced a single electronic ticket – the Octopus card – in its five public transport networks; by 2008, 95 per cent of Hong Kong residents were using the card. Based on RFID technology, the customer checks into the system when boarding a bus or train and checks out when leaving; the ticket fee is automatically deducted from the card or the customer's bank account, depending on the type of card. The Netherlands has also adopted the Octopus card system (*OV-chipkaart*) for its public transport: first in Rotterdam in 2005 and the following year in Amsterdam, with expectations of extending the system to all public transport (including the metro and *Snel-Tram*) throughout the country in 2009.

Mobile phone manufacturers have begun integrating RFID chips into their products and hope to sell electronic public transport tickets as a new service. In 2007, the East Japan Railways tested this system, but with limited success due to the data security and privacy of the RFID-based electronic tickets paid for via telephone.

Other uses for RFID chips are in 'electronic passports' and to facilitate car-sharing organisations' vehicle management and billing.

- **Small and micro fuel cells.** Small-scale energy-generation technologies, such as micro-CHP (combined heat and power) generation based on fuel cells combined with wind and solar energy, contain a huge potential as decentralised energy sources. They also provide energy services the opportunity to market these innovative technologies if they accept to carry all the risks (see Energy Management Services in Section 3.3.5). In the European Union, the implementation of its new Directive on Energy Performance of Buildings (EPBD, 2002/91/EC) should give a boost to energy management services.

  The launch of micro-fuel-cell production in Japan received wide media exposure in September 2004, when the Japanese Government announced plans to install the world's first commercial fuel-cell cogeneration system for residential use at the Prime Minister's new official residence. In Japan, home-use fuel-cell cogeneration is expected to play a major role in answering both energy needs and environmental concerns.

  Fuel-cell cogeneration systems, which provide both electricity and hot water to homes, have been developed and installed in growing numbers by Tokyo Gas and other companies in Japan since February 2005. The Ebara Ballard Corporation and Matsushita Electric Industrial Company introduced the world's first fuel-cell cogeneration system for residential use that employs a polymer electrolyte fuel cell (PEFC) and has a rated electricity generation capacity of one kilowatt and a hot water tank capacity of 20 litres. And Hitachi Ltd developed micro fuel cells for mobile devices that were shown at the Hitachi Group Pavilion during Japan's 2005 World Exposition in Aichi and commercialised the following year (see also Section 1.2.5).

  But the question remains: Who carries the development risk? Will the fuel cells be sold or leased to customers?
- **SR Technics – selling hours of jet engine functioning.** In the past, jet engines were regularly remanufactured to meet noise restrictions at major airports, long before wear and tear would necessitate it: generally after an average of 5000 flight hours. In the past, the engines were remanufactured by specialised maintenance companies, such as SR Technics and Lufthansa Technik, as a contract service for airlines.

  In the late 1990s, SR Technics, then a subsidiary of Swissair, realised that a higher quality of remanufacturing could not only reduce the engine's initial noise level but also extend the interval between two remanufacturing interventions by 40 per cent to 7000 flight hours. For airlines, this results in substantial savings through lower maintenance costs and a higher availability of aircraft. For SR Technics, however, the better quality of its remanufacturing service meant 40 per cent less revenue!

As a consequence, SR Technics changed its business model and offered select clients the payment of a performance fee corresponding to 20 per cent of the traditional remanufacturing cost for each 1000 flight hours of a remanufactured engine. SR Technics now made a higher profit from the extended operation of engines, but also carried a higher risk; the airline gained a higher operation availability of the aircraft. In order to manage the risks of its new business model, SR Technics developed Falcon, its own jet engine performance-monitoring software.

In October 2006, SR Technics was acquired by Dubai Aerospace Enterprise (DAE). This acquisition of a maintenance company known for its high quality and a broad client basis has given DAE a guarantee for the performance of the rapidly growing fleets of Ethihad, Emirates and other new airlines in the region. Today, SR Technics is owned by a consortium comprising DAE (a 30 per cent share) and Mubadala Development (a 70 per cent share).

But SR Technics still depends on the fluctuations of the aviation market. In July 2006, it won an exclusive maintenance contract for Boeing's new 787 Dreamliner but then in April 2009, had to close its plant in Ireland after the airlines were hard hit by the economic crisis. And the market also changed in another way.

For jet engine manufacturers, longer intervals mean fewer jet engines as back-ups and thus fewer sales. Some manufacturers changed their own business model to selling hours of flight time through an operational lease that included remanufacturing, instead of outright sales of jet engines, such as Rolls-Royce's power-by-the-hour strategy. As a result, SR Technics lost part of its customers to Rolls-Royce. This example is a warning to any innovative service contractor: an innovation can be short-circuited by engine manufacturers reaching down to the final customer.

- **Rolls-Royce: power-by-the-hour, selling hours of turbine function.** Rolls-Royce has transformed itself from a manufacturer and seller of turbines to a turbine leasing company, with corporate strategy and language adapted to clients' thinking. Its new strategy of 'selling total service' includes O&M-friendly design (spare-less repairs), operation (in-flight monitoring) and maintenance optimisation (selection of time and place of repairs) and reuse. It has also adapted its commercial language according to the customer:

- long-term service agreements to clients in the energy sector,
- mission-ready management solutions for military applications and
- total care (pay-by-the hour) for civil applications.

In 2006, Rolls-Royce's profits rose 17 per cent despite higher costs and a weaker US dollar. Revenues from services rose by 13 per cent and accounted for more than 50 per cent of turnover.

For aero-turbines, the economic system performance of total care is optimised through:

– in-flight monitoring of the engine's key parameters such as temperature, vibrations and in-flight anomalies, and regular reporting to Rolls-Royce,
– real-time management, based on the flight plans of the airplane carrying the engine, enables Rolls-Royce to do preventive repairs and maintenance. If an engine's in-flight monitoring system detects a need for intervention, a mechanic will perform the job at one of the airplane's next stops. If an engine must be changed, the airplane's flight plan is analysed to choose an airport on route with a spare engine available and an engine repair capability available,
– spare-less repair technologies have replaced stocks of spare parts at airports, since most parts can be repaired if the fault is identified before a part is broken. But even after breakage, technologies – such as diffusion bonding for fan blades – can recreate the original.

- **Hydrogen-fuel cell systems**. The most recent examples of hydrogen fuel cell systems for home and automotive applications are presented in Section 1.2.5.

2.4.1.2 Sufficiency-driven performance services

The following examples cover catalytic goods such as engine oil, consumption goods (energy and water), buildings and computers.

- **Mobil's synthetic long-life oil and related motor diagnostic service.** In the early 1990s, Mobil Oil introduced the first long-life synthetic engine oil, appropriately named Mobil One, and at the same time offered fleet managers of vehicles a motor diagnostic service (MDS). Thanks to the new oil, oil changes were stretched to 40,000 km or more without any risk to the engines. But as clients had doubts about the truth of this bold statement, MDS was the tool to convince them.

After the traditional mileage, fleet managers were asked to send samples of used oil to MDS for a free analysis, instead of changing the oil. MDS then returned a detailed analysis of the metals found in the oil sample to the customer, distinguishing between manufacturer's additives and customer's additives, thus giving indications of an excessive wear on critical engine parts and helping the fleet managers to optimise their maintenance activities to avoid breakdowns.

Once the system proved successful, Mobil Oil had to then convince its customers to pay for this service, as throwing away the used oil means throwing out key information on the functioning quality of the engine.

Mobil One in combination with MDS is an outstanding example of the commercial innovations necessary to sell the advantages of new long-life products to customers.

- **Energy- and water-saving contracting.** In energy- and water-saving contracting, the supplier is paid a fixed fee for supplying the heat or water needed. The smaller the resource volume consumed, the higher are the profits. Alternatively, a success-based fee with a split of the savings is agreed upon between service provider and client. In both cases, the contractor has an incentive to provide a solution with near-zero-energy or near-zero-water consumption. This involves a system design of new, or an adaptation of existing, buildings to include on-site energy and rainwater collection as well as such sufficiency technologies as waterless urinals (see also Section 1.2.3).
- **4 Times Square.** In 1996, 4 Times Square[8] in the heart of Manhattan, New York, became one of the city's first skyscrapers (48 floors, 160,000 m^2) to adopt standards for energy efficiency, indoor ecology and sustainable materials and to follow specified responsible construction, operations and maintenance procedures.

  The building incorporates on-site electricity generation using fuel cells and façade-integrated photovoltaic cells. The initial plan was to place on the roof eight 200 kW fuel cells to provide the base energy load, and PV cells to provide 50 per cent of the base building load, to make the building a net producer of energy. However, this plan was cut short as the weight and size of the commercially available fuel cells were incompatible with the hoisting equipment. The building, however, can be upgraded at a later stage if the appropriate technology becomes available. It should be noted that the tower became famous for being the only lit building in an otherwise black Manhattan during the 2003 New York blackout.

- **DestiNY, sustainable shopping centre in Syracuse.** DestiNY USA, a new centre on a former industrial brown site in Syracuse, New York, claims to be the world's first sustainable retail city with a 800-acre footprint, 200 acres of which are under the world's largest climate-controlled glass roof.

  Its over 100 million square feet of occupied space, which houses over 800 retail and entertainment outlets and 100,000 hotel rooms, is powered by a sustainable energy plant that means absolutely no fossil fuels are needed. DestiNY USA wants to become a showcase and living laboratory that facilitates innovations in renewable energy, security and other technologies (www.destinyusa.com).
- **Buildings designed as power stations.** The Science House at the Science Museum of Minnesota, in St Paul, a US region known for its harsh climate, has been designed to produce – not consume – electricity. In its first year, from February 2004 to February 2005, the 1400-sqft building generated 8000 kW of electricity and used 6000 kilowatt hours. The building has six-inch-thick walls filled with high-grade foam and high energy-efficient windows that draw in southern light without letting the heat escape and bring in daylight to minimise the need for lighting. About 12,000 sqft of razor-thin photovoltaic film applied to the metal roof converts 8 per cent of sunlight to electricity, which is stored in four direct-current boxes on the building's side. The technology used in the Science House won the award for the most innovative method at the summer 2005 conference of the European Council for an Energy Efficient Economy (www.smm.org/sciencehouse/).

  For more recent examples of buildings as energy autonomous systems, see Section 2.4.2.
- **Hewlett Packard, selling pay for capacity.** 'If you are not at capacity, don't pay for capacity', was Hewlett Packard's publicity slogan some years ago. 'With the new HP superdome, you can pay less when you use less, and/or buy more when you need more. By adjusting capacity with a simple phone call, you pay only for what you use – not unlike how you pay for electricity. You can run IA-64, you can run multiple operation systems and, because comprehensive service is included, you can run your business instead of your server'. By the end of 2005, its website hp.com/superdome had been deactivated, which could mean that the demand-side response had probably been unsatisfactory.

  In September 2007, Hewlett Packard Japan launched a new leasing contract – the HP BladeSystem Pay Per Use Service-CO_2 Reduction

Incentive Programme – aimed at reducing the cost of computer system use, as well as related power consumption and CO_2 emissions. HP Japan calculates the leasing charge by using a pay-per-use billing programme based on the tallied number of servers that are switched on each day, not on system configuration. The new discount programme compares the actual power consumption of servers working in the 'dynamic power saving mode' with the estimated power consumption in the conventional mode.

2.4.1.3 Efficiency-driven performance services

The following examples cover pioneers and champions in performance services involving consumption goods such as light, durable industrial goods, dissipative goods such as software, catalytic goods (reprocessing medical devices and transport packaging), aircraft and road vehicles, and computers.

- **Matsushita's Light and Trust Service.** Japan's Matsushita Electric Industrial Company launched in April 2002 its Light and Trust Service, in which fluorescent lamps are leased rather than sold and payment is made only for their lighting function.
- **General Electric.** General Electric (GE), the company that flaunted the biggest market capitalisation until the 2009 economic crisis – and a manufacturer of almost anything electromechanical, from white goods to jet engines, has since the late 1990s achieved 75 per cent of its sales revenue from services, and only 25 per cent from goods. But since the 2009 credit crunch changed the availability of loans to corporations, this business model has been seriously questioned. Yet, GE's financial arm, GE Capital Finance, still contributed one third of GE's total profits in the first quarter of 2009 and is still among the company's most profitable departments. (The resource recovery programme of another division, GEMS, is described in Section 3.4.2.1.)
- **Vesuvius' ceramic slide-gate service for the steel and iron industry.** Vesuvius, the ceramics division of the UK's Cookson Group, is a worldwide leader in high-performance speciality ceramics, refractory products and control systems for demanding industrial applications in steel, ferrous and non-ferrous foundries, and glass industries. It offers a full line of refractory products and services for the construction and maintenance of industrial processes through experienced installation contractors and distributors that supply all installation needs in the areas of refractory construction.

Vesuvius also provides the steel and iron industry with a full range of products and systems for the continuous casting of steel, including an operational leasing system for slide gate systems and refractories. Whereas in the past, ceramic slide gates were used until they broke up, Vesuvius now offers a slide-gate service that will change the worn slide gates before destruction, followed by remanufacturing (www.vesuvius.com).

- **Xerox: Selling customer satisfaction.**[9] After World War Two, Xerox was one of the first manufacturers to lease its equipment for a fee per copy rather than selling it, thus enabling the company to conquer the market at a time when customers did not yet have confidence in the new technology. In 1994, Xerox's 'Design for the Environment' became the first Service Economy case study of the Harvard Business School.[10] The study showed that savings from reduced material and component costs could be highly significant. For instance, between 1992 and 1995 Rank Xerox saved supply costs of €64 million, after it introduced a voluntary programme to recover parts of end-of-life photocopiers for reuse or recycling.

Xerox was a pioneer in incorporating such approaches as Design for Environment and the commonality principle – component standardisation across the different equipments – for its machines. At the end of a contract, the machines are re-leased, remanufactured or cannibalised for reuse of components. Components that cannot be reused are recycled by Xerox (see Section 3.4.3 the Loop Economy of Molecules). In the early 1990s, Xerox set the objective of zero waste for its complete operation, including all equipment and consumables. However, Jack Azar, who was then in charge of its Design for the Environment strategy, always stressed that the objective was to achieve a higher competitiveness!

The Xerox example shows that by selling customer satisfaction, the liability for anything that goes wrong falls back to the manufacturer-cum-fleet manager. While the introduction of a new generation of equipment with problems in the Industrial Economy will lead to higher revenues from repairs, it will lead to reduced profits in the case of operational leasing!

The Service Economy does not mean stand still! Innovations in the best corporate strategy have moved Xerox from a photocopier to a document company, while integrating permanent adaptations to customer changes as well as technological progress to its equipment, processes and business models. Book printing on demand and public service centres are today part of its 'photocopying services'.

- **SAP's on-demand software.** In February 2006, SAP, a world leading business software firm, introduced its on-demand solution, whereby customers access applications that run on centrally managed servers rather than installing and running them on their own machines. They pay a monthly subscription fee rather than up-front licence fees, which includes regular annual maintenance. SAP hopes to attract many new large companies, but expects them to eventually switch to running the software in-house instead, reverting back to the business model of the Industrial Economy. Meanwhile, SAP risks cannibalising its existing customer base.

  At the CEBIT 2007 fair in Hanover, Germany, SAP presented the first version of its AIS Software-as-a-Service concept (SaaS) for small and medium-sized enterprises, but it was not yet freely available. The idea seems to be moving very slowly.
- **Symantec SaaS software.** In March 2009, Symantec's new CEO Enrique Salem announced that the company will focus on Software-as-a-Service (SaaS) to market its products in the future. Expectations are that SaaS will continue to increase its market share and dominate the market by 2015.
- **Vanguard: Reprocessing medical devices.** Vanguard is Germany's technology and market leader in reprocessing specialised single-use medical equipment such as heart catheters as well as in-house reprocessing of medical devices for hospitals. It implements all quality and safety standards with respect to hygiene and technical functionality.

  As a result of the changed paradigm in remuneration of medical services by health-care insurance agencies, hospital administrations are under enormous pressure to contain costs. This has led to outsourcing entire departments – for example, the reprocessing of sterile equipment – to outside service providers, like Vanguard, that can perform core tasks more efficiently and with lower costs while increasing service quality and safety.

  The Vanguard Group offers hospitals a service spectrum focused on high-tech reprocessing of medical products and devices in accordance with legal requirements and guidelines. Vanguard has developed a unique technological platform, using validated, optimised processes.

  In-house sterilisation of both reuseable and single-use medical devices performed at the hospital or at its modern facilities nearby involves managing and/or operating hospital supply units at Vanguard's responsibility. Safety for patient and user is of the highest priority, as are documented reprocessing procedures, which can be reliably reproduced to show consistent results and which conform to defined specifications. This sector forms the nucleus for Vanguard's other activities and gives it a competitive edge.

A fundamental component of quality assurance and risk management is the ability to uniquely identify each individual medical device. To ensure that a device can be retraced back through all the applications and reprocesses it has encountered during its service life, Vanguard has established a reliable instrument coding system (www.vanguard.de).

- **CHEP rental packaging.** With more than 300,000 customers worldwide, CHEP is the global leader in pallet and container pooling services, serving raw materials and ingredients suppliers, manufacturers, growers, transporters, distributors and retailers to move their products efficiently and cost effectively through the supply chain. Goods transported include consumer goods, fruit and vegetables, meat, home improvement products, beverages, raw materials, petrochemicals and automotive parts.

  In its simplest form, pallet and container pooling is the shared use of standard pallets and containers by multiple customers or users. Wooden and plastic pallets are available, and customers pay a daily rent plus a fee for pallets lost.

  CHEP issues ready-for-use pallets and containers from its service centres to manufacturers and growers, who load and ship their products through the supply chain, at the end of which the receiving retailer or distributor offloads the goods and returns the pallets or containers to the nearest CHEP service centre, which inspects the pallets or containers and ensures they meet the quality standards for next customer use. High quality pallets and containers are constantly maintained, controlled, tracked and reused to benefit the entire supply chain. CHEP leverages a unique combination of customer-driven solutions, sophisticated control systems, a well-managed global infrastructure and advanced transport/logistics capabilities to synchronise the flow of pallets and containers to meet customers' specific demands. CHEP manages the daily movements of over 265 million pallets and containers from a global network of over 440 service centres in 42 countries.
- **FreePackNet – system design for kitchen appliances and their packaging.** A change in packaging can lead to a smart redesign of goods and their marketing. Kitchen appliances today require minimal packaging as the goods themselves are designed to with-

stand the physical forces – clamping, stacking, and shocks – during storage and transport. However, if transport packaging were made robust enough to absorb physical impact, the goods could be designed for optimal utilisation by being lightweight and energy efficient. Refrigerators, for instance, can be built using vacuum-insulated wall panels (VIP) instead of a frame with foamed insulation material (Mitsubishi, in 2005, was the first manufacturer to produce 'energy-miser' refrigerators using VIPs).

Furthermore, a standardised reusable transport packaging facilitates goods handling during both delivery and take-back in the Lake and the Loop Economy. It also enables a substantial loss prevention during transport. During the 2008 test phase, transport losses were reduced by a factor ten, from 5 per cent to 0.5 per cent.

The advantages of solid transport packaging combined with a lightweight product design are savings in material costs in production, and the option to remarket goods and components after take-back. However, existing production lines must be adapted, and the control of the value chain between manufacturers, distributors, sellers and the fleet managers of the reusable packaging must be renegotiated.

- **Lufthansa Technik – general manager for component support services.** In October 2004, Lufthansa Technik signed a 15-year contract with Spirit Airlines for a product service called 'Total Component Support', providing product-services for component life-cycle events for Spirit's new fleet of Airbus A321s and A318s (Spirit has placed a firm purchase for 35 Airbuses and an option for another 60).

  Components covered include avionics and APUs under a maintenance-cost per-hour or per-cycle programme. Wheels and brakes are covered on a per-landing basis, with work to be performed by Heico, of which Lufthansa Technik is part owner. Major landing gear and airframe components have not yet been included in the contract. Kits for Al through A8 checks will be kept at all Spirit stations, and Lufthansa Technik will maintain a pool of components at Fort Lauderdale, Florida, with back-up at its facilities in Germany.

  Spirit uses its own airplanes to transport components, kits and materials from base to base while Lufthansa Logistik manages the flow of products between Lufthansa Technik and Spirit. Lufthansa Technik has retained ownership of most contracted components, which helps Spirit keep its asset investment low.

- **ILFC imposing technological upgrade guarantees.** Individual customers have little power to force manufacturers to design goods for efficient operation and maintenance. But independent aircraft leasing companies, such as International Lease and Finance Corporation (ILFC) based in Los Angeles, took the lead in imposing their conditions on manufacturers.

  In 1990, 17 per cent of all aircraft was leased; by 2006, this share rose to 30 per cent and total assets of the 20 largest aircraft lessors worldwide reached US$120bn. The two leaders are ILFC, controlled by the American International Group (AIG), and GECAS, a subsidiary of GE Commercial Finance. Aircraft leasing companies active worldwide suffer less from volatile demand. After September 11, unused aircraft were transferred from the USA to Europe and China, while during its financial crisis, Brazil moved its idle aircraft to Australia and Taiwan.

  As the financial depreciation period for aircraft in most countries is 15 years, leasing companies would welcome a technological upgrading guarantee from major component manufacturers for at least 15 years, at which time they could re-market their assets with state-of-the-art technology. Manufacturers, however, have preferred to sell new goods rather than upgrades, even if most components could be designed for upgrading, by using a system design with component standardisation.

  During a period of slack demand in the sale of aircraft engines, ILFC imposed a 15-year upgrading condition in its contracts, and the engine manufacturers with low order books accepted it in order to survive. Today, long-term upgrading guarantees for aircraft have become the industry standard.

  AIG bought ILFC in the early 2000s, but due to financial losses in 2008–2009, it put ILFC up for sale. ILFC founder Steve Udvar-Hazy, who is said to have invented aircraft leasing, started negotiations (along with other interested investors) to buy back his former company, which in 2009 managed a fleet of over 900 aircraft and was worth an estimated US$5bn.
- **Michelin Fleet Solution – selling miles of motoring to lorry fleet operators.** In 2002, the French Michelin company started to sell truck tyre performance to fleet managers by offering to manage their tyre stock for a fee per kilometre driven, rather than selling the tires outright. This service results in reduced fuel consumption and longer service-life of tyres. Mobile workshops re-groove the tyres after 100,000 km and Michelin plants retread them after 125,000 km

using a remix that integrates rubber from used tyres. The Michelin Fleet Solution is a European market leader, with over 250,000 vehicles under contract. On the drawing board is a new tyre design with a 'double-decker' construction and an in-built re-grooving that should give a longer service-life to the tyres and thus less work for Michelin.

In 2006, Michelin won a Performance-Based Logistics contract from the US Armed Forces to supply, maintain and repair tyres worldwide, with payment per service unit (see also Performance-Based Logistics – PBL – in Section 2.4.3).

- **United Rentals.** The UK investment company Cerberus offered US$4bn to buy the US' leading equipment rental company, United Rentals. But as the 2007 credit debacle led to a major drop in United Rental's turnover and profits, Cerberus cancelled its bid for a fee of US$100 million. This shows that leasing companies and other economic actors selling performance are not immune against economic downturns.
- **Mercedes-Benz' Charter Way.** In the 1980s, Charter Way, the financial services division of Mercedes-Benz was a pioneer in selling haulage capacity instead of trucks through its Charter Way business model. Today, Charter Way offers its customers a number of alternatives, ranging from a legal guarantee to a total mobility guarantee. Mercedes-Benz declares that this gives its customers a choice between the minimum and the total outsourcing of the risk. Selling performance, however, applies only to the total mobility guarantee with flexibility in use.

  An example of a Mercedes-Benz van charter in the UK is its £9.5 million contract hire arrangement with the online Ocado supermarket to use its fleet of vans to deliver Waitrose groceries. The 2005 deal continues the relationship between Ocado and Charter Way that has been in place since 2001. Ocado has a fleet of 328 specially adapted Mercedes-Benz vans, including 318 Sprinters and 25 Axor tractor units.

IT outsourcing is an area where selling performance has excelled over the last decade. Outsourcing is defined as assigning tasks or activities to third parties outside of corporate in-house locations. Offshoring is when the activities are carried out abroad, and it is this area that is experiencing particularly high growth rates in newly industrialised countries, especially India.

Outsourcing's popularity derives largely from the huge cost savings it can bring and the value it can create. A study of shares of British-quoted firms showed that after having announced outsourcing deals, they outperformed comparable firms without such a deal by an average of 1.7 per cent within a month of the announcement.

Thirty years ago, the strategy to sell the desired results of operating computer systems was pioneered by Ross Perot, an American businessman who founded Electronic Data Systems (EDS), a 100 per cent service company that 'invented' IT outsourcing and was later sold to General Motors. In 1993, EDS beat IBM to win a €1.5bn, 10-year contract to run the Inland Revenue's computer service in the UK – at the time the biggest contract of its kind ever made in Europe. In 1995, EDS was spun off but remained a key service contractor to GM. By 1999, EDS boasted 130,000 employees and a revenue of US$11bn, but was overtaken by IBM Global Services when it began selling the desired results, shifting from manufacturer to solution provider. In 2008, EDS was still a leading global IT service company, with 120,000 staff worldwide.

Other competitors include companies such as WNS Global Services Ltd, which started as a captive of British Airways before it repositioned itself as a third-party provider after a strategic buyout.

New independent IT service companies that have sprung up include Computer Services Corporation (CSC) and Debis, the service company of DaimlerChrysler, which claims to be the fourth largest financial service company worldwide outside the banking and insurance sector, managing assets worth €70bn.

However, outsourcing may introduce new risks. Companies keen on outsourcing business processes are trying to include punitive financial liabilities for service providers in the case of data theft or loss at the offshore locations. TPI, an outsourcing advisory, notes that while a bank's deal size could be worth US$10 million involving, for example, credit card processing, the potential liability for data theft could be well over US$300 million. NASSCOM, India's software manufacturers' association, expects to meet with government, banks and insurers to see what kind of cover can be provided, although many risks related to outsourcing may not be insurable.

- **Velocient, New Delhi.** The offshoring of IT services started in the 1980s when airlines, such as Swissair, moved their ticket management to India. Today, Indian companies such as Tata Consultancy Services and Velocient are using their home advantage to 'in-shore' contracts. By having brilliant account managers in Europe and North America, they acquire IT outsourcing contracts locally for execution at their offices in India. According to the National

Association of Software and Service Companies in Delhi, Indian exports of IT services in 2005 reached US$17bn, a 34 per cent increase over 2004.

Founded in 1994, Velocient, a digital consulting and e-integration company, today has more than 200 employees in offices in New York, Cleveland, San Francisco, Munich, Zurich, London and New Delhi. The company, which had a revenue of US$6 million in 2004, provides a full range of consulting services to help companies transform into e-businesses.

In 2005, Velocient mapped out a US$5 million expansion plan to strengthen its operations in the USA and Europe. Earlier, the company had received funding to the tune of US$3 million from Credit Suisse First Boston and SMIFS Venture Capital, both of which together hold 26 per cent of Velocient's equity capital. Velocient had already signed up business worth US$20 million for 2005 and projected a 100 per cent growth over the previous year.

2.4.2 Performance management services in B2B markets

B2B performance management services are grouped according to their sectors of application, namely:

- **FM** Real Estate Facility Management (Section 2.4.2.1),
- **IPM** Industrial Plant Facility Management (Section 2.4.2.2),
- **TLS** Textile Leasing Services (Section 2.4.2.3),
- **CMS** Chemical Management Services (Section 2.4.2.4),
- **EMS** Energy Management Services (Section 2.4.2.5) and
- **ICM** Integrated Crop Management and Agro-Management Services (Section 2.4.2.6).

2.4.2.1 FM – Facility management

Facility management here is limited to real estate, including such complex structures as airports and infrastructures. Industrial plants are considered in the following section.

Facility management has several origins: real-estate managers, construction companies, service companies involved in cleaning activities or operating motorways and airports, as well as manufacturers of key components. Lately, such financial actors as pension schemes, infrastructure funds and sovereign wealth funds have also started to compete for the facility management of infrastructures.

As operating buildings and infrastructures is a more profitable business than constructing them, building contractors are now bidding for operating contracts of, for example, motorways and airports. In June 2006, the Spanish Ferrovial infrastructure conglomerate bought the rights to operate the Heathrow, Gatwick and Standsted airports from the British Airport Authorities (BAA) for the sum of €15bn. Ferrovial thus transformed itself from the second biggest Spanish construction company to one of the world's leading infrastructure operators. The transaction made Ferrovial Europe's number-one operator, overtaking its Spanish rival ACS and its French competitors Bouygues and Vinci. Ferrovial also controls the Indiana Toll Road and Chicago's Skyway in the USA as well as airports in Australia, Chile, Scotland and Switzerland. However, because of its monopoly of UK airports, in March 2009 the UK's Competition Commission ordered Ferrovial to sell three of its seven airports – Gatwick, Stansted and Glasgow or Edinburgh – no later than 2011. In addition, Ferrovial was accused of not sufficiently implementing new security requirements at the ex-BAA airports and thus causing unacceptable conditions for passengers.

Hard hit by the 2008/9 financial crisis, Spain's Sacyr Vallehermoso construction and infrastructure management group in December 2008 agreed to sell Itinere, its toll road business, for €7.9bn to Citi Infrastructure Investors, a Citigroup fund, to ease its debt burden.

Typical examples of real estate and infrastructure facility management are:

- **Building managers: Customer satisfaction for a given price.** Residential and commercial rental properties are generally available at a wide quality and price range, with or without central heating or air-conditioning. Many of the buildings' owner-managers, such as life insurance companies, are investors with a long-term objective.

  Rental property is managed with a view of long-term economic optimisation, which means that repairs are often reduced to functional aspects. Interior renovations with the objective of aesthetic improvements are normally left to the tenants. Thorough renovations are undertaken at some point to maintain the property in a rental state within the quality range envisaged by the owner, or to be sold.
- **Total service contractors: Steiner and Vinci.** Construction companies at regional level, such as Zurich-based Steiner, have transformed their activities into total service contractors that accompany a building throughout its life cycle, from feasibility study to planning and construction and technical operation and maintenance management, including periodic renovations.

Other companies, such as the French Vinci, are active at regional, national and international levels in both construction activities and facility management, such as operating *Autoroutes du Sud de la France* (ASF) and multi-storey parkings in France. With a share of 15 per cent of annual turnover, facility management activities contributed 58 per cent of Vinci's annual profits in 2008.

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- **The privatisation of the US Pennsylvania Turnpike**. In May 2008, a consortium led by the Spanish infrastructure and services group Albertis won the contract to operate and manage the 801 kilometres of the Pennsylvania Turnpike between Philadelphia and Pittsburgh. An average 35,000 vehicles use the turnpike daily, generating an annual revenue of about US$600 million. In this so far biggest motorways privatisation in the USA, the winning consortium paid US$12.8bn, with Abertis holding a 50 per cent stake, Citigroup 42 per cent and the Spanish holding company Criteria and the Catalan savings bank La Caixa, the remaining 7 per cent.
- **Cleaning service companies, ISS, CCS and Rentokil-Initial.** Similarly to building contractors, cleaning service companies are increasingly moving into the business of operation and maintenance of large buildings that need a variety of sophisticated cleaning services, such as airports, schools, hotels, conference centres and barracks. This provides a door opener to other management services, such as energy and security management.

  Cleaning-services-turned-facility-managers also offer full services for public washrooms, such as at airports, exhibition halls and conference centres, and manage restrooms, primarily in restaurants.
- **Interface, the all-inclusive green carpet lease.** Based in Atlanta, Interface is a major manufacturer of carpet tiles and wall-to-wall carpeting with worldwide activities and a leader in greening the Industrial Economy. Interface's green lease business model for its carpet tiles guarantees customers a 'perfect carpet' for ten years. The lease includes cleaning and maintenance costs as well as the exchange of damaged tiles, thus providing facility managers with fixed costs for a ten-year period.

The new strategy is supported by an innovative design of the carpet tiles, using such concepts as bio-mimicry and quilt patterns, and the exclusive use of materials that enable a profitable reuse of molecules (see Section 3.4.3).

However, few green leases have been signed so far. The demand-side has not shown great enthusiasm for the new concept. Most companies and institutions prefer to own their carpets and decide when to clean them and when to change them. State authorities have justified this attitude with budget problems. The lease is a fixed cost, whereas cleaning and replacement can be suspended when finances are low. The reasons of facility managers are more complex, and linked with a fear of 'losing control over their carpets'.

2.4.2.2 Industrial plant facility management

Similarly to construction companies moving into the operational management of buildings and infrastructures, industrial companies have discovered the operational management of industrial plants, hotels or hospitals for their clients or other third parties. Some companies, such as the Suez conglomerate, are active in national markets under other names. Pioneers and champions in the industrial plant facility management are:

- **ABB's full-service partnership agreements to manage client's industrial plants.** ABB is a leader in power and automation technologies that enable utility and industry customers to improve performance while lowering environmental impact. ABB has more than 150 full-service partnership agreements with customers in the paper, mining, chemicals and oil and gas industries around the world. These agreements are strategic initiatives that help customers improve the performance and reliability of their production assets. ABB's proven best practices apply the full spectrum of maintenance activities to improve plant efficiency and allow partners to focus on their core business, thus adding new value to the bottom line. ABB's full-service agreement typically improves productivity and equipment availability while reducing maintenance costs for customers by up to 20 per cent. ABB designs, executes and manages a customer's entire asset base, including maintenance labour, repairs, daily operations, indirect maintenance and subcontracting.

  The biggest joint venture of its kind in the pulp and paper industry began in January 2000 between ABB and Stora Enso, with a contract to provide all maintenance operations and improve efficiency at six pulp, paper and board mills in Finland. The estimated annual turnover is US$200–270 million.

Other clients of ABB's full-service solution include: US Cooper Tire and Rubber Company, specialising in tyre design, manufacture, marketing and sales worldwide; Finland's Myllykoski Paper Oy (a US$150 million contract); the industrial park in Boebingen, Germany (a US$150 million contract); ENI Group's Enichem and Nuova Polimeri Europa to assume all maintenance activities at their petrochemical plants in Italy (a four-year US$82 million contract).

- **Veolia Environnement's management of PSA-Peugeot Citroën plants.** In 2007, Sense, a division of the French Veolia Environnement group, took over the integral management of the environmental responsibilities of the PSA-Peugot Citroën plants at Sochaux, Mulhouse and Vesoul in France. Sense manages the production and distribution of the plants' liquids and energies, and the management of cleaning, industrial wastes, waste-water treatment, railway tracks and storage logistics. Sense has accepted the performance objective of achieving a 25 per cent economic savings and a substantial increase in energy performance over five years. Initially, €19 million were spent to reduce energy consumption by 20 per cent, SO_2 emissions by 76 per cent, NOx emissions by 39 per cent and dust emissions by 67 per cent. Almost all of the 1000 employees that Sense has engaged to do this work are former PSA-Peugeot Citroën employees.
- **Dow Chemical's service contract for General Motors.** Since the early 1990s, Dow Chemical has been providing in-house least-cost management of all the chemicals handled in General Motors' plants, initially for an annual fee of US$10 million. DuPont de Nemours has similar service contracts with major customers. (See examples in Section 2.4.2.4.)

2.4.2.3 TLS – Textile leasing and cleaning services

Textile leasing is common, particularly of airline uniforms, hospital and operation room textiles, hotel bed sheets and bathroom towels, and is offered by a large number of companies. In Europe, multinational companies compete with franchising networks using similar strategies and quality standards.

Textile leasing pays only if high-grade fabrics are used. The choice of material is crucial to optimise service-life costs, with a break-even period of about three years. These are some of the leading companies:

- **MEWA, from renting reusable wipers to leasing business attire.** The MEWA group is a leading European textile leasing company, employing 4000 people in ten European countries and registering sales of €331 million in 2004. Founded in 1908 as Mechanische Weberei Altstadt GmbH in Saxony, Germany, the company began by offering an innovative service to produce, rent and wash cotton wipers used to clean machinery and equipment. By 1938, MEWA had 15 wiper plants in Germany and started to rent wipers under a full-service concept.

  After World War II, the company started anew at Nuremberg and then in 1965 moved its headquarters to Wiesbaden, from where MEWA now coordinates its 34 service and production units. Besides providing wipers for industry, MEWA today leases work clothes to clients in a wide range of industries and textiles to hospitals and hotels. Its service ranges from design and production to fleet management and maintenance and disposal of the textiles.

  MEWA supplies 93,000 customers with 685,000 uniforms and looks after a fleet of 18,200 tons of other textiles, as well as 630 million wipers that are washed and redelivered to customers. The uniforms meet the highest standards and the use of the Risk Analysis and Bio-contamination Control System guarantees the microbiologic quality of the cleaning processes. But MEWA also rents fashionable business outfits through its ‘corporate fashion’ services, a full-service concept that offers need-focused clothing with a high flexibility with regard to changes in size and number of employees, for a guaranteed price.

  MEWA has permanently optimised its washing processes and today cleans its wastewater to 99.8 purity. Since 1995, the specific water consumption (per kilogram of textiles) has been reduced by 46 per cent. MEWA is also the leader in leasing reusable wipers to the German car and metal machinery industry, which it has brought to perfection. As used wipers contain a high degree of oil and grease residue, washing translates into an expensive process of waste separation and wastewater treatment. MEWA thus becomes liable for its customer waste! But MEWA has turned this problem into an opportunity by developing a process that enables it to separate the oil residues from the wipers and incinerate them to produce steam for heating the wash water, thus reducing energy costs.

The waste from the washing process is an oil-water mixture of 8–10 tons per annum. Out of this, MEWA recovers roughly 6000–7000 tons of oil, which is similar to light heating oil. The remainder is disposed of according to special waste legislation.

- **ProfiTex and RenTex: A franchising success in Europe.** The RenTex service is offered by a group of experienced industrial laundries specialising in meeting the textile needs in the healthcare and welfare sectors. With facilities in Germany, France, the Netherlands, Austria, Switzerland and Slovenia, this network of laundries offers the same service and ensures that even the temporary breakdown of one facility can be absorbed without causing any inconvenience to the customer. The network also provides a tool for communication: a permanent international exchange of information to ensure ongoing development and innovation.

  RenTex supplies surgical textiles, incontinence protection and uniforms, including individual care of residents' personal clothing. The quality is carefully monitored, based on long-term experience and development. The logistics ensure that articles are available at the right place, at the right time, in the right quantity – that is customised to meet customers' individual needs. Drivers deliver the ordered articles to the location where they are needed and pick up the used ones, either individually to each point of usage or to a central point for in-house distribution.

  A similar franchising network, called ProfiTex, provides textile-leasing services for professional clothing. It offers uniforms and overalls for employees and cleaning mats and textiles for washrooms, again in a full-service contract including design, procurement, maintenance, repair and exchange.
- **Unifolk Company's operational leasing service for company uniforms.** In May 2005, the Japanese Ministry of Economy, Trade and Industry (METI) ran a 'Green Servicizing Model Business' competition to promote eco-friendly businesses. Out of 42 applications, three projects were selected, one of which a textile leasing service for employee uniforms by Unifolk Company, a Japanese uniform distributor. It involves leasing uniforms to companies; collecting, cleaning and repairing them and finally recycling the material after the uniforms are worn out.
- **Textile leasing now offered in most countries.** The leading company in France is Elis, which specialises in professional clothing and 'collective' linen for hotels and hospitals. Elis operates along the same lines as the companies above. But in contrast to MEWA, Elis

has extended the service-life of its textiles by the use of synthetic materials in the manufacturing of its products, which also saves water in the cleaning process.

2.4.2.4 CMS – Chemical management services

Chemical management services (CMS) are based on full chemical life-cycle costs (including material, labour and waste management). The CMS model originated in the US automotive, electronics, aerospace and metalworking industries. The Chemical Strategies Partnership (CSP), a non-profit organisation set up to promote the approach, estimated that more than 10 per cent of the US aerospace industry, 20 per cent of the metalworking industry, 35 per cent of the electronics industry and 50–80 per cent of the auto industry had adopted this model.[11]

This level of take-up suggests that there must be significant benefits to the approach. But it also raises the question of why, if the benefits are so impressive, the approach has not spread more widely outside the USA. It could be that because the size of European manufacturing plants is smaller, suppliers deal with a greater number of customers and the financial benefits at each plant are smaller. Another reason could be that European consensus management is less efficient than the US confrontation management, as suggested in the European Commission's Blueprint report.[12]

In February 2006, the International Council of Chemical Associations launched a voluntary initiative called 'responsible care global charter', and simultaneously a global product strategy that recommends measures to improve the way chemicals are used and handled not only in production but also by suppliers and customers in the manufacturing sector and by end-users. These programmes might accelerate the progress of CMS in Europe.

- **CSP – The US' Chemical Strategies Partnership.** The Chemical Strategies Partnership (CSP) was founded to bring together US chemical users and manufacturers, trade associations, non-governmental organisations and other stakeholders to promote the above CMS model. CSP may have given the USA an edge over Europe, which has no comparable organisation to promote and help exploit the model's social, environmental and economic potential.

  CSP found that in the USA, full chemical life-cycle costs typically range between US$1 and US$10 for every dollar of chemicals purchased.[13] CMS includes optimisation of a range of processes – such as: procurement, inspection, inventory, delivery, use, storage, disposal, emergency preparedness and liability – thus representing a powerful management tool regardless of environmental benefits. Reduced purchase costs, waste costs and labour costs all contribute directly to a healthier balance sheet. The process also helps in assessing and managing the risks associated with chemical use, improving data management and, in some cases, reducing insurance costs.

The US' complex environmental and health and safety regulations concerning chemical distribution, use and disposal have been an important driver. Reporting requirements have made it easier to highlight the opportunities of service approaches. Companies such as General Motors have taken up CMS in the early 1990s through a desire to address the complexity and number of chemicals they were using.

According to a CSP survey, 80 per cent of CMS customers achieved a reduction in chemical volume.[14] This translates into environmental benefits resulting from reduced chemical use and thus reduced hazardous waste volume. The contribution of chemical leasing to the effective risk management of chemical substances has also attracted scientific attention (Ohl and Moser 2007). In Europe, the European Commission has implemented a regulatory framework for the Registration, Evaluation and Authorization of Chemicals (REACH) that requires companies using chemicals to prove the safety of these substances, which involves some 30,000 chemicals used in everyday products like detergents, toys, car seats and face creams. A crucial aspect of this information management may be the honesty and accuracy of the relevant knowledge transfer from the chemical producer to its user. The traditional sales concept provides no incentives for transferring this knowledge, as an increased user knowledge of a chemical's properties may raise the efficiency of its application. In the case of chemical leasing, the management service company has an obvious economic incentive to maximise the chemical's efficiency in applications.

Chemical leasing is a service-oriented business model that shifts the focus from increasing sales volume of chemicals towards a value-added approach. The producer mainly sells the functions performed by the chemical and 'function units' are the main basis for payment (UNIDO). Below are some pioneers and champions of CMS:

- **Nortel – the benefits of applying CMS.** The experience of Nortel, a semi-conductor producer in the USA, illustrates the environmental benefits that can be achieved from a CMS programme through both sufficiency and efficiency measures. The following results were achieved after three years:

- reduced annual chemical consumption by 50 per cent in two years,
- lowered on-site chemical inventory by 50 per cent,
- decreased hazardous waste by 8 per cent in two years, resulting in savings of US$24,000/year,
- substituted several chemicals, saving US$120,000/year and
- changed chemical container size, saving US$55,000/year.

- **Car industry as CMS pioneers.** Major world car manufacturers were among the first clients of the chemical industry to apply CMS. Painting of individual parts or entire bodies in white and the management of the paint shops inside car factories are outsourced to a paint supplier, which is paid a fixed price for each perfectly painted part. As the outsourcing contract includes responsibility for workers' health and emissions to the environment, this in turn triggered technical innovation to use water-based paints that avoid emissions of volatile organic compounds (VOC) and enable recovery of the paint overspray for reuse as an undercoat. The Austrian Herberts company was a pioneer in this area and today is part of DuPont de Nemours.
- **Mazda Motor and Nippon Paint develop eco-friendly coating process.** An electro-deposition base coat known as e-coating that substantially reduces both volatile organic compounds (VOCs) and carbon dioxide (CO_2) emissions was developed by the Mazda Motor Corporation, a major Japanese automaker, in collaboration with the Nippon Paint Company in 2005. The new coating significantly reduces environment-impacting substances included for rust protection in the base coat process. Earlier, Mazda had already developed a three-layer wet paint system that combined the primer, base and clear coats into one painting process, and introduced it to all its plants in Japan.
- **UNIDO's chemical leasing programme.** In May 2008, the United Nations Industrial Development Organization (UNIDO) launched a 'Chemical Leasing' project for Northern Africa at a conference in Morocco. UNIDO promotes chemical leasing business models, where the responsibility of the producer and service provider is extended to include the management of the entire life cycle.

  For UNIDO, chemical leasing is a win-win situation. Its aim is to increase the efficient use of chemicals while reducing the risks and protecting human health. Further, it improves the economic and environmental performance of participating companies and enhances their access to new markets. The key elements of successful chemical leasing models are proper benefit sharing, high quality standards and mutual trust between participating companies (www.unido.org).

- **Tiefenbacher's chemical rental strategy.** Tiefenbacher GmbH is a chemical-technical company based in Ennsdorf, Austria, which has changed its business model to selling the cleaning of surfaces of metal, plastic and wood objects to industrial customers. The company produces and takes back the chemicals used in the cleaning process, which it previously sold. Tiefenbacher recently changed its business model and now retrieves the leased cleaning chemicals (including the dirt) from its customers. Its present objective is to minimise the loss of chemicals during the application process, to recover 50 per cent of the chemicals in re-refining and to optimise the waste elimination process. Tiefenbacher today invoices its customers not for the volume of chemicals used but for the surfaces cleaned (www.tibagmbh.at).

2.4.2.5 EMS – Energy management services

Energy management services (EMS) can overcome many problems created by specialised energy providers by supplying a mix of energy to consumers, with a single energy invoice covering gas consumption and both inflows and outflows of electricity. Witness the later example of Stadtwerke Rottweil in Section 2.4.4.

As in the facility management sector, more economic actors are joining the EMS market and competition is increasing as a result. Among the newcomers are facility managers, major construction and engineering companies and local farmers, in addition to the utility and energy companies that have dominated the field so far.

Most energy suppliers currently sell a single product – electricity or gas. Previously, the city works (*Stadtwerke* in Germany) supplied several types of resources – typically gas, water and electricity – but they disappeared with privatisation and specialisation. Yet today, the old structure has partly been reinvented by EMS, which provides a full service of energy supplies and consulting, including a package of measures to make energy use more efficient and thus cheaper.

EMS companies take complete responsibility for providing the end needs of customers. The approach integrates generation, supply and use of energy rather than addressing them separately. A typical contract specifies that the service company is in charge of financing, installing and managing electricity and/or heat-generating equipment on the basis of a long-term supply contract at an agreed price. Fixed-price contracts give the supplier an incentive to introduce energy sufficiency and efficiency measures, such as energy-efficient equipment.

EMS contracts are specified in terms of output rather than input. The service company may provide capital financing for efficiency improvements, transferring risk to an expert company, and freeing management resources to focus on core activities.

This business model is equally successful in Business-to-Business and Business-to-Consumer markets and is receiving greater political support:

- In December 2003, the **European Commission** issued a draft directive on '**eco-energy services**' that should identify the reactions of economic actors in Europe. This directive has now been accepted.
- In October 2003, the **Tokyo Gas Company** began to offer an EMS for administrative buildings under the name of 'TG Green Monitor', a service that remotely monitors a building's energy consumption and communicates the findings to the building manager.
- In October 2002, **Austria's Federal Ministry for Agriculture and Forests** published a study of best-practice examples in energy-contracting[15] that lists a number of EMS's in the country.
- The leading Swiss energy-contracting company, **Swiss Contracting**, has so far executed EMS projects for €15 million. But the Swiss EMS has developed less fast than originally expected.
- '**Energy farmers**' in Austria, Germany and the UK sell heat and remote control to private house owners in a local service economy, occasionally also to large public buildings such as schools (see also Section 2.4.5).
- In Wales, communities can **rent energy infrastructure** rather than paying for the energy the infrastructure provides, according to a report by Green Alliance.[16] A revenue stream can then be generated through selling excess energy to the grid, which can be used to support local economic development.

Energy management services are drivers of innovation. They can: (1) contribute to the flexible provision of energy; (2) stimulate new models of energy delivery; and (3) speed up the market introduction of new energy technologies as well as novel ways of financing them. EMS can also make it easier to engage consumers in the energy and climate change debate, as they have a direct influence on energy provision. Among the EMS pioneers are:

- **Totem by Fiat.** Energy management services have always presented the opportunity to promote decentralised heat and power production. Numerous systems have been available to private house owners, starting with the Totem system by the Italian automobile producer Fiat in the 1970s. Totem consisted of a reliable Fiat engine producing electricity (the 'generator') and heat (the 'radiator') and was sold to Italian farmers.

  Similar systems still exist in many rural areas in Europe. For example, Austrian farmers have converted old car engines to burn biogas produced by composting farm waste, manure and used cooking oil in a specified way.
- **Energy service companies (ESCOs).** A 2006 study found that since the early 1990s, US energy service companies (ESCOs), which provide energy services to commercial markets, averaged annual revenue increases of 24 per cent and completed projects for US$1.8–2.1bn in 2000.[17] Of the 1420 ESCO projects covered in the study, some 73 per cent were institutional buildings (schools, universities, hospitals and government offices).

  Of the 11 'measure categories', lighting was the most prevalent, installed by 82 per cent of the projects, followed by comfort conditioning and motors/drives, the latter having been promoted by Amory B. Lovins from the Rocky Mountain Institute for more than a decade.

  ESCOs have been successful in achieving energy savings even once the contract has ended. The study found that 21 of the 29 projects analysed reported increased electricity savings after termination of the initial project (up to four years). There was a median simple payback time of seven years for institutional projects, and three years for the private-sector ones.

  Although some markets already have a well-established ESCO presence, others are still nascent. Some experts estimate the market potential for ESCO activities in the building sector alone at €70bn for Europe, and US$100bn for the USA. Such a market could lead to substantial reductions in energy consumption and CO_2 emissions. As energy services rely mostly on local employment and expertise, the savings in energy costs can be transferred to salaries and maintenance upkeep. The development of the ESCO market would thus significantly contribute to the sustainable development goal of decoupling economic and employment growth from energy consumption (Steinberger 2008).

- **The Zurich Electricity Company (EWZ).** EWZ has had a monopoly of electricity supply in Zurich since 1892. Starting in 1997, EWZ began supplying the energy needed for heating and cooling. It has even become a supplier of EMS, from designing and financing to constructing and operating energy systems, selling its 220,000 customers electricity and heat at fixed rates. It focuses on resource-efficient technologies, such as geothermal energy and heat pumps using the water from Zurich Lake. By February 2009, 130 EMS contracts had been signed, which promise to reduce oil consumption by 3.8 million litres and thus lower CO_2 emissions by 10,000 tons. Because of an under-utilisation of the new infrastructure, the volume of energy to heat or cool buildings can in the future be increased tenfold.

2.4.2.6 Integrated Crop Management (ICM) and Agricultural Management Services (AMS)

Chemical and agricultural management services have always been closely connected. The Taona Zina project in Madagascar is one of the first examples of a pest management service. It was started by the Swiss chemical company Ciba-Geigy,[18] but terminated even though it was a success. The failure of this historic project (described below) underscores the importance of symbiotic partnerships for any system solutions to succeed in the long term.

The trend in large-scale agriculture is to rely on chemicals and machinery that require a large capital investment and expertise for its safe and efficient use. In the past, cooperatives provided money and expertise, while today commercial service companies – such as contract harvesting or spraying services – are increasingly taking over this role by spreading the costs of expensive equipment through more intensive use.

The area of greatest potential is 'precision agriculture', which monitors the characteristics of fields and crops to determine how a field should be managed. In North America, an estimated 16,000 farms use private Agricultural Management Services (AMS), whereas acceptance of this concept is still low in Europe. This may be linked to an emphasis of bio- and integrated production (IP) methods, and a distrust of progress in agriculture (including GMO).

Precision Agriculture has a number of potential environmental benefits. The most attractive so far is the application of chemicals in a more targeted way and only when needed, thus minimising use; advocates claim that use of nitrogenous fertiliser can be reduced by up to 34 per cent. Further, there are records of what chemicals have been applied where, which is important, for example, in nitrate vulnerable zones (NVZs), where the use of nitrogenous fertiliser is restricted and controlled.

- **Ciba-Geigy's ICM 'Taona Zina' project in Madagascar.** In the late 1980s, Ciby-Geigy,[19] a Swiss agrochemical producer, was accused of poisoning rice farmers in Madagascar with its pesticides. To prove that its products were not at fault, Ciba-Geigy offered a service to create pest-free fields and a higher yield (bushels of rice per hectare) to the accusing governments, for a price equivalent to the past pesticides' sales.

  The strategy was a scientific and economic success. Scientists decided when, where and how much pesticide should be sprayed to fight pests. Within a few years, the use of pesticides dropped by about 70 per cent, while the yield increased by up to 400 per cent. However, due to fierce opposition by Ciba-Geigy's former distributors of the pesticides, the strategy was abandoned before 1995.

  Integrated Crop Management, which Ciba-Geigy had pioneered in Madagascar in the 1980s, has since seen a strong development in the US.
- **Precision agriculture.** This concept is based on very accurate mapping of farms through global positioning systems (GPS) that collect data on key environmental and crop variables: soil types, soil nutrients and moisture levels; real-time sensing data, such as yield data from flows of cereals into combine harvesters; crop health sensing based on the colour of plants; and satellite data on crop health based on light reflection. The maps can then be used to influence farm management, for example, in applying different amounts of fertilisers, herbicides, fungicides or insecticides to respective parts of a field.

  The main physical components of precision agriculture are available on the market: GPS receivers, specialised electronic equipment and software, and control devices in farm equipment. To use precision agriculture, farmers need the capabilities to operate the systems and exploit the data collected.

  Farmers have been able to identify areas of low or no profits thanks to such innovations as 'profit maps' that show the relationship between income (based on crop yield) for a given area and the costs of fertiliser, pesticides and other inputs. In future profit-loosing fields can be planted for bio-fuels or left out of commercial production and instead be sown with wild grass and flowers to provide natural habitats for wildlife and contribute to biodiversity.

A number of US companies – from agricultural equipment suppliers such as Agco and John Deere, to advisors and information managers such as Soyl – and European chemical manufacturers such as Bayer and Syngenta offer integrated solutions, giving them a direct incentive to reduce the use of their products. Ultimately, performance-based solutions could emerge whereby agrochemical and fertiliser companies take complete responsibility for application and any financial savings from reduced use are shared between them and farmers. ICM is a possible business model for the use of genetically modified seeds, as a joint venture between farmers and seed producers.

- **ICM – Integrated Crop Management.** According to the European Crop Protection Association, ICM is an environmentally sound, socially responsible and economically viable business model which combines, in addition to the core tasks of monitoring, auditing and organisation, the following specific management issues: crop nutrition, variety, rotation and protection; waste and pollution, wildlife and landscape; soil and water; and energy.

2.4.3 Performance services in Business-to-Government (B2G) markets

This section gives examples of the most popular business models with the characteristic of a Private Finance Initiative (PFI). These can be grouped into three main blocks:

- Build-Own-Operate (BOO), Build-Operate-Transfer (BOT) and Private Finance Initiative (PFI) (Section 2.4.3.1)
- Performance-Based Logistics (PBL) (Section 2.4.3.2)
- Public-Private Partnerships (PPP) (Section 2.4.3.3).

Several of these business models have been used for centuries. Others, such as PFI and PPP, have emerged more recently, or been regrouped under a new name. Note that the distinction between the three groups is not clear, and their classification as BOT, PFI, PBL or PPP is often dictated by political rather than objective criteria. As their roles overlap, these models should thus be viewed as interchangeable.

The celebrated engineers of the past were often also entrepreneurs who developed, financed and executed their projects with their own company, and often lost their health and wealth in the process. Below are some famous pioneers:

- Isambard Kingdom Brunel – the flamboyant British engineer who built the first tunnel under the Thames (1843 in Greenwich), the first suspension bridge (1864 in Bristol), and the first ocean vessel with an iron hull (the Great Western in 1843);
- Louis Favre, the Swiss engineer who built the Gotthard rail tunnel, which opened to traffic in 1882;
- Ferdinand de Lesseps, the French entrepreneur who built the Suez Canal, which opened in 1869;
- the builder-operator companies of the French and Italian motorway systems; and
- the builders of the English Channel tunnel – which was finished in December 1990 – managed by the Mott MacDonald Group.

The BOO and BOT business models pick up on the same idea: that entrepreneurs build and operate the works with a cost guarantee, or at no cost, to the state. A recent change in US Government procurement policy requires federal agencies such as the National Aeronautics and Space Administration (NASA) and the Department of Defence to buy performance services instead of hardware whenever available.

2.4.3.1 BOO and BOT performance services and Private Finance Initiatives (PFIs)

Recent PFI projects include new bridges in Europe and Korea, power stations in India and a high-speed railway line in Taiwan. In exchange for the construction and operation of the infrastructure, the entrepreneur or consortium receives permission to collect a toll for a specified period of time, often with the stipulation that the works become state property after a given period – the T for Transfer in BOT. Compared to construction projects that end when the building or works has been built, these business models are less volatile and guarantee a relatively steady income over longer periods. For this reason, the competition has recently become fierce to gain control over new projects. PFI projects can be state contracts with the private sector to exploit operations normally reserved for the state, such as toll roads but also government projects that are financed by the private sector and then leased back to the state. The following are some typical applications of these business models:

- **The Railways** were one of the first systems solutions, combining track, rolling stock, signalling systems and security to guarantee a safe journey. Trains allowed quicker, safer and more comfortable long-distance mass transport over land than horse-drawn coaches on dirt trails, or coastal or river shipping. But entrepreneurs were needed to build the bridges and tunnels and to maintain tracks and rolling stock. And many of these successful entrepreneurs, such as the Swiss engineer Louis Favre who built the Gotthard rail tunnel, sacrificed both their fortune and life to attain their dream.

  The disadvantage of public transport is the limited availability in time and space. Timetables and station locations define or limit customer convenience. Contrarily, individual mobility allows more freedom in the choice of travel time and location.

  Innovations – such as mobile telecommunication for train management and mobile rail-grinding units that eliminate the need to change worn rails – have improved the system functioning since the early days: trains can run uninterruptedly and safely over the tracks for much longer periods of time.
- **Taiwan's BOT high-speed rail link.** The world's largest BOT project to date is Taiwan's Shinkansen line linking Taipei with Kaohsiung, its second largest city, covering 345 kilometres in 90 minutes. In 1994, the Taiwan Government granted a private consortium – the Taiwan High-Speed Rail Corporation (THSRC) – a BOT contract to finance, build and operate the railway for 35 years, after which the state will take over ownership and responsibility. The high-speed train began operating at end-2006 after several postponements due to contractual and technical reasons.
- **Jaypee Group developing BOO in India.** The Indian Jaypee Group's Build-Own-Operate (BOO) Hydropower Initiative was behind the 2003 startup of the 300 MW Baspa II power station, its first in Himachal Pradesh. Located in North India, the country's fastest growing region, the project enjoys a ten-year tax holiday and promises assured returns of 16 per cent plus incentives (www.jhpl.com).

  A second project, a 400 MW hydropower plant in Vishnu Prayag, was commissioned in 2006, and a third, a 1000 MW Karcham-Wangtoo project, is to be commissioned by 2010.
- **Le Viaduc de Millau – France's most visible PFI project.** In 2001, the French construction company Eiffage landed a 78-year govern-

ment contract to design, finance, build and operate a 270-metre-high bridge towering over the Tarn river valley near Millau, France – the tallest vehicular bridge in the world. The deadline of 31 December 2079 started running with the signing of the contract. The bridge was designed by the structural engineer Michel Virlogeux and British architect Norman Foster. Eiffage will also be in charge of the bridge's maintenance until 2121.

The construction of the bridge, which was inaugurated in December 2004, has not cost the French state a single cent, and it was built in a record three years. In exchange for the costs of building and operating the bridge, Eiffage can charge a road toll until 31 December 2079, when the property of the bridge will be transferred to the French state.

The Millau Bridge shows how the Service Economy can transfer the full responsibility to actors of the market economy, by providing incentives for speed and long-term efficiency, and provide solutions without increasing public debt at the expense of future generations.

- **Incheon bridge, South Korea – a build-operate-transfer PFI.** The 12.3 km Incheon toll bridge, which will rank fifth among the world's longest when opened in 2009, has been built, financed and managed by KODA Development, a joint venture between the UK-based AMEC and the city of Incheon of South Korea. Once construction is completed, KODA Development will manage the bridge for 30 years before handing it over to the Korean Government. With its 23 per cent controlling interest in KODA, AMEC has become South Korea's first foreign investor to lead a major Public-Private Partnership (PPP) project. It cost US$1.4bn to build the three-lane bridge, consisting of three sections: a 1.3 km cable-stayed bridge with an 800 m main span; a 1.78 km approach bridge and an 8.4 km viaduct. The bridge connects the new international airport on Yeongjong Island with the Songdo New Town economic development zone in Incheon and shortens the journey from the airport to downtown Seoul by 40 minutes.
- **Wall AG: Operational leasing of street furniture with billboards.** The German Wall AG offers towns free street furniture designed to meet their needs and specifications, including free operation and maintenance services against the right to integrate publicity panels in the furniture. The billboards are then rented out to publicity agencies. As other companies offer similar integrated services, Wall has no monopoly, but it goes beyond most competitors by not

imposing its standard design but adapting the furniture to municipal specifications.

Wall's street furniture includes bus-stop shelters, kiosks and benches that need occasional maintenance, but also public toilets accessible for the handicapped that need 24-hour security service seven days a week, as well as frequent maintenance and cleaning.

Street furniture is a considerable cost item for most towns. In addition, its management is not optimised as a number of public offices are in charge – that is, public transport for the bus shelter, park department for the benches and another department for the public toilets (which today are often underground and thus not accessible for the handicapped).

The right to place advertisements on public grounds, on the other hand, is a tightly guarded cash cow for most mayors. Wall offers a systems solution, which minimises overall costs to towns while at the same time guaranteeing a 24-hour service that today, if available, is split between a number of public departments (police or security, public works and public transport for cleaning, operation and repairs) without any synergy between the construction, lighting and cleaning of public street furniture and advertising installations.

The main obstacle is that some public authorities do not want to relinquish power (control over advertising income and tenders for street furniture) for overall efficiency at a considerably higher benefit/cost ratio.

Fierce competition has arisen from such advertising heavy weights as JCDecaux, the world's second-largest outdoor advertising company, which also offers free bicycles for people to use in Paris.

- **Building and operating safe and clean toilets in railway stations**. Public toilets in European railway stations have been free but notorious for their uninviting conditions. In an effort to improve their image, several railway companies outsourced the problem to McClean, a company that builds, owns and operates safe, clean and well-lit restrooms at major railway stations – but for a fee. The service charge keeps unwanted users away but also alienates some traditional travellers accustomed to free toilets.
- **Operational leasing of kindergarten toys**. In May 2005, the Japanese Ministry of Economy, Trade and Industry (METI) ran a 'Green Servicizing Model Business' competition to promote environment-friendly businesses. Out of 42 applications, three projects were selected.

One winning project is a leasing service to kindergartens and day nurseries for wooden play equipment, started by Amita Corporation, a Japanese company that recycles wood, among other materials. The equipment is produced by a forestry cooperative in Nishiawakura, Okayama Prefecture, and is made of Japanese cedar or cypress wood left over from forest management operations. Through the service, the company also hopes to promote environmental awareness.

The cooperative fixes, reprocesses and reuses returned or damaged play equipment to avoid waste. The proponents believe that using wood from forest-thinning will promote good forest management, and that by converting damaged play equipment into fuel for biomass energy, it can reduce the impact on the environment.

- **Aguas del Illimani – clean drinking water supply in Bolivia**. A key issue in fighting poverty and improving health in developing countries is providing clean water.[20] A step in this direction was made in Bolivia in 1997 when the French company Suez-Lyonnaise des Eaux won a US$30 million contract to lead Aguas del Illimani, a consortium of private Bolivian and foreign companies and the International Finance Corporation to manage and extend the water and sanitation system for the city of La Paz and its neighbouring municipality of El Alto as a build-operate-transfer (BOT) project over 30 years.

  Aguas del Illimani in 2004 was also entrusted to manage a US$3 million project to install drinking water and sanitation connections in a poor El Alto district not covered by the initial contract. Designed as a revolving-credit scheme, the money received by the water company from house owners as connection charges was to be reinvested into new water mains to reach more homes in other districts.

  The Aguas del Illimani project, however, has run into a political debate over whether public water works or private contractors should be in charge of supplying water to private homes. When Bolivia started to privatise the inefficient and old public water works in the 1990s, people paid for water through taxes. Since the 'water war of Cochabamba' in 2001, some development organisations have been fighting against the privatisation of natural resources and for water as a free common good, leading to a freeze of Bolivia's Private-Public Partnership projects. In March 2005, a government decree required the public authorities to cancel Aguas del Illimani's contract. People in the poor district will again have to buy expensive water from water lorries and carry it into their homes, and will no longer be connected to a functioning sewer system.

- **AirTanker's UK programme.** What may be the world's largest Private Finance Initiative in the defence sector is the 27-year £13bn (€19bn) contract awarded in March 2008 by the UK Ministry of Defence to AirTanker, the European Aeronautic Defence and Space (EADS) consortium. The PFI contract calls for AirTanker to provide air transport and air refuelling capability to the Royal Air Force (RAF). AirTanker will own the new aircraft and the RAF will lease them when needed. The contract also includes provision for all necessary infrastructure, training, maintenance, flight management, fleet management and ground services to enable the RAF to fly air-to-air refuelling and transport missions worldwide. While PFIs have been used successfully by the Ministry of Defence for smaller procurement projects, some businessmen feel PFI is unsuited for large 'front-line' projects, such as the AirTanker deal. (The AirTanker example can also be considered a PBL.)

2.4.3.2 Performance-Based Logistics (PBL)

Buying performance services instead of hardware is becoming the dominating business model in military procurement, under the term of Performance-Based Logistics (PBL). In fact, PBL is the US Department of Defence's preferred approach for product support. According to its Directive 5000.1, as of 20 November 2007, 'Procurement managers (PMs) shall develop and implement performance-based logistics strategies that optimise total system availability while minimising cost and logistics footprint. Trade-off decisions involving cost, useful service and effectiveness shall consider corrosion prevention and mitigation. Sustainment strategies shall include the best use of public and private-sector capabilities through government/industry partnering initiatives, in accordance with statutory requirements.' (www.dtic.mil/whs/directives/).

PBL is further defined as the purchase of support as an integrated, affordable, performance package designed to optimise system readiness and meet performance goals for a weapon system through long-term support arrangements with clear lines of authority and responsibility. Application of PBL may be at the system, subsystem or major assembly level. (http://akss.dau.mil/DAG/Guidebook)

It is important to note that each PBL arrangement is unique and can take many forms. There is no one-size-fits-all approach. A key criterion is affordable system operation effectiveness and life cycle cost and total ownership cost.

PBL projects are based primarily in North America and the UK. Policymakers in the European Union prefer to view them as Public-

Private Partnerships (PPPs, see the following section), such as the Herkules project for the German Armed Forces.

Among the pioneers and champions of PBL contracts are:

- **NASA will buy only performance services in the future.** After its last space shuttle flight in 2010, NASA will have finished the phase as owner and operator of space hardware. NASA's space exploration programme will then be based on buying services, not hardware. At that time, NASA hopes to take advantage of commercial lunar ventures and the opportunities they offer in communications, resupply, robotic science and resource extraction. Categories include commercial microgravity flight services (Zero-G contract award), suborbital crew training services and orbital crew transportation.

  This puts a new light on NASA's insurance coverage. In some past cases, like the shuttle, some contractors receive 'first dollar' indemnification. However, a different approach is needed for NASA's Launch Services Program and indemnification for users of its space vehicles. Among the first possible suppliers of services to NASA are SpaceX, SOHO China and Odyssey Moon Ventures.

> NASA buys commercial launch services, not hardware. The contractors, rather than NASA, retain title to the hardware and control of vehicle standards, specifications, etc. But NASA specifies mission unique requirements.

  SpaceX's activity for NASA is part of the Commercial Orbital Transportation Services and the Commercial Resupply Services Programs, aimed at private operators delivering cargo and crew to the lower earth orbit and to the International Space Station. Both programmes are FAA-licenced and require third-party liability insurance for launch and re-entry as well as insurance for payloads and vehicles. The Odyssey Moon Ventures' project is to be the first private space mission to the moon.

  NASA's strategy of buying services instead of hardware has already created a new business sector, as SpaceX typically builds all the main rockets' components internally to keep costs down and avoid delays, as well as clustering and testing their engines.
- **EADS services: The paradigm contract.** The European Aeronautic Defence and Space (EADS) Company produces the Airbus aircraft, military transport aircraft, helicopters, defence and security systems

as well as space services. Customers increasingly favour buying performance services rather than purchasing assets, even for space projects. The aim of EADS' new Space Services is to develop, promote and provide satellite services.

A typical contract concerns Paradigm Secure Communications Ltd, a subsidiary of EADS Space Services and the first commercial provider of secure military satellite communications services. Its Skynet-5 contract signed in October 2003 with the UK Ministry of Defence was at the time the UK ministry's largest PFI deal. It includes an upgrade of the existing Skynet-4 ground infrastructure and delivery of a new generation system, consisting of two Skynet-5 satellites and new terminals. Projected revenues are US$5bn. Paradigm owns the Skynet satellite infrastructure as well as the installations on the ground, and is exclusive supplier of 'beyond line-of-sight' telecom services to the UK Ministry of Defence. A February 2006 amendment to the contract extends the 15-year Skynet 5 PFI service contract for military communications, a key feature being the construction of a third satellite Skynet 5C by EADS Astrium.

The PFI model has been used in UK infrastructure contracts for a long time and has advantages for both the public entity and the industry involved. A PFI provides complete service rather than asset procurement, a partner relationship with key customers, guaranteed maintenance of assets and timely deliveries. Budget and control are retained by the public sector, and some risks can be transferred to the insurance sector. One drawback is that the public entity demands a service guarantee to maintain the required level of performance at all times.

- **Michelin's contract with the US Armed Forces.** Michelin, a French tyre manufacturer, was awarded a PBL contract in 2007 to supply the US Armed Forces with land vehicle tyres, which could amount to 2.87 million tyres worth US$1.7bn. The contract includes maintenance and repairs worldwide, with payment per service unit. The contract is for a base period of five years with an option for five additional years. This deal is in addition to an earlier US$368 million PBL contract for Michelin to privatise the production and logistics for its aircraft tyres. The engineering and technical services provider Science Applications International Corporation (SAIC), based in California, has a US$300 million contract with Michelin North American to help it supply the ground tyres to the US military and contribute supply chain management expertise in forecasting, inventory management and worldwide distribution.

Michelin was already the first tyre manufacturer to lease its tyres for a fee per one hundred kilometres rather than selling them (see Section 2.4.1.3).

- **Helicopters for the Canadian Navy.** In 2004, the Canadian Government contracted to buy 28 Sikorsky helicopters for its navy, worth US$5bn, of which US$3.2bn for full maintenance over 20 years, or two thirds of the total 'dry' cost. Only US$1.8bn was for the helicopters. An optimisation of the maintenance costs can thus increase the manufacturer's profit more than an optimisation of the production process.

  PBL can help to avoid 'Storob' situations that can affect the combat capability of armed forces (see the example of the British Navy in Section 3.2.1).

2.4.3.3 Public-Private Partnership (PPP)

PPPs fulfil a public mission with an economic objective, for example, building and operating museums, toll roads and tunnels. A PPP can also have two phases, such as first strategic research financed by governments, followed by a commercial exploitation of the research results by the private sector. For most PPPs, the government is the driver, often with an open or hidden agenda: hazard reduction, risk transfer, capacity building, national competitiveness and/or improved governance. The advantages for governments are that no public expenses are involved and that, in some cases such as toll roads, no operating expenses are paid either. The case is different for hospitals, however.

It is generally accepted that PPPs accelerate the realisation of major infrastructure projects such as the Millau Bridge in France (see Section 2.4.3.1) and reduce costs. In the UK, it is estimated that PPP projects are on average 20 per cent cheaper than traditional state-financed projects.

PPP-infrastructure projects can be funded jointly by governments and private business. Governments often provide the initial capital, or transfer ownership of public assets as payment in kind. Alternatively, financial incentives are provided through a tax reduction on the revenues from the project when completed.

Critics argue that PPP projects are not partnerships, as the government as prime broker dictates the terms, which include non-recourse financing to buyers of financial assets who take the first-loss risk.

PPP have had a high rate of failure over the last decade. The Aguas del Illimani project in Bolivia failed because it ran into a political debate over whether public water works or private contractors should be in charge of water supply to private homes – which was actually a hidden debate over the price of water. The Cross-City-Tunnel in Sydney was boycotted by the users and went into bankruptcy, with a loss of $500 million for the private partners. And the European Union's plans to set off the Galileo Satellite PPP failed due to risk management and financial concerns by the private sector.

PPPs integrate a cultural aspect, as they are popular in only a few countries, such as Australia and the UK but also India. In 2006, 110 PPP projects worth a total €27bn were contracted in Europe, of which 55 in the UK (€9.9bn), 19 in Spain (€6.7bn) and only eight each in France (€2.6bn) and Germany (€0.3bn). The majority (60 per cent) of the European PPP projects were bridges, tunnels and roads, 22 per cent railways and the remainder distributed among seven economic sectors. In the UK, 15 per cent of all infrastructure investments follow the PPP model and by April 2007, 800 projects worth £19bn had been signed, compared to only 46 projects worth €1.4bn in Germany by the same date. Below are some PPP pioneers, champions and failures:

- **Cross-city tunnel in Sydney, Australia**. Since the opening in 2005 of this US$800 million, two-kilometre tunnel, which passes under Sydney's main business centre, residents refused to pay the $3.50 toll and because of underuse, the project went bankrupt two years later. The main reason for the public's refusal to use the tunnel was a secret agreement between the government and the consortium to close a number of roads above it, thus forcing drivers to take the tunnel and pay the toll. The cross-city tunnel has thus opened a wide debate on the governance involved in choices between the state as a builder-operator of infrastructure projects versus PPP.
- **Lane-Cove tunnel in Sydney**. Sydney's Lane-Cove tunnel was built and financed by a private consortium that also took over responsibility for operation and maintenance. In exchange, the consortium collects toll fees and should reap benefits over the exploitation period. In fact, the tunnel's inauguration date of 25 May 2007 was postponed until after the parliamentary elections in New South Wales, primarily because of PPP's bad experience with the earlier cross-city tunnel.
- **The Herkules PPP project.** The Herkules project to improve the communication system of the German Armed Forces is one of Europe's largest PPPs, which included IBM in the consortium. Since its planned creation in the 1990s, its overall price has increased and

its commissioning date postponed several times due to adaptations and an enlargement of tasks.

- **The EU Galileo project – a failed PPP.** The Galileo project, consisting of 30 orbiting satellites, is Europe's answer to the US global position system (GPS) system. The European Space Agency was in charge of the R&D phase; Galileo's commercialisation should have become the second phase of a major PPP project. But a lack of clarity in third-party liability dampened the attractiveness of the Galileo PPP for private investors.

  By 2009, plans to set up a PPP had been dropped due to both risk management and financial concerns. The EU Galileo programme now has a €3.4 billion budget and an 80 people-strong management and is due to be fully deployed by 2013. An invitation to tender for project management and market development, launched under EU rules in 2008, attracted 21 offers. Efficient coordination with similar systems will be important to avoid redundancy with the US' GPS network, which is cheaper and has a track record, and with the European Geostationary Navigation Overlay Service (EGNOS), a satellite system composed of three geostationary satellites, a ground network of 40 positioning stations and four mission-control centres that are supplementing Galileo.

  EGNOS should improve the accuracy of the current global positioning systems from ten to two meters and provide information about the integrity of the GPS system. Tailored for the aviation sector, EGNOS was developed to increase satellite navigation reliability and accuracy by complementing the US' GPS system. EGNOS makes existing satellite navigation systems suitable for safety-critical applications such as flying and landing aircraft, or navigating ships through narrow channels. On 31 March 2009, its operative control passed from the European Space Agency (ESA) to the European Commission (www.gsa.europe.eu).
- **The European Hydrogen and Fuel Cell Technology Platform.** This joint technology initiative on hydrogen and fuel cells should become a milestone in EU target-oriented research. Approved by the EU Parliament on 20 May 2008, this PPP will implement EU research and development and provide market support for the introduction of resulting technologies. As part of its Seventh Framework Programme over the next six years, the European Commission will provide half of the budgeted €1bn, a figure that is to be matched or bettered by the private sector (https://www.hfpeurope.org/).

- **PPP of Holcim and GTZ in El Salvador**. The German Technical Cooperation Authority (GTZ) and the Swiss cement maker Holcim are helping El Salvador solve its huge urban waste problem by incinerating combustible waste – such as used tyres and engine oil – in cement kilns. As there was hardly a waste-collection system in the country, GTZ succeeded in grouping small municipalities into an association to manage the collecting, sorting and supplying of combustible waste for the Holcim cement kilns and then disposing the remaining debris in controlled dumps. As used tyres are a major breeding ground for mosquitoes, this project is also improving public health in the country.
- **China's PPPs.** A number of PPP projects have recently been set up in China, the most publicised being certainly the Three Gorges Dam. Many smaller ones have been established to solve urban infrastructure issues, such as the Shanghai Chengtou Corporation's PPP in water, waste management, real estate and infrastructure projects, to quote but one.
- **The Caribbean Catastrophe Risk Insurance facility.** This PPP was designed to limit the financial impact of hurricanes and earthquakes for 16 Caribbean governments. Established in 2007, the facility provides quick, short-term liquidity to participating governments when the policy is triggered by a catastrophe. The Zurich-based Swiss Reinsurance Company has a lead role in the facility's structure, which is designed to cope with the financial consequences of climate-related disaster risks. It is expected that new forms of public-private risk transfer will allow governments, development banks or non-governmental organisations to leverage their funds through the use of insurance and capital market instruments.
- **PPP to overcome India's infrastructure needs.** India's infrastructure dates to a great extent from colonial times, or is lacking. The Indian railways can count some 51,000 bridges that were built in the 19^{th} century. Some 300,000 villages – 45 per cent of all settlements – are not connected to the road system. With its economy increasing an annual average 10 per cent or higher, India needs money: it has budgeted spending US$50bn for road construction in the quadrangle Delhi, Mumbai, Chennai and Kolkata over the next four years.

  PPPs may be one tool to solve India's many infrastructure problems. As shown in the movie 'Slumdog Millionaire', the largest slum of Mumbai has no electricity, sewer system or piped drinking water. But it needs to be shown that private investors can be found to take the risks of participating in PPP projects to solve some of these problems.

Bangalore's new airport is the first Indian airport to be built and operated as a PPP project by private investors under the leadership of Zurich Airport Company. The opening of the airport in early 2009 had to be postponed due to a lack of coordination between the PPP managers and the state authorities in charge of air space control. It is estimated that 11.5 passengers will use Bangalore airport in its first year of operation.

- **Russia is looking into PPP.** In 2007, Russia announced plans to invest US$1000bn over the next three years (to 2010). It also expressed its view that PPPs with foreign investors were the most efficient way to solve this investment issue. In order to control this market, Russia's Bank for External Economy (*Wneschekonombank*), founded in 1924, was transformed in 2007 into the Bank for Development and External Economy. However, the 2008–09 economic downturn has put many of these development projects on hold.

2.4.4 Performance services in Business-to-Consumer (B2C) markets

For B2C performance services involving investment goods (tools), such as houses, consumers act in an economically rational way. But B2C performance services for consumer goods must contend with consumers using them as fashion 'toys', based on emotion rather than function, with a focus on having fun and ignoring economic efficiency.

Whereas tools are used in an economic performance sense, toys compete with fashion and gadgetry more than with performance. New electronic goods, such as mobile phones or mobile music centres, are bought because they are trendy, not for better economic performance. In fact, mobile phones today are a major reason for the debt problems of young Europeans. The new goods lead to rising costs but not higher revenue and, due to the focus on fashion, seldom live up to their technical service-life.

Teddy bears are the exceptional toys. Due to a strong and durable emotional link with the owner, teddies live for ever. They offer an exit from the consumer society, but mainly work for jewellery, watches, personal clothing and old cars. In the case of goods that are part of the national heritage, stewardship has the function of the teddy bear effect.

Another exit from the consumer society are rental goods. For most toy-like consumer goods, with the exception of cars, ownership is normally a precondition for use. But this situation is slowly changing, possibly linked to the new Internet generation, according to the US trend researcher Daniel Nissanoff in his book *Futureshop* (Nissanoff 2006). The trend to rent luxury goods started in the USA and has spread to Europe. Other consumers buy a luxury item and sell it quickly on ebay.com. Of e-bay's US$12.6 billion turnover in the second quarter of 2006, US$1.7 billion was spent on watches and jewellery.

The short-term rental of fashion goods can achieve a higher value-per-weight ratio through more intensive utilisation.

Below are some pioneers and champions of B2C performance services involving consumer goods (tools):

- **Ladies' handbag rentals**. Since 2005, a number of companies have sprung up, first in the USA, then in Europe, which rent pricey exclusive handbags for a few days at a moderate cost. One of the first rental companies was www.bagborroworsteal.com, which was then copied by www.bagstealandborrow.co.uk and www.luxusbabe.de. Another rental company, www.runawaybag.com, has copied the US business model of http://frombagstoriches.com. And even provincial areas in Switzerland have caught the bug (www.monsac.ch and www.city-luxe.ch) and offer the 'fashion victims' the latest designer handbag for from €50 to €180 a week.
- **Rent-a-ski.** Rent-a-ski is a franchise network of sports shops headquartered in Davos, Switzerland. Its members offer customers rental of winter sports equipment – including not only skis but snowboards, rackets, clothes, shoes, gloves, goggles and other winter wear – in a package decided by the customer. Thanks to the seasonal character of winter sports, the equipment can be repaired and overhauled during off-season.

  People skiing only a few days every year prefer rentals, as they reduce their capital expense and enable them to always have the latest skis and equipment. The sports shops use a cascading strategy. The latest models are rented out for two years in high-price locations, and then moved to lower-price locations with less choosy customers.
- **Single-use cameras**. Single-use cameras by Eastman Kodak and Fuji are sold in a closed-loop system. The film guarantees that the cameras are returned to shops and developing laboratories in perfect condition. A sophisticated reverse logistics, with incentives and free

shipping, then assures a return of the cameras from the laboratories to the manufacturer.

The manufacturer disassembles the cameras, exercising strict quality control, and replaces certain key components (such as the plastic lens) before re-assembling the cameras with a new film for resale. After up to 12 loops, the cameras are ground and the plastic granulate is reused to produce new cameras.

This strategy enables manufacturers to offer fashionable goods while at the same time preventing waste. As each generation of cameras lasts about 12 loops corresponding to less than a year, 'new-look' cameras with new features arrive frequently on the consumer market.

But single-use cameras do not protect actors in the Functional Service Economy against the hazard of technological progress. The success of digital photography, and its inherent advantage for individual customers to develop and print pictures themselves, has led to a large drop in sales of chemical film and single-use cameras.

For B2C performance services involving investment goods (tools), such as houses and apartments, consumers act in an economically rational way. Among the pioneers and champions of B2C performance services involving investment goods are:

- **Stadtwerke Rottweil**. The city works (*Stadtwerke*) of Rottweil in southern Germany introduced an EMS concept in the 1980s for private residential properties. The city works provided a car engine running on natural gas and its maintenance on a leasing contract to home owners, who adjusted the engine output according to their heating needs. The electricity produced went into the grid and was bought by the city works, with the gas bill to the homeowner crediting the customers.

  This systems solution was made possible by the fact that, at the time, the Rottweil city works were in charge of both the local gas and the electricity utility.
- **Negawatt.**[21] Many houses in rural areas of the USA are of wood-frame construction, with little or no insulation and are electrically heated. This means that houses are cheap to build but entail high power consumption for heating in winter and air conditioning in summer. As many Americans have a highly mobile lifestyle, they prefer to pay high power bills rather than spend money insulating their temporary or second homes. Their attitude gave the Tennessee Valley Authority (TVA) the idea of concluding contracts with homeowners for the supply of comfort (indoor climate and light) instead

of electricity. In exchange for a multi-year contract in the amount of the latest power bill, TVA insulated the buildings against wind and cold ('weatherising'). Amory B. Lovins calculated that this investment in its customers' houses yielded a higher return on investment for TVA than building new power plants. He called his approach 'negawatt', because he equated unused watts with negative power consumption. However, this approach does not take into account that TVA is bearing all future risks, including the 'moral hazard' of customers wasting energy that they no longer pay for (leaving windows open), the possibility of a massive growth in energy consumption by new electrical devices (computers) or that climate change could significantly increase power demand for heating and cooling. In all these cases, TVA's profit could drop, whereas if it were still selling electricity, its turnover and profit would increase!

- **Sekisui zero-energy-cost homes.** In Chapter 1, the zero-energy-cost house developed by Sekisui, a Japanese chemical company, was described as a sufficiency example; but the manufacturer so far still sells the houses rather than the function. This step forward has been taken by the Vallon Institute in the USA.
- **The Vallon Institute and its Renewable Urban Space Initiative.** The Vallon Institute is a not-for-profit research and development corporation that creates simple, sustainable solutions to complex social problems. It has developed the Renewable Urban Space Initiative (RUSI), which is a real estate development system for leased multi-family structures that aims to let affordable workers' housing in metropolitan areas. RUSI erects a building much the same as a traditional building. The difference is that the building is constructed of products leased directly from original equipment manufacturers (OEMs), known as performance contracting (www.valloninstitute.org).

  Through performance contracting, the property owner does not own the 'bricks and blocks' of the building but rather contracts with the various OEMs that maintain ownership of their individual assets. Each OEM enters into a long-term performance contract with the property owner to provide their assets in the form of a building system, including maintenance and performance; the liability and costs for risk, quality and waste remain with the OEM guarantee throughout the contract term. The property owner is thus able to offer a higher level of quality to the customer at lower than market prices.
- **Laundromats.** Communal washing centres have existed for centuries, combining repetitious work with chatting as a social information exchange. Modern laundromats appeared with the invention of the

washing machine as a cheaper alternative to buying a household machine, and are a classic example of lower resource consumption in a shared utilisation of goods.

But the success of selling laundromat services depends more on its social environment than on equipment design, and varies greatly in different countries. In Californian condominiums they are often located near the swimming pool, to provide an excuse to chat; in Sweden and the USA many apartment blocks have a laundromat in the entrance hall; Le Corbusier put them on the roof of his 'living machine' tower blocks so that housewives could enjoy the sun; in the UK they are often located in residential shopping areas to enable customers to intelligently use the waiting time. After German reunification, new laundromats in the east were combined with beer halls, dancing cafés and Internet shops to achieve the same multi-functional efficiency. In contrast, shared laundromats in Swiss apartment buildings are traditionally located in the basement; and as many Swiss women are afraid of being alone in the basement, many prefer to buy their own household machine.

- **Electrolux Gotland (Sweden): pay-per-wash.** 'The "smart home" paves the way for new business models'. This is how Electrolux – the world's largest producer of such electric appliances as refrigerators, washing machines, cookers and vacuum cleaners – announced 'rent-a-wash' in 2000.

  In cooperation with the Swedish power utility Vattenfall, Electrolux offered 7000 households on the Swedish island of Gotland free washing machines in one of the first commercialised projects of offering functional sales: instead of buying a machine, consumers paid according to how much they used it – a 'pay-per-wash' scheme with free maintenance included. After 1000 washes (about four to five years for a normal family), households could have the machine replaced or upgraded. According to Electrolux, families on the pay-per-wash scheme were able to plan their laundry loads more effectively, which translates into cost savings and reduced energy and water consumption.

  At the heart of the project was a new technology of 'smart electricity meters' in every home. Households received a specified electricity bill also charging them for the number of wash loads. The project was however cancelled after only a year because its systemic nature had been underestimated. The control of such a solution is in the hands of the economic actor who collects the data for invoices, not who manufactures the washing machines. In other words, Electrolux was no longer in the driver's seat in this type of business.

The rent-a-wash services were designed from an equipment manufacturer's viewpoint to reduce life cycle costs by focusing on durability, ease of repair, recycling of materials and attention to supply and reverse logistics with associated supply and material recovery chains. The systems issue outside the control of the manufacturer, however, was underestimated.

One fact is clear: systemic and systems solutions thrive in the Functional Service Economy and on appropriate framework conditions, such as an extended producer responsibility!

2.4.5 Generic performance management services

Generic performance management services, which are offered to corporate and individual clients alike, are among the oldest functional sales in the performance economy. They include urban transport, railways, toll motorways, bridges and tunnels as well as airlines, shipping lines, hotels, the post office and similar 'public services'. The best-developed markets for selling performance and utilisation in generic management services are in the distribution of immaterial goods via telephone and the Internet.

Many generic performance management systems were originally privately developed and later became state-owned. Recently, they have come under pressure from competing private companies to become more efficient or otherwise to be privatised. In some cases, free public and fee-based private systems exist in parallel, as, for instance, the urban road system in Tokyo, where fast private toll roads supplement 'normal' roads.

In the physical goods markets, business opportunities are mainly in the following services:

- housing performance,
- performance-based energy management services,
- transport and mobility performance

For generic performance management systems, the difference between tools and toys is vital, as they are offered to corporate and individual clients. Tools and toys here are different with regard to money.

Tools are production or investment goods used by economic actors to make money. Tools are influenced by the needs of efficiency in both economic and productive terms. In contrast to consumer goods (toys), fashion plays a minor part; performance and results are what is expected from tools, similarly to workhorses. In exchange, tools are cared for and properly maintained and repaired to function perfectly. The differences between tools and toys were explained in Sections 2.4 and 2.4.4.

2.4.5.1 Housing performance management services

The following examples detail real estate management systems selling performance to both private individuals and commercial companies.

- **Rental apartments: Selling performance**. Most housing management services with the exception of social housing are open to both individuals and corporate customers, whose choice often depends on price, apartments in prime locations commanding a higher price. The rental agreements generally include central heating and hot water but depend on local tradition.

  In many countries, the trend is to buy a house with a garden in a suburb rather than rent an apartment in an urban area. In Europe and the USA, the ageing of the population has started to reverse this trend. As concierge services that elderly people appreciate are normally not available in private homes, they are increasingly moving to residential centres in urban settings. The attraction of the home in the green is fading in favour of the attractions of the city, which offers a wide range of cultural and health services.

  Fairfield Residential LLC, based in Houston, Texas, for instance, built 29,000 apartments between 2000 and 2005; the ten largest US developers built 225,000 during the same period. These developments offer concierge services, business and fitness centres, swimming pools and even kindergartens. This change from ownership to rental apartments is expected to continue in the USA.
- **Inns and hotels: Selling safe and comfortable places to sleep**. Inns are one of the oldest solutions to offer food and lodgings to strangers searching for a safe place to sleep in an unknown territory. Improvements benefit both the innkeeper through a higher income and the traveller through a more agreeable stay.

  The service offered today by many eco-friendly hotels asks guests to reuse their towels. Selling the service of a good night's sleep is by many European guests seen as independent of fresh towels every morning. And helping the environment makes sense. This strategy gives financial advantages to the hotel – fewer expenses for washing towels and less wear on towels – and makes customers feel good about less pollution and less water consumption. It is quite popular in Europe, but less in the USA where customers expect a discount on their room rate for their cooperation. And it does not apply to five-star hotels that are obliged to change towels every day or risk being downgraded to four stars.

- **Providing security instead of selling alarm systems.** Installing a burglar alarm system with an outside siren was for a long time a state-of-the-art technology. In many cases, however, it proved to be more of a nuisance to neighbours than a protection against robbers.

  The main advantage of buying a security service instead of a burglar alarm is that the system is linked to a surveillance centre that will immediately despatch private security personnel to check the site and, if necessary, intervene by force or alert the police or fire brigade.

  A security service thus guarantees that a client's problem will be solved swiftly in case of a real emergency, something a burglar alarm cannot do! In addition, a security service eliminates most protection hardware, such as steel bars in front of windows, which regularly turn into a safety hazard in case of fire.

  And no security provider will try to convince its clients that they regularly need new expensive hardware; it would only reduce his profit margins. Instead, existing installations are maintained and technologically updated if necessary.

2.4.5.2 Performance-based Energy Management Services (EMS)

The following is an example of an energy management system that opens performance-based business opportunities for farmers.

- **'Energy farmers' in Austria, Germany and the UK.** Energy farmers own and operate a district heating service and sell heat and sometimes remote surveillance to local homes.

  When Austria joined the European Union in 1995, the government had to abandon its subsidies to milk farmers. Finding it increasingly difficult to make a living, many farmers in the hilly forested areas left their homestead and moved into urban areas to seek paid employment. A few farmers situated near villages and small towns decided to stay and become 'energy farmers', selling the energy needed to heat the houses and buildings in the neighbourhood. They built steam-based district heating systems and leased containerised combustion units, which are available on the European market in different sizes, providing them with the flexibility for future growth.

  The farmers are now burning low-grade wood from their forests, for which there is no market, to produce the steam for the district heating system. The ashes are spread in the forest as before, when forest waste was burnt on site.

House owners are the big winners of this service! They pay only for the heat consumed; they have gained the space previously needed for the heating installation as additional living space; and then have no investment and operating costs for the heating installations. In addition, heating is remotely monitored when occupants are absent through telephone lines that run along the steam pipes from the plant to each customer. These lines enable the energy farmer to provide remote surveillance as an additional service to the house owner, and income for the farmer.

Farmers make a better living than before and, for the first time in their life, can go on a summer holiday, as previously cows needed to be milked twice a day and did not allow holidays!

However, under legislation in force in the 1990s, this business model was considered illegal in several ways: industrial plants were not allowed on agricultural land; ashes from industrial plants were considered toxic waste and thus expensive to eliminate; and farmers were not qualified to operate a combustion plant. The solution to this problem in Austria was tolerance: the energy farmers will not be prosecuted for doing the right thing! The Bavarian Government in southern Germany and the UK authorities have found another solution for the same problem. Existing legislation has been changed so that energy farmers are considered agricultural installations, not industrial plants.

In general, the domestic sector has a great potential for energy savings, but the actual uptake has been low so far, in contrast to the industrial and public sector.[22]

Energy services also present the opportunity to promote micropower generation to produce heat, hot water and electricity simultaneously from a single source. A number of systems have been available to farmers and house owners, starting with Fiat's Totem system 30 years ago, Stadtwerke Rottweil in the 1980s and farmers burning their own compost gas today. In the UK, BG Microgen may be the first to go into leasing and service contracts for private households (www.microgen.com).

2.4.5.3 Generic transport management services

The following are examples of performance-based transport management systems open to both private individuals and commercial companies.

- **Public transport systems**. Public transport systems on water and land have existed in different forms in most countries for a long time and in the air for over half a century. But most public transport systems lack flexibility in where they will stop, and demand certain knowledge from their passengers on how to use them, which increases with the technical sophistication of the networks.

Furthermore, public transport is a modern form of 'Commons'. The comfort and safety of passengers depend to some degree on the behaviour of their fellow passengers. Systematic abuse can lead to a collapse of the solution. It is only recently that public transport has accepted its role as a systems solution, which is to transport a customer from where he is to where he wants to be. The Dutch railways were the pioneers of the *trein taxi*, a train service that includes transport by taxi to the railway station and by collective taxi to the final destination.

Several towns now experiment with more flexible services, such as call buses and look for public transport solutions that are adaptable to client needs.

- **Taxis: Selling safe and comfortable transport.** In order to go from A to B in an unknown town, the best solution is a taxi driver, which combines the cabby's knowledge of the area, his driving skills and the cab. The passenger has no responsibility other than to pay the fare, which is normally regulated and controlled by authorities. The sufficiency benefit comes from the intensively shared utilisation of taxis by many customers, the incentive for the driver to minimise the mileage driven when empty and the shorter use of urban parking space.

  However, with few exceptions, such as the famous black London cab or the Jeepneys in the Philippines, manufacturers have not produced vehicles that answer the needs of taxi drivers and their customers: a comfortable and adaptable means of transport that can easily carry wheelchairs, baby prams and large parcels.
- **Car sharing and rent-a-car: Shifting from car ownership to functional services.** The concept of a shared use of goods enables a more intensive utilisation and thus a higher value-per-weight ratio per unit of service. But no manufacturer has adapted the design of cars to facilitate shared use, such as ease of cleaning and protection against driver abuse, with the possible exception of the London taxi.

The concept of a shared use of goods enables a more intensive utilisation and thus a higher value-per-weight ratio per unit of service.

An optimisation of the new quality presented in Figure 2.1 – the Quality Cube – is thus not possible. In fact, one of the few durable goods designed to specifically take into account intensive use by many different customers are the semi-commercial washing machines in laundromats described on page 108.

Car sharing and rental cars have probably existed as long as cars have been on the market; the main difference is that car sharing is for short use, typically one or several hours at a time, while car rental is for a longer period, ranging from several hours to several days. Rental cars were meant for the business traveller away from home; they had to be clean and recent models in order to present the right appearance. The first derogation from this principle was 'rent-a-wreck', a company that rented used cars at a fraction of the price charged by normal rental companies.

Car sharing was the second deviation from the established rental car norm. The first car-sharing scheme was a Swiss self-help organisation called *Selbstfahrgemeinschaft* in Zurich, which existed from 1948 to 1998. Its objective was to give people who could not afford a car the option to share one. In the 1970s, the idea caught on in other European countries, Japan and the USA, but the companies had a short life. In 1997, two small Swiss cooperatives, AutoTeilet in Stans and SharCom in Zurich – both established in 1987 – merged to form a new company called Mobility, which no longer is a cooperative making its cars available only to its members.

The difference between car sharing and car rental are disappearing. Car sharing originally was based on an agreement between the co-owners to return the car in clean and working order on time. But rental cars still have the advantage that they do not have to be returned to the place of rental, offering a higher flexibility at a higher cost.

The growth of car sharing in **Switzerland** has been phenomenal. Starting with 20 members and two cars in 1997, by 2007, Mobility Switzerland boasted 73,600 customers, 1950 vehicles at 1050 locations, 150 employees and an annual revenue of €30 million. Worldwide, some 600 cities now have car-sharing schemes with an estimated 350,000 people sharing 12,000 vehicles. Switzerland still has a 20 per cent share of the world market, the rest of Europe has 40 per cent, North America 34 per cent and Asia six per cent.

In **Germany**, several car-sharing schemes were started in 2008 by established car-rental companies such as Sixt and Flinkster, the latter operated by the German railways, which also runs an urban bike rental scheme, 'Call-a-bike'. Hertz now offers car sharing in London, Paris and New York and claims that each car-sharing vehicle in New York City eliminates up to 14 passenger cars from the road. So, the environmental benefits of car sharing are clear. Among London's car-sharing companies are streetcar, self-service, pay-as-you-go, citycar-club.co.uk, zipcar.com and shareacar.com, to name but a few.

In **Japan**, shifting from car ownership to services and function has become popular in 2002 when several companies established a joint venture called CEV Sharing Company (CEV) to test whether the car-sharing idea could be successfully applied in Japan. By 2007, CEV was integrated into ORIX Auto Company's new car-sharing division (short use) within its rental car department. By August 2008, 19 car sharing companies were operating in Japan, according to a survey by the Foundation for Promoting Personal Mobility and Ecological Transportation. A total of 522 cars were shared at 323 car stations by 3875 registered members; compared to the previous survey in January 2007, the number of cars and cars stations more than doubled, while the number of clients expanded by 50 per cent. Among the reasons for car-sharing's popularity have been rising gasoline prices, the growing awareness of environmental issues and the spread of such eco-friendly lifestyles as LOHAS and a 'green servicizing' concept, which refers to the use of the services or function of goods rather than the ownership of the products.

Car sharing is also spreading to condominiums in Japan: 40 buildings with a total of 80 vehicles had, or planned to introduce, a system by July 2009 to provide residents with cars close to their apartments, thus alleviating a shortage of parking spaces. Companies are also shifting to car sharing to downsize their fleet and cut costs: about 20 per cent of ORIX Auto Corporation's clients are businessmen. Hokuriku Railway is the first Japanese public transport company to get involved in a car-sharing scheme similar to European cooperation agreements.

- **Bike sharing:** the shift from ownership to functional services is not limited to cars. Bike sharing has sprung up as a Private-Public Partnership (PPP) in a number of towns in such traditional bicycle countries like the Netherlands and Denmark but also in the French capital Paris. JCDecaux, the world's No. 2 outdoor advertising company, designed a heavy-duty bicycle, had thousands built in Hungary and opened 750 rental stations in Paris. It operates the network at its own expense and in return has been granted the exclusive right to sell advertising on the city's 1628 urban billboards for the next ten years. Other European capitals offering JCDecaux rental bikes are Brussels, Vienna and Seville.

Bike Off Company, a Japanese motorcycle dealer, in October 2007 opened a website called Echochari.com to start its free bicycle rental service for college students, using illegally parked or abandoned bicycles removed from the city streets. The costs for repairing the bicycles are covered by revenues from advertising on its website and on its bicycles, in addition to financial assistance from supporting companies. This enables college students to rent the bicycles for free until graduation (www. echochari.com).

Other product-sharing schemes have also been launched for sailing boats, business aircraft and timeshare apartments.

2.5 Change drivers

Various actors are driving the changes in selling performance instead of goods, the most important are briefly described in the following sections.

2.5.1 Competitiveness in the market as change driver

Historically, changes have oscillated between services and goods. Washing clothes, for instance, went from do-it-yourself to having hired help and then to outside laundry services. With the commercialisation of the washing machine it is back to (mechanised) do-it-yourself and finally to the concierge services of today. In each case, economic power shifted to a new economic actor: from the household to the laundry service to the equipment manufacturer to the laundry service or textile leasing company. The only constant elements have been detergents and laundry soap.

In future, the pace of change will accelerate due to a shift from selling to buying performance. At the 2009 International Space Insurance Conference, a NASA representative pointed out that his organisation's procurement policy would change to buying services instead of hardware after the last space shuttle flight in 2010. At that time NASA will have finished the phase as owner and operator of space hardware. The private sector will have a greater opportunity, but it will need the technical personnel with an education and expertise in space engineering. Do you remember the birth of computer sciences? The academic field of computer sciences exists in part due to IBM's insistence that it did not belong in the physics, engineering or mathematics department.

The new private-sector companies vying for space services, such as Odyssey Moon Ltd, SpaceX and SOHO China, may have to lobby for a space engineering department in universities. The only European university offering a degree in space engineering is the International Space University in Strasbourg, France. The UK's University of Surrey, which is located in a region renowned for promoting small satellite manufacturers, announced in early 2009 a prestigious new Research Chair in Space Engineering (www.rocketeers.co.uk/node/542); and several other UK universities have already dedicated space centres. While Chinese and Indian universities are graduating an increasing number of engineers and scientists, they are still insufficient to fill the skill gap in space engineering in the short term.

Another change driver is competition from economic actors of the Lake and the Loop Economy. The Swiss aircraft maintenance company SR Technics' invention of selling hours of jet engine functioning as a means to market its superior remanufacturing quality convinced manufacturers to adopt the strategy themselves in order to defend their core business revenue (see Section 2.4.1.1).

2.5.2 Corporate memory can be a strong driver

Past corporate experience of selling performance has helped to convince managers that it can be done again:

- The original Kodak Brownie cameras were launched in 1900 with the film inside; the film had to be removed in a photographer's dark room, and the camera reloaded with a film at the factory or at a photographer's. The market introduction of the single-use camera meant simply going back to the original business model.
- Xerox knew from its history that operational leasing is a financially advantageous business model, if all factors, including taxes and depreciation, are taken into account. After losing its patent protection, Xerox engaged in a sales price battle for small copiers with cheaper competitors before reverting to selling customer satisfaction through operational leasing to corporate clients.
- IBM's historic success of mainframe servers was based on the sale of system performance (hardware/software packages) and retained ownership. Today's IT services mean again running an office, possibly in the client's workplace, by operating the IT system to produce the desired results. It was started 40 years ago by outsiders such as EDS, today a global leader in technology services, and taken up by IBM. Cost-cutting later led to outsourcing to locations with the

cheapest production cost (India), a development facilitated by the digital supply chain.

Shifting from manufacturing to the Functional Service Economy without previous experience – 'doing it the first time' – however, proved difficult for many economic actors that were successful in the Industrial Economy, such as Microsoft. Microsoft's software alliance project of selling software utilisation, and Hewlett Packard's 'pay for capacity' did not convince the market or came with unattractive conditions attached.

The change from selling goods to selling performance is loaded with uncertainties. And operating the two strategies in parallel, as practised by Dow Chemical's traditional business competing with its subsidiary SafeChem, may not make good business sense for catalytic goods. But Caterpillar, which offers its equipment for sale, lease and rent, has shown that parallel strategies are feasible for durable investment goods.

2.5.3 Supply-driven performance selling is still the norm

GE Medical Services' (GEMS) decision in 1990 to start the take-back and remarketing of used equipment and components was based on the simple question: 'Can we make money this way?'. In other cases, the shift to the Functional Service Economy has come through peer pressure to give the customer what he wants. Caterpillar started remanufacturing diesel engines for GM trucks because this was a condition imposed by GM, as it was the (cheaper) norm in trucking. Caterpillar has since passed the knowledge gained onto its suppliers. The autonomous European operations of US companies have sometimes resisted the application of US know-how, for instance, in Chemical Management Systems (CMS).

CMS is a widespread, largely market-driven model in the US and a workable proposition in Europe. But the European business model needs to demonstrate its environmental potential besides its economic advantages. Catalysts can play a key role. US companies have been given a helping hand by the Chemical Strategies Partnership (CSP), which serves as an independent source of information and guidance in developing CMS programmes. CSP's independent nature has been an important factor in its success, as it can help build trust between suppliers and clients. Its approach to initiating a CMS programme is based on the fact that companies are not aware of the total cost of chemical use, another example of the cost iceberg. Revealing this cost creates the opportunity to restructure supplier-customer relationships and create new value. CSP has developed a step-by-step approach to evaluate true chemical costs and to design a comprehensive CMS programme, which is described in its manual for manufacturing firms, Tools for Optimizing Chemical Management.[23]

The European Crop Protection Association could possibly play a role for agro-management services similar to that of CSP for chemicals in the USA. A lack of honest information might explain the slow progress of sustainable solutions, such as Interface's 'green lease' and cold-zymes, and could hold back the future introduction of radio frequency identification (RFID) labels in some countries.

Both global players and start-up companies contribute to spreading these business models. DuPont's paint-shop-in-the-plant principle to sell painted car parts to car manufacturers is a global example, whereas Vanguard's service of reprocessing medical devices in-house at hospitals in Germany is a successful start-up. Physical work linked to the supply chain is difficult to outsource geographically and often demands an insourcing approach in the client's plant, in contrast to digital IT outsourcing.

Franchising systems can be another route to success, witness the case of textile leasing for small laundries in Europe (RenTex and ProfiTex).

2.5.4 Demand-driven performance buying is growing

Military procurement and Performance-Based Logistics (PBL) are strong drivers in Anglo-Saxon countries that still believe in maintaining strong and efficient armed forces. The US administration's preferred procurement option is performance (services instead of hardware). This also includes the National Air and Space Administration (NASA), which recently declared that the space shuttle is the last piece of hardware that NASA will have owned and operated.

The first corporate business models based on buying performance start to be tested. The Vallon Institute defines itself as intermediary player who buys the performance of building materials and equipment, and sells the performance of housing services to individuals. It has adapted the role of the housing developer to the concept of the Performance Economy.

2.5.5 Legal frameworks as change driver

In the case of chemicals, accountability can be a driver. The introduction of the Toxic Release Inventory (TRI) in the USA helped the shift to Chemical Management System (CMS) accountability; the EU's REACH regulation could become a similar driver in Europe. Future regulatory developments in the European Environment Agency's move towards risk-based regulations are also likely to increase compliance demands on EU companies that use chemicals. Continued tight margins in the sector will also continue to force innovation and cost-cutting, creating opportunities for companies that can deliver. A well-developed model of service innovation in the chemicals sector, CMS can help respond to these pressures.

In July 2008, Japan drew up an action plan for achieving a low-carbon society to reduce greenhouse gas (GHG) emissions. Among the recommendations of this plan was the launch of a study group to promote car sharing and examine ways to address obstacles and increase convenience. A 2005 survey by the Eco-Mo Foundation showed that the introduction of car-sharing systems in urban areas led to a reduction of members' travel distances and number of cars owned by 79 per cent and 76 per cent, respectively. Car sharing thus eases traffic jams and pressure on parking spaces in urban areas, supports the use of public transport and reduces GHG emissions.

The EU bill of rights for air passengers, the EU directive 261/2004 that became law in 2005, requires airlines to reimburse passengers in case of non-transportation due to overbooking, late departure or cancellation. This right applies to all passengers travelling to or from European Union countries and is independent of the reasons, which include technical problems, weather, etc. (http://apr.europa.eu). In April 2007, the US Senate started hearings on the introduction of similar guarantees for airline passengers travelling in the USA.

The introduction of the 'Factor Time' into the market economy calls for new free market safety nets and guarantees, such as risk transfer and insurance. The Functional Service Economy enables nation states to exploit insurability as the natural borderline between the state and the private sector. Risks that are insurable do not need state legislation. For uninsurable risks, however, governments must either forbid the solution or, through legislation, oblige the actors who carry the costs of risks and liabilities to guarantee the internalisation of a negative outcome. By not observing the above natural border, nation states act as free insurers without charging a premium and favour the development of sub-optimal solutions. Economic risk actors, such as insurance companies, price risks individually through risk-based premiums, thus providing strong incentives for economic actors to reduce or eliminate the biggest risks and liabilities rapidly.

Respecting the limits on state debt, called for in the EU's Maastricht agreement, can promote the development of public infrastructure in the Functional Service Economy: Private Finance Initiatives (PFI) shift the debt burden to banks and the risks to insurance companies.

2.5.6 Exploiting science and technology as change driver

As shown in Table 2.4, targeted research and development in science and technology will speed up change towards the Functional Service Economy that acts as a door opener for marketing scientific solutions from the Performance Economy (described in Chapter 1) that:

- need a systemic solution approach, such as smart materials or Micro-CHP (combined heat and power) generation plants,
- make the manufacturer liable for the safe disposal of goods, such as carbon nano-tubes (CNTs) and
- provide a very long service-life, such as nano-polished bearings and Ecosys printers; or 'Stradivarius-type' products.

2.6 How to overcome obstacles

Most obstacles to selling performance are on the buyer's side. Many facility managers, for instance, seem to prefer negotiating with a number of independent service contractors, while others prefer a high initial payment rather than small rental fees for a 20-year period. This reluctance in the market will change with the shift from selling performance to buying performance, as observed in the US administration's preferred procurement option to buy services instead of products. Another reason for change may be the growing preference for performance rather than ownership for reasons of liability costs. And there are many more reasons to be optimistic, as shown in the following sections.

2.6.1 A global competition of corporate culture

Among the leading industrial powers, the USA, Japan, Germany and China have different attitudes towards tackling the shift from a manufacturing to a functional service economy.

Most German capital goods manufacturers appear to be still fixed on the traditional business model of 'develop, produce and sell'. In mechanical engineering the share of services compared to total revenues was only around 8 per cent, according to the German Ministry of Statistics. Front-runner companies with a service revenue share of over 20 per cent are the exception. Surveys show that customers increasingly demand a complete servicing of investment goods; yet, many manufacturers are reluctant to offer services in binding agreements,

Table 2.4 Key capabilities that are specific for each product group

Corporate Strategies and product groups	S1 prevention strategies	S2 manufacturers selling performance, services or results	S3 manufacturers fleet managers with loop responsibility	S4 fleet managers with m + O responsibility operation	R independent remanufacturers
	SCIENCE				
consumption goods (fuel, paint)	generic strategies	**LIFE SCIENCES** **MATERIAL SCIENCES**			
catalytic goods (engine oil, solvents)		**REVERSE LOGISTICS/RE-REFINING TECHNOLOGIES**			
durable goods (cars, buildings)		**DfE DESIGN FOR ENVIRONMENT** **RE-MANUFACTURING MARKET/TECHNOLOGIES**			
		EPeR Extended Performance Responsibility			**JOBS** job creation potential

financing services or even independent systems operations, ignoring the opportunity to increase competitiveness and open up new markets.

Since the 1990s, GE has earned 75 per cent of its revenue from the sale of services, and only 25 per cent from selling goods! As US capitalism focuses upon market-driven solutions, many other US companies today have a similar proportion of revenues from services. Rolls-Royce today earns more than half its revenue from such services as 'pay-by-the-hour flying'.

In 2005, the Japanese Ministry of Economy, Trade and Industry (METI) launched the 'Green Servicizing Model Business' to support service-providing businesses that reduce impacts on the environment. Its examples of model businesses include a car-sharing system, home appliance repair, computer support and repair, toner module recycling, repair or service of electric or electronic appliances (for example, air-conditioner cleaning). Another example is the 'Light and Trust Service' by Matsushita Electric Industrial Company that leases rather than sells fluorescent lamps, with remuneration received for only the lighting function. This plan promotes 'services for the environment' as well as examples from both the Functional Service Economy and the Lake and the Loop Economy (see Chapter 3).

The US administration's preference to buy performance rather than hardware has led to military officers familiarising themselves with this changed concept. Some ex-personnel of the US Armed Forces have even started to apply this knowledge in civil life to gain a competitive advantage (see the example of the Vallon Institute above). This is similar to the boom in the leasing of Xerox equipment at the end of World War II, when returning military officers demanded that companies adopt the efficient Xerox copiers that they had been using.

2.6.2 A global competition of legal systems

Many business models of the Functional Service Economy work well in most countries, such as facility management. Others hit barriers due to fragmented markets or are restrained by rulings on technical objectives by non-technical experts in administration. One such case is the acceptance of resterilisation methods for disposable medical devices in the USA, but not in many European countries.

The US focus is on market-driven solutions of the Functional Service Economy, whereas the European Union favours a heavily government-regulated economic system. If the Functional Service Economy is a means to move advanced industrial nations to the next level of capitalism, the 'more-from-less' objective of the Performance Economy, then framework conditions based on the legacy system of the Industrial Economy (more-is-better) can become major obstacles.

An appropriate performance energy services framework, for example, requires: 1) new regulatory and fiscal incentives for energy suppliers to market their services; 2) incentives for domestic customers to buy energy services; 3) the adaptation of building standards to encourage energy services; and 4) further research on the economic benefits of energy services. Energy performance services need to be simple and attractive to convince consumers.

Tough legislation on liability and waste, as well as a confrontational attitude of legislators versus industry, can promote the Functional Service Economy by creating a level playing field. According to the conclusion of the European Commission's Blueprint report, consensus is less efficient than confrontation management.[24] Recent European waste policies obliging manufacturers to pay for the take-back and recycling of such goods as end-of-life vehicles and discarded electrical and electronic goods, has been based on consensus. These new policies miss the profit maximisation issue: in most cases, only manufacturers-cum-fleet managers of the Functional Service Economy have the capability and incentive to re-integrate the components and goods into the supply chain, turning used goods into new revenue.

Nation states today subsidise their transport infrastructures, which is necessary for the cheap functioning of the global Industrial Economy, and nationalise a major part of the costs of risks and consumer waste. Stopping this practice would speed up the transition to the Performance Economy that focuses on maximising utilisation value in a regional approach and at the same time considerably shrinks public budget deficits.

A similar situation can be found in most health services (see the earlier example of the Chinese doctors).

2.6.3 Market-inherent obstacles

One major market-inherent obstacle is that systems solutions that replace products often lead to stranded capital, changes in the economic power structure and/or additional costs for changes in production and marketing. One of the first examples of Pest Management Services worldwide, Ciba-Geigy's Taona Zina project in Madagascar, was terminated after a very successful trial period due to changes in the market structure that were unacceptable to some economic actors. The failure of this historic example is a warning to not underestimate the resistance from economic losers.

A lack of understanding the full costs of chemical management – of the cost iceberg – is another major obstacle. While the benefits of chemical management services are clearly significant, it is a challenging business model for both users and suppliers. Chemical purchases normally account for a small proportion of total costs and therefore are a low priority. The hidden cost of chemical management, which can be up to 10 times the purchase price, is often not understood. Therefore, the budget for chemicals is seen as too insignificant for management to focus cost-saving efforts on.

High start-up costs are a third obstacle. Precision agriculture, for instance, is based on capital-intensive expert systems, typically in the range of €5000–€20,000. Persuading small farmers to adopt the approach in Europe may be hard, as a high percentage of farmers are not computer savvy and distrust such new technologies as GMOs. A service-based business model selling results for a fixed cost may be the best way to give small farmers access to the necessary equipment and expertise.

Bonuses are the last market-inherent obstacle. In the case of standardised reusable transport packaging for household appliances, the 2008 test phase showed that wastage could be reduced by a factor ten, from 5 per cent to 0.5 per cent. However, as the delivery contract foresees a discount of 5 per cent to compensate for this loss, the interest in loss prevention was modest.

Trust is an essential part of a business model that reaches down to the customer. Contract terms must be clear but flexible, with incentives to ensure environmental benefits yet at the same time allowing service suppliers to recoup their investment. Hidden bonuses obscure the economic logic.

Private Finance Initiatives (PFIs) use finance and risk transfer but also rely on the 'Consumer Pays' principle, which contradicts the concept of 'free goods'. The Aguas del Illimani project in Bolivia failed because it ran into a political debate over whether public water works or private contractors should be in charge of supplying water to private homes – which was actually a hidden political debate over the price of water.

Opening such public service markets as roads, water and energy supply to the private sector excludes the concept of solidarity, where rich taxpayers will carry most of the financial burden. Maintaining state control of public infrastructure, on the other hand, will scare away the private sector from entering into PFI contracts. This issue could play a decisive role in the future competitiveness of emerging economies.

2.7 How to measure it!

The first published article to highlight the problem of measuring performance might well have been 'The performance concept and its terminology' in the January/February 1975 edition of Building Research and Practice, pp. 18–22. The term used to characterise products that must have certain properties to enable them to function when exposed to stress was 'performance', which was defined as 'behaviour related to use' – a definition that corresponds to the use of the term 'performance' in the Functional Service Economy.

The new measure of sustainable financial efficiency in the Functional Service Economy, and the Performance Economy in general, is the part of the total costs for risk and waste of a product that is internalised by the manufacturer or fleet manager:

INTERNALISED RISKS AND LIABILITIES

measured in per cent of total risks and liabilities over the full life cycle of goods.

The key is not a 'servicizing' of the economy but an internalisation of liability and waste costs by all economic actors. This may be difficult to judge for the customer as long as no generalised life cycle costing approach exists. What can be judged at the initial sale is the service contract itself, which should stipulate specifically what is excluded from the performance sold, not what guarantees are covered.

Selling performance in the Performance Economy is competitive because it includes economic incentives for loss and waste prevention, which is inherently cheaper than the cost of repairs and waste elimination, on a micro- and a macro-level. The fact that losses and waste reduce corporate profits led General Electric to formulate its famous Six Sigma strategy, which enabled it to tackle the cost 'iceberg' mentioned in Chapter 1.

The Performance Economy is sustainable because less accidents and less waste avoid individual hardship and save resources, as well as reducing emissions at both the micro- and macro-levels. These factors increase the value-per-weight ratio presented in Chapter 1 and reduce the resource throughput of the economy.

Selling performance thus means to internalise all costs for waste and risk over the full lifetime of a product.

Selling performance means to internalise all costs for waste and risk over the full lifetime of a product.

Marketing terminology should be treated with a pinch of salt. Concepts such as 'servicizing' and product-service systems do not necessarily include an internalisation of liability and waste costs by economic actors. The term product-service-system (PPS) was first used as a title for a report by Dr Arthur Purcell, Los Angeles, and Walter R. Stahel, Geneva, to the US Environment Protection Agency (EPA) in 1993 but consequently abandoned because the terminology and mind frame corresponded to those of the Industrial Economy, treating products and services as separate entities. The term PSS became popular at the start of the third millennium but in most cases still misses the performance and liability issue, which is key to the Functional Service Economy (Figure 2.5).

Paul Hawken and Amory and Hunter Lovin suggest in their 2001 book 'Natural Capitalism' that one of the four principles of natural capitalism is the shift to an economy where value is produced in the

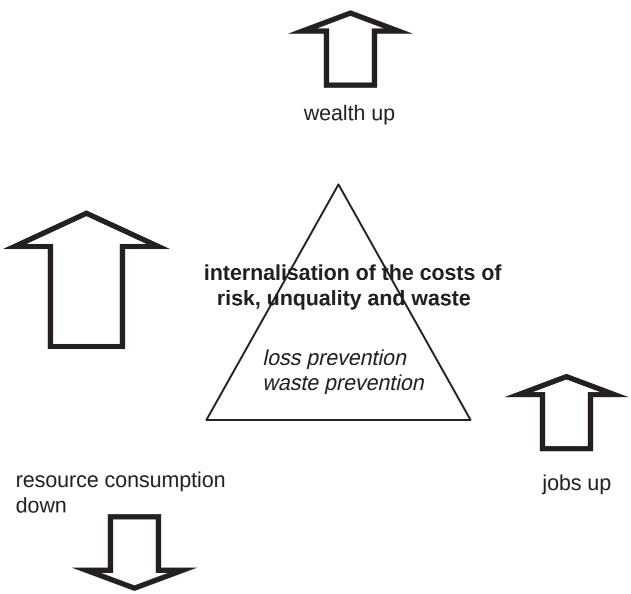

Figure 2.5 The objectives and metrics of Selling Performance in Chapter 2

form of services. The book also gives credit to Walter Stahel for having invented the concept of selling services instead of goods.

In March 2007, Japan's Environmental Industries Office, which is part of METI, published a report entitled 'Green servicizing businesses – A new Society being created by businesses focusing on function'. The report describes the findings of studies and the performance of model projects conducted by the METI since 2005, as well as actual conditions and problems faced by green servicizing businesses.

As used in Japan, 'servicizing' refers to a shift from the sale of products to the provision of services, which focuses on the function of products and providing these functions as services. The term incorporates the aim of reducing environmental damage by reducing the amounts of resource and energy required during production, delivery and consumption, and by reducing the number of products that end up being discarded after use.

Japan's report on 'Green Servicizing Businesses' identifies five business models, the first three based on material services, the last two of non-material services:

- Service providers own and maintain products. Examples include the rental or leasing of products, pay-per-use for copying or laundry machines, and waste treatment or recycling under contract. There is no distinction between manufacturer-operators and fleet managers – this corresponds roughly to selling performance in this Chapter 2.
- Users enjoy advanced maintenance and effective use. Examples include repairing, reforming, upgrading, inspection and maintenance services, and trade-ins and sales of used products and parts. This corresponds to the business models in Chapter 3.
- Joint ownership of products. Examples include car sharing and joint use of farm machinery, which were dealt with in this Chapter 2.
- Substitution of products with services. The use of information, knowledge and labour leads to a reduction in the environmental impact of material products. Examples include music distribution services and the management of digital images.
- Enhanced services and value-added. Examples include better coordination of waste treatment and energy service companies (ESCOs).

Applying the metrics of the Performance Economy – that is, the degree of internalised risks and liabilities measured as a percentage of total risks and liabilities over the full life cycle – the first and third groups may qualify for selling performance by internalising all risks and costs, depending on the ownership situation of end-of-life goods, and the incentives to protect the environment and prevent loss over a product's full life.

Economic incentives, one of the key drivers of the Performance Economy, are not in the focus of the Japanese report. The difference to the business models of selling performance is thus the lack of incentives for economic actors to internalise the costs of waste and of risks.

3
Managing Performance Over Time

> Insourcing jobs in the Lake and the Loop Economy creates new openings and skills in the workplace through the skilful management of existing assets.[1]
>
> The standardised components in today's goods are the manufacturing input of tomorrow at yesterday's prices.

Why the shift? How it works! How to measure it!

Expert managing of the performance of physical assets over time in the Lake and the Loop Economy, in the best cases, can achieve a triple-win objective with regard to sustainability:

- delivering a major contribution towards a low-carbon economy,
- substituting renewable resources (labour) for non-renewable ones (material and energy) and
- increasing the resource productivity of jobs (a higher man-hour-per weight ratio).

This is achieved by the conservation of the materials and their embodied energy that make up goods and, in some cases, profit from the multiplicator effect of the '*pars pro toto*' syndrome, whereby upgrading or repairing a small part of a technical system enables continued exploitation of the whole system.

3.1 Why the shift to managing performance over time?

The shift is imperative for our welfare; it is feasible and its progress can be measured.

It is imperative because the Industrial Economy is inherently unsustainable as its value creation is directly coupled to resource throughput. Decoupling wealth from resource consumption is thus no option in the Industrial Economy. In addition, managing the performance of physical assets over time competes directly with production volumes and reduces their economy of scale.

Jobs in manufacturing industries are subject to several trends:

- Jobs in manufacturing will continue to move from high labour-cost regions to regions with considerably lower-wage levels, helping the economies of these less developed regions to grow through a rise in manufacturing, related services and in exports; but jobs in maintaining performance over time will increase in industrialised economies.
- Rationalisation and automation to increase productivity will later entail job cutbacks in manufacturing and a shift to jobs in maintaining performance over time in these industrialising economies.
- Industrialised countries that try to preserve jobs in manufacturing industries through state subsidies – for example, the European coal and steel industry – will only defer structural change; a shift to managing performance over time will create new sustainable jobs in a decentralised pattern.

The shift to managing performance over time is feasible because the Performance Economy can create new skilled and manual jobs locally, especially in industrialised economies:

- Many manual jobs with a large variety of skills and skill levels can be created through innovative asset management of the largely saturated markets for durable goods in industrialised countries and by intelligently exploiting this existing wealth.
- Managing performance over time is an integral part of the business model of selling performance instead of goods and profit from the latter's expansion.
- The first goal of the Performance Economy – exploiting science – will certainly create new jobs in the knowledge economy but few openings with a profile for manual labour. Further, these jobs will often require a high mobility as they are embodied in a global market.

Managing performance over time implies a shift from a 'river' industrial economy to a 'lake' economy that conserves wealth and creates value, thanks to the judicious management of existing physical assets. A key capability is to optimise the operation and maintenance of the infrastructure, buildings, durable goods and equipment in industrialised countries.

And the progress of the shift from manufacturing to managing performance over time can be measured using the simple metrics of labour-input-per-weight (man-hours/kg), and value-per-weight, or €/kg.

3.1.1 Using goods in the Lake and the Loop Economy

A shift from the Industrial Economy towards the Lake and the Loop Economy entails a radical change in an economy's function: from an emphasis on periodically replacing existing goods by new ones to efficiently managing existing material assets. Optimising and extending the full service-life of goods is a complementary activity to manufacturing and gives a strong impetus to it. National economic accounting will have to account for human capital (labour) in addition to financial and natural capital and measure its fluctuations. The quality of human capital can be greatly improved through education and training – and it is the only type of capital that will deteriorate over time if left unused. This shift may also imply a review of the concept of property, from a focus on dowry to one on patrimony, from ownership to stewardship.[2]

Compared to the fast replacement of goods in the Industrial Economy, the Lake and the Loop Economy extends product-life by substituting transformation and service activities for extractive and base material production, thus replacing large-scale capital-intensive units with small-scale labour-intensive, independent, locally integrated work units. At the same time, the economic focus shifts from production optimisation to utilisation optimisation over the total lifespan of a product or system.

How will this shift to the Lake and the Loop Economy impact the factor inputs into the economy? Figure 3.1 shows the development of the life cycle costs for operating an automobile over 50 years.[3] This analysis is representative of the life cycle costs of most durable goods.

At the point of sale (POS), the producer-distributor in an Industrial Economy sells a durable good to the user-consumer, the sales price being equal to the exchange value. The value embodied in the product is represented mostly by the *non-renewable (depletable)* **ENERGY + MATERIALS** used in the manufacturing and distribution processes, making up about 90 per cent. Labour is a small part of the manufacturing input.[4] The sales price remains constant throughout the utilisation

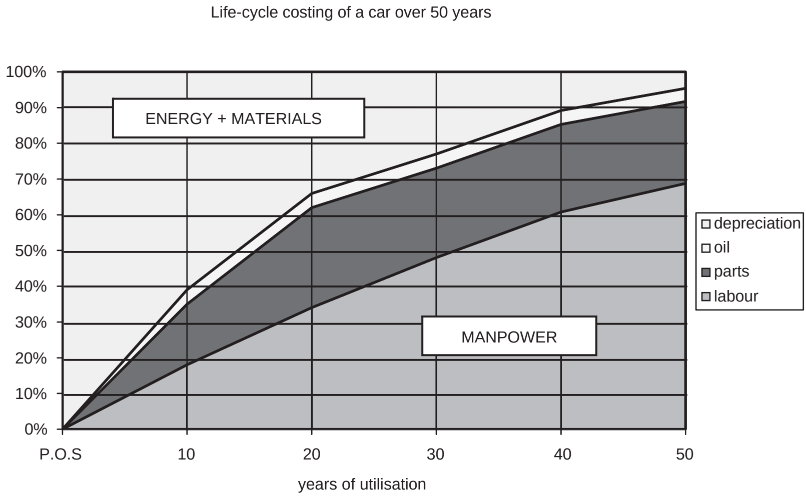

Figure 3.1 Evolution of the life cycle costs for goods in the Lake Economy

period, so its relative weight will *decrease* over time. It is represented by the left upper triangle in Figure 3.1.

During the utilisation period, the main resources employed are *renewable*, mainly in the form of human labour for such service activities as maintenance and repairs. These **MANPOWER** costs *accumulate*

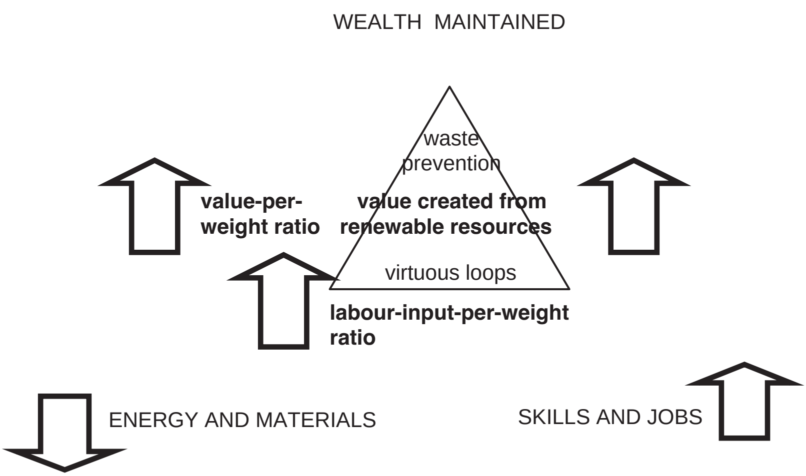

Figure 3.2 The factor impact of service-life extension activities

over the years, up to a ceiling of about 75 per cent, and are represented by the lower right triangle.

Spare parts and components make up a relatively stable 20 per cent of life-cycle costs (the dark wedge). These parts have a high potential to be remanufactured in the Loop Economy, adding up to 15 additional percentage points to the pure manpower input shown in Figure 3.1. This leads to a change in factor impacts shown in Figure 3.2.

The focus on utilisation in managing performance over time will also produce new key capabilities of the Lake and the Loop Economy, such as component standardisation, in-use monitoring of the performance of goods and product design for reuse and remanufacturing, which have been of no interest in manufacturing.

3.1.2 Managing performance over time – creating jobs at home

With increasing service-life (years of utilisation), the cost share of depletable resources diminishes rapidly, while that of renewable resources (manpower) increases. A strategy of service-life extension for durable goods – such as infrastructure, buildings, ships, aircraft, equipment and cars – is thus equivalent to a substitution of manpower for energy and materials.[5] This strategy creates jobs at home while at the same time reducing resource throughput in the economy. It also has a much higher value-per-weight ratio than manufacturing, as will be shown later. In addition, it preserves energy investments (also called grey or embodied energy) and therefore greatly reduces CO_2 emissions, compared to replacement goods.

Skilled and experienced craftsmen are needed in repair and remanufacturing activities, which can be undertaken in comparatively small workshops, scattered widely throughout the country where there is a need for product renovation and customers for them, as is the case with car-repair workshops. These enterprises can be located in any rural or urban area with high unemployment, making product-life extension a doubly attractive proposition for job creation.

3.1.3 Pursuing cost efficiency

As the cost of remanufacturing a mass-produced good is about two-thirds of the cost of manufacturing an equivalent new one,[6] service-life extension increases economic competitiveness on the supply side and increases disposable consumer income! The business models of managing performance over time, such as product-life extension, enhance the competitiveness of regions as these activities are best performed close to the customer.

Physical asset management in the Lake and the Loop Economy concerns three areas:

- goods and components,
- embodied energy and CO_2 and
- materials and molecules.

The physical asset management of goods and components is dealt extensively with in the following sections; its competitiveness depends partly on the cost and availability of new goods, local labour, raw materials and energy as well as on the differences in the economy of scale in manufacturing versus remanufacturing.

The efficiency of asset management of embodied energy and CO_2 depends on the strategies chosen. Reusing goods will conserve the embodied or grey energy almost completely; in reusing materials, their conservation depends on the material. The recycling of aluminium conserves 95 per cent of embodied energy, while the energy in cement can only be maintained by service-life extensions of the structures in which it is bound. Rising energy prices will thus give an economic advantage to physical asset management that extends the service-life of any goods and components, but only to the reuse of the few materials that can be recycled or de-polymerised with little energy input, such as aluminium and polymethacrylate (Plexiglas). Emissions-trading schemes that recognise the conservation of embodied CO_2 would lead to good asset management of embodied energy but are excluded under the Kyoto Protocol of 1997.

The profitability of the physical asset management of materials and molecules varies according to the prices for raw materials. When their prices are high, the cost advantage of the loop of reusing goods and components is greater than that of reusing molecules. Asset management of materials and molecules for which rises in prices or future supply scarcities are foreseeable, intensifies the competitiveness of the asset owner and manager. The copper pool of Deutsche Telecom is an example.

3.1.4 Managing performance over time – increasing corporate and national competitiveness

Manufacturers can increase their profitability by selling performance and accepting an extended performance responsibility over the full service-life of their goods.[7] Manufacturers become fleet managers in the Lake and the Loop Economy when they retain control of their goods, selling results, system utilisation and customer satisfaction instead of selling the goods. Managing performance over time – for instance by extending the service-life of components and goods – then becomes an integral part of a highly profitable business model.

This extended performance responsibility then also demands control over the functioning of the goods. Rolls-Royce uses an in-flight monitoring system to optimise its fly-by-the-hour business model, and to match the availability of spare parts and equipment with the global position of its leased jet engines. Economic actors selling the performance of jet engines – both independent remanufacturers and OEMs – were the pioneers of a continuous monitoring approach.

Similarly, Caterpillar has built prognostic systems into its equipment that determines when a part is about to fail or maintenance is required. Caterpillar runs a worldwide supply network based on predictions supplied by its equipment to prevent prolonged break-downs.

Lockheed plans to use the same concept for its new Joint Strike Fighter (JSF) plane. As the US military adopts a new contracting approach, paying suppliers to make fighter jets available rather than to purchase them, constant monitoring and preventive maintenance become key capabilities for corporate competitiveness.

Xerox's marketing strategy of selling customer satisfaction instead of photocopiers is an early example in the capital goods sector; large Xerox equipment had its own telephone line to enable remote monitoring. Kodak and Fuji's single-use cameras, which are taken back for a quality check before re-marketing, are examples for consumer goods. These cases are driven by corporate strategy; the resulting jobs and the higher labour-input per weight ratio are a *result* of the new business model, not its driver. And the jobs do not depend on state subsidies.

> These examples are driven by corporate strategy; the resulting jobs and the higher labour-input-per-weight ratio are a *result* of the new business model, not its driver.

But governments can influence a transformation to the Lake and the Loop Economy! The long average service-life of aircraft, for instance, stems from the legal product liability of manufacturers for 18–22 years, and a fiscal depreciation period of 15 years. There is thus a strong correlation between the service-life of goods, a manufacturer's extended performance responsibility and the length of tax depreciation periods. Legislators can use longer tax depreciation and/or longer product liability periods as a policy to create jobs at home, prevent waste and boost regional economic development.

> There is a strong correlation between the service-life of goods, a manufacturer's extended performance responsibility and the length of tax depreciation periods.

The substantial reduction of CO_2 emissions of the Lake and the Loop Economy, as compared to manufacturing, could also boost service-life extension activities. Yet, countries signatory to the Kyoto Protocol have not yet even started to exploit the huge potential of CO_2-emission reductions possible through managing the existing physical assets. Together with job creation, this makes service-life extension a doubly attractive solution for industrialised countries. For details on the emission reductions, see the case studies on ICE1 Redesign and on Restoring automotive engines[8] in Section 3.4.l.

However, most of today's policy frameworks, such as the Kyoto Protocol of 1997, only give carbon credits for improvements of the linear industrial economy; reductions of CO_2-emissions in managing performance over time are excluded!

> The 1997 Kyoto Protocol only gives carbon credits for improvements of the linear industrial economy, and ignores reductions of CO_2-emissions in managing performance over time.

3.2 Maintaining performance over time: How the Lake and the Loop Economy work

Historically, regional economies based on an exploitation of local resources were the norm, supplemented by trade of goods with other regions. In the pre-Industrial Economy, main resources were agricultural produce including fish, salt and other products such as coal and iron, sometimes precious stones. In the mature Industrial Economy of the 20th century, oil, gas and electricity partly replaced coal as a main energy source, and scientific and technical knowledge and R&D were added as new locally available resources.

The Lake and the Loop Economy add existing physical assets such as goods, equipment and infrastructure as locally available resources, and proposes business models to manage and exploit these assets economically. To do this efficiently, economic actors and governments need new qualitative and quantitative statistics of the wealth of physical goods.

The Lake and the Loop Economy are two interlinked business models with different customers and different marketing approaches and intertwined with the Functional Service Economy (Chapter 2). The latter has a commercial and marketing focus, the former have a technical and organisational one.

The business models of the Lake and the Loop Economy can be applied to all product-life phases:

- production (upgradable equipment design and recycling of production waste),
- utilisation (service-life extension, more intensive use of goods and re-marketing) and
- end-of-life goods (take-back logistics, reuse of components and recycling the molecules of discarded goods).

The activity of tyre retreading can serve as an example to show the commonalities and differences between the Lake Economy and the Loop Economy, and how retreading differs from tyre manufacturing.

The main commonality is the technology, namely, the retreading process used for lorry and car tyres. Each used tyre undergoes a quality control to eliminate tyres unsuitable for retreading, and each outgoing tyre is checked to guarantee a quality product. This differs from the production of new tyres, where statistical quality control is applied. Out of a lot of 100 tyres, one is tested; if its quality passes the test, it is assumed that the other 99 are also in order. Retreads, by contrast, are tested individually for quality.

The main difference between the retreading of lorry tyres and car tyres is their economic nature as 'tools' or 'toys'.

> *Lorry tyres are 'tools' designed for intensive use and to keep life cycle costs low. They are manufactured to facilitate regrooving and retreading to maximise service-life under defined conditions (speed limits).*

Lorry tyres are retreaded in the *Lake Economy* by specialised retreaders as a service activity for lorry owners. There is no change of ownership and no transaction cost. The decision for retreading is taken by fleet managers based on considerations of adequate quality, cost versus benefit and spare parts management. Trust plays a small role as the client gets his own tyres back. The possibility of regrooving and retreading is a precondition for the tyre purchase.

Lorry tyres are retreaded several times over their service-life. Similarly, aircraft tyres, which suffer heavy wear in landing, are retreaded up to 12 times.

Some tyre manufacturers, such as the French multinational Michelin, have started selling mileage instead of lorry tyres to benefit from the longer service-life of their tyres. Manufacturers-turned-service-contractors have to rethink their corporate strategy to integrate mobile repair and service activities at the fleet managers' sites, as well as retreading as a second core activity. However, this implies a departure from the centralised high-volume production process and development of a regionalised business model for service and retreading activities, which are fundamentally different from tyre production!

> *Car tyres are 'toys' manufactured to comply with the top speed of cars, ignoring the fact that only one country worldwide, Germany, has no general speed limit!*

Car tyres are retreaded in the *Loop Economy*. At the end of their service-life, used tyres become consumer waste. Retreaders buy them from scrap dealers in competition with industry – for example, cement works – which use them as a cheap and tax-free energy source. A strategy of selectively buying the most suitable used tyres directly from the last owner is not open to retreaders. After retreading, the tyres are remarketed and compete with new tyres.

Transaction costs are thus high due to a double change in ownership. Buyers of retreaded tyres are influenced by fear and mistrust (how did the previous owner treat them?), ignorance (how safe are retreads?) and by advertisements for new tyres versus the absence of publicity for retreads.

The motivation guiding the economic actors involved is also different:

- In the Lake Economy, the lorry owner manages the stocks (fleets) of his tyres over time in order to minimise overall cost.
- In the Loop Economy, scrap merchants buy end-of-life goods (car tyre waste) and resell them to the highest bidder. They have no preference between energy recovery (incineration), material recycling (to recover rubber and steel scrap) or retreading scrap tyres into goods 'as good as new' for reuse.

These differences between the Lake Economy and Loop Economy are valid for most types of durable goods and can be shown in general

Table 3.1 Differences between the Lake Economy and the Loop Economy

Product-life phase	THE LAKE ECONOMY	THE LOOP ECONOMY	Ruling principle of product-life phases
Production	Upgradable system design	Primary recycling of production waste	100% yield
Utilisation	Reuse of goods and components	*Remanufacturing and technological upgrading of goods*	Efficiency of the smallest loop
End-of-life	Remarketing of components	Secondary recycling of mixed wastes	Zero waste
Limits	Outdated technology	Second law of thermodynamics	
Nature	*Forest, fish stocks*	*Waste is food*	*Cycles (water cycle, leaves)*

terms (Table 3.1). Further, the phenomenon of 'recyclable is not recycled' plays a role. Recyclable is a manufacurer's design characteristic; the decision if the goods are recycled (or dumped or incinerated), depends on a number of actors.

- In the Lake Economy, materials and components are chosen and goods are designed to facilitate a profitable reuse of goods and/or recycling of molecules, as there is ownership continuity.
- In the Loop Economy, materials are chosen for their technical recyclability by the manufacturer, but only recycled if the recycler can make a profit or if, for example, a deposit scheme will pay him.

The Lake Economy overlaps with the Loop Economy when it remanufactures or upgrades components that are subject to wear and tear, changes in fashion or technology or when manufacturers take back their goods at the end of their life.

3.2.1 The Lake Economy

The larger part of the Lake Economy consists of such economic actors as original equipment manufacturers (OEMs) or fleet managers in charge of a stock of goods over their full service-life (but with an emphasis on the utilisation phase). The same product may have several users over its full service-life, but normally only a single owner.

Consumers become actors of the Lake Economy if and when they keep goods over long periods of time, such as teddy bears, oldtimer cars, antique furniture and musical instruments. Nevertheless, two product groups can be distinguished in the case of consumers:

- a Stradivarius violin never dies, but
- a teddy bear hardly ever outlives its owner!

Typical capital goods of the Lake Economy are infrastructure, railway rolling stock and aircraft fleet. Typical goods in the Lake Economy are products under warranty, standard exchange systems and take-back schemes, such as computer parts, electric motors used in such equipment as washing machines and automotive components such as starter engines that suffer wear and tear.

The take-back of used or unwanted goods in order to reuse components in the production of new goods (for OEMs) or as repair spares

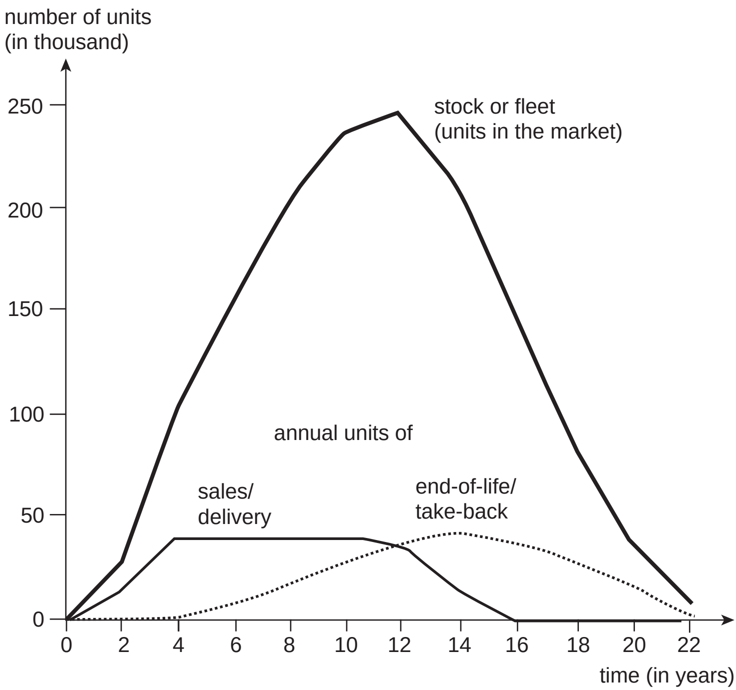

Figure 3.3 Quantitative development of the market for a durable good over its lifetime in the Lake Economy

(for fleet managers) makes sense and is economically viable in the Lake Economy, as there is a permanent and substantial overlap between production/sales, stock and take-back, as shown in Figure 3.3.

Tools in the Lake Economy to facilitate a long service-life without restricting social and technical progress are modular product design, standardised components and the availability of support services for reuse, repair and remanufacturing with technological upgrading.

The quest for an even higher efficiency has led a growing number of companies to adopt a workshop-in-the-factory approach.

- DuPont was one of the pioneers of this approach, by taking over the extended performance responsibility for the painting of car parts inside automobile manufacturers' plants.
- The French tyre manufacturer Michelin, which now sells mileage of lorry tyres instead of the tyres, has adopted a system of mobile workshops to do repairs and regrooving on the premises of the fleet managers using its tyres.
- Edwards Vacuum Ltd is a world leading specialist in the design, manufacturer and operation of vacuum pumps for general and semiconductor applications. Edwards operates like a global industrial player by locating its own remanufacturing and support facilities near its major customers. In the large plants, where even a small downtime due to loss of pumping capacity can far outweigh the cost of repairing or replacing a pump, Edwards may opt for an on-site service team.

The support services for repair and remanufacturing activities are efficient tools in the Lake Economy despite an extremely high labour-input per weight ratio. The Eiffel Tower in Paris is a perfect example. When the iron construction built in 1889 is completely repainted every seven years, 25 painters spend more than 12 months to apply 60 tonnes of paint on 250,000 square meters of iron elements. With seven million visitors annually, the Eiffel Tower is the most frequented paying attraction worldwide.

The repainting of the Eiffel Tower has a labour-input-per-weight ratio of about 0.7 manhours per kg.

3.2.2 The Loop Economy

The larger part of the Loop Economy consists of a succession of economic actors: original equipment manufacturers (OEMs), fleet managers in charge of a stock of goods, customers who have bought a product, independent remanufacturers or resource managers active at the end of a goods' service-life. The same product will pass several points of sale and have several users and owners over its service-life.

Consumers become actors of the Loop Economy if and when they trade, buy or sell used goods with other consumers. Nevertheless, two customer groups can be distinguished:

- economic actors active in the monetary Loop Economy and
- individuals preferring to trade in the informal economy (e-bay, flea markets, garage sales, fashion swaps).

In the Loop Economy, the stock of goods in the market plays a minor role, compared to the Lake Economy. The overlap between production (delivery) and take-back is limited in time and volume, especially for fashionable goods with short service-lives. In a defensive approach, manufacturers taking back used goods can disassemble the products and sell them as service parts, a strategy pursued by many computer manufacturers. OEMs can provide a service exchange system, supplying a remanufactured product in exchange for a faulty one at a reduced price.

- Bosch practised this business model for its power tools with aluminium casing.
- Sony Computer Entertainment Europe offers a remanufacured product when customers return a faulty product, to reduce the time a customer is without the product.
- Service companies taking back used goods can provide clients with out-of-production spares.
- Many remanufacturers of automotive components have always offered a service-exchange system.

In an aggressive marketing approach, the take-back of third-party used goods enables an OEM to supply out-of-production spares to clients using competitors' equipment, thus creating goodwill that later may lead to sales and an increased market share.

Loops are the key business model of the Loop Economy (see Section 3.4). To maximise financial benefits, job creation and resource

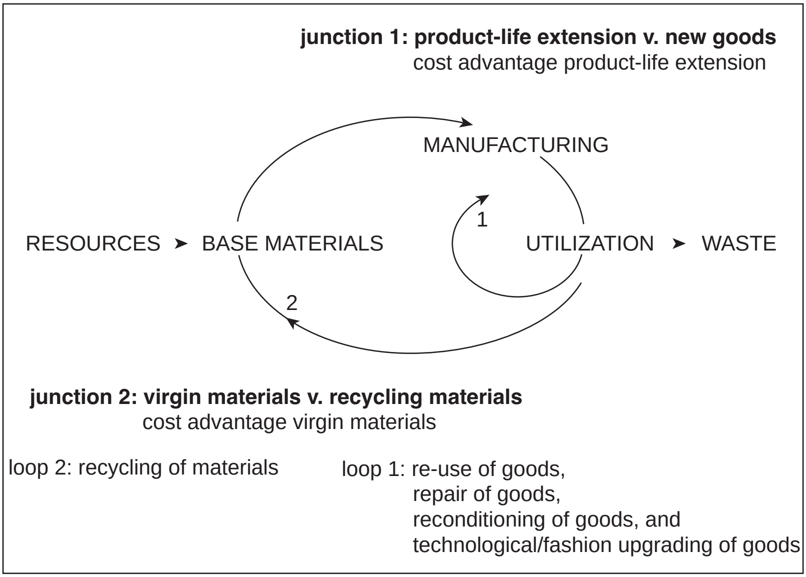

Figure 3.4 Closing the loops: A self-replenishing, more sustainable Loop Economy and the junctions between these loops and a linear economy[9]

savings, it is crucial to distinguish clearly between reusing goods and components (Loop 1) and reusing molecules (Loop 2) in Figure 3.4.

The economic opportunities of product reuse are high for components of capital goods with a long service-life, for goods of a modular system design, and for standardised modules; examples are General Electric's Medical Systems, components in equipment by Xerox and Hewlett Packard and modules such as toner and ink cartridges for computer printers.

The economic feasibility of material recycling, to reuse molecules, depends mainly on the market value of the materials and the difference between recycling costs and the price of new materials.

The two loops are fundamentally different with regard to their economic feasibility.

Loop 1:

- Reusing and remarketing goods means a slowdown in the flow of materials and goods through the economy, from raw material production to recycling or disposal. It also means waste prevention in utilisation, production, distribution and packaging as well as in recycling activities.

- Reuse and remarketing saves about 75 per cent of the energy embodied in a product. Rising energy prices thus increase the economic advantage of product reuse versus new goods.
- Economically, reused and remanufactured goods have a cost advantage of about one-third over new goods at Junction 1. This advantage is even higher for goods that are not mass-produced, as shown in the example of remanufacturing the first generation of German high-speed trains (ICE 1 redesign).

Loop 2:

- Material recycling means closing the loop between end-of-life waste and basic material production. Recycling does not influence the speed of the flow of materials or goods through the economy, which is similar to that of the Industrial Economy.
- Energy savings in material recycling vary widely among different materials. Recycling aluminium needs only five per cent of the original energy input, but recycling concrete may need more energy than producing new cement.
- In industrialised countries with high labour costs, secondary resources at Junction 2 can be more expensive than virgin resources due to the labour input involved in collection and sorting waste materials.
- However, in emerging economies and situations of scarcity, the unavailability or high costs of virgin materials in connection with low labour costs give secondary local resources a strong economic advantage at Junction 2.

3.2.3 The principles behind the Lake and the Loop Economy

Several issues can be observed in the Lake and the Loop Economy that explain why their productivity and competitiveness cannot be measured with the metrics of the Industrial Economy. These issues concern:

- axioms,
- manpower,
- 'caring',
- quality,
- '*pars pro toto*' and
- component standardisation.

3.2.3.1 The issue of axioms

Both the Lake and the Loop Economy are based on a number of axioms, facts that can be shown in practice but only with difficulty in theory, opening opportunities for research.

- Time is money! A longer service-life reduces overall life cycle costs, but statistical information to prove it is lacking. Many fleet managers, such as railways and airlines, keep data only from one major overhaul to the next, true to the remanufacturing motto 'as good as new'. A full life cycle analysis (LCA) is thus difficult to do.
- Loops have no beginning and no end! An economic concept of 'preservation value' to measure the efficiency of the management of physical assets still needs to be developed.
- The smaller the loop, the more profitable it is! The effectiveness of these loops is greatly enhanced by keeping them as small as possible, a truth already known to our forefathers who coined the phrase:

  Do not repair what is not broken, do not remanufacture something that can be repaired, do not recycle a product that can be remanufactured.

This 'inertia principle' applies to products and components: replace or treat only the smallest possible part in order to maintain the existing economic value of the technical system.

3.2.3.2 The manpower issue in reusing goods

First, some basic figures: roughly three-quarters of all industrial energy consumption is associated with the extraction or production of basic materials like steel and cement, while only about one-quarter is used to transform materials into such finished goods as machines or buildings. The converse is true of labour: about three times as much is being used in the conversion of materials to finished products as is required in the production of basic materials.

In a building, 80 per cent of the energy used in production is embodied in the structure (the 'grey' energy). The same is true for infrastructure and heavy equipment, such as railway rolling stock. Renovating a building or remanufacturing a train needs nearly as much manpower as building a new one, yet conserves 80 per cent of the original investment in materials and energy.

An increase in transformation-type industries, such as remanufacturing, thus corresponds to substituting labour for energy. Skilled and experienced craftsmen are needed in repair and remanufacturing activities, which can be undertaken in comparatively small workshops, scattered widely throughout the country wherever there are items in need of renovation and customers for them, as is still the case for workshops to repair cars and buildings. These enterprises can be located in any rural or urban area with high unemployment, making remanufacturing a doubly attractive proposition for job creation.

The Lake and the Loop Economy creates jobs at home by shifting jobs and skills from the resource throughput of global manufacturing to the local management of existing physical assets.

The Lake and the Loop Economy shift jobs and skills from the resource throughput of global manufacturing to the local management of existing physical assets.

Compared to manufacturing, higher skills are needed in the Lake and the Loop Economy to disassemble complex technical systems and to determine the quality 'as is' as well as the remaining service-life of each component. As these skills are not required in manufacturing, workers must be trained and new fields of research and economic activity created.[10]

3.2.3.3 The issue of 'caring' for maintaining performance over time

Reusing goods and service-life extension implies a new relationship with time: utilisation as an open-ended time factor!

The Industrial Revolution overcame the problem of scarcity of goods, making it possible to shift current attention from production optimisation and production knowledge to services and knowledge development focusing on system optimisation and on management of existing wealth, including labour and skills. This shift demands an understanding of the underlying principle of many service jobs, 'caring' and 'sharing', which are soft words often relating to activities with invisible results. Once a sick person has recovered, the sickness and the healing process (or service) are no longer visible!

Once a sick person has recovered, the sickness and the healing process (or services) are no longer visible!

Caring also implies an awareness and motivation over time: servicing and repairing the same car regularly, or cooking the family meal every day, is periodic work that leaves no trace and is only too often taken for granted. The fact that the car keeps running is credited to the engineer who designed it, at least in industrialised countries, rather than to the anonymous mechanic in a workshop who services it regularly. In the long run, this consumer attitude tends to influence negatively the food quality as well as the quality of the car service, and thus its operation.[11]

Caring has to be rewarded. When Caterpillar, the US heavy equipment company, started to take back diesel engines for remanufacturing, it sold the remanufactured engines at a large discount. As the used engines had a status of waste, they were often returned in battered condition. When Caterpillar changed its strategy to buy the used engines back for a price that depended on its condition and completeness, the quality of the used engines significantly improved. The remanufactured engines are now sold with the same guarantees and for the same price as new ones.

3.2.3.4 The quality issue for maintaining performance over time

In some cases, the Lake and the Loop Economy can achieve a higher quality than the manufacturing process of new goods. Exploiting these opportunities results in increased competitiveness with a greatly reduced resource throughput, but needs an understanding of the differences in the business models applied. The superior product quality in remanufacturing is achieved through superior technology or the virtuous effect of time.

- In rail grinding (the in-situ ‘milling’ of worn railway rails by mobile units fixed under special trains), the higher quality is due to a high precision remanufacturing process, compared to the hot rolling process in steel mills.
- In the retreading of Green Diamond car tyres, the superior quality is due to the use of special treads – the tyre component in contact with the road surface.
- In the resterilisation of disposable plastic tubing in hospitals, the higher quality is a result of the sterilisation process, which is different from the manufacturing process.
- In used electronic components, the higher quality is the result of the component having gone through and survived the burn-in period of the previous utilisation.

- In combustion engines, the better quality is due to the fact that tensions inside new engine blocks disappear through utilisation. The resulting deformations of engine blocks are permanently eliminated in remanufacturing.
- In structural timber and concrete structures, improvements are due to a natural hardening of the material when protected against humidity and corrosive agents.

3.2.3.5 The 'pars pro toto' issue in reusing goods

The Lake and the Loop Economy introduces new multiplicators such as the '*pars pro toto*' issue (one part saves the whole), which is described in the following example of remanufacturing a car engine.

The sustainability impacts of remanufacturing a car engine are job creation, resource savings and financial savings! The key is to look at the full picture, as shown in the following example of a 1969 Jaguar XJ6 2.8 litre that weighs 1640 kg, of which the engine accounts for 220 kg (Figure 3.5).

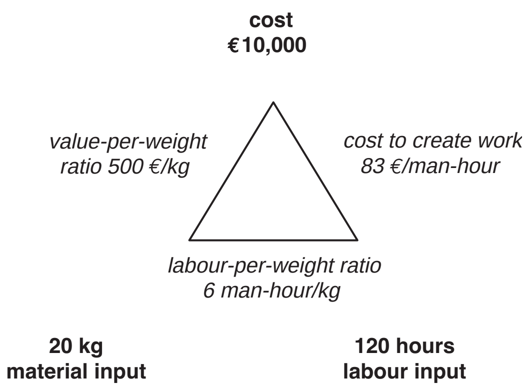

Figure 3.5 Factor inputs necessary to remanufacture a car engine

Remanufacturing the engine necessitates new parts of a total weight of about 20 kg (pistons, sleeves, valves, engine chains), plus 120 hours of work, and costs about €10,000.[12] The value-per-weight ratio[13] (€10,000 divided by 20 kg) is €500/kg. The labour-input per weight ratio, man-hours/kg of resources consumed, is 6 man-hour/kg.

The remanufacturing of a Jaguar XJ6 engine has a value-per-weight ratio of €500/kg and a labour-input-per-weight ratio of 6 man-hour/kg.

Yet remanufacturing an engine is not an aim in itself but a means to extend the service-life of the entire automobile. One part saves the whole, or '*pars pro toto*'! An input of 20 kg of new material enables conserving an existing wealth of 1640 kg, giving the car a new service-life.

The real economic impact is therefore found by comparing the factor inputs necessary to remanufacture the engine, with those necessary to manufacture an equivalent new car to replace the old one. This gives the following metrics:

- **Value-per-weight**. The value-per-weight ratio (€10,000 divided by 20 kg) of €500/kg is 27 times that of a new car equal to €18/kg (€30,000 divided by 1640 kg).

  The *higher* the value-per-weight ratio is, the more wealth is created per kilogram of material consumed (see Chapter 1).

The value-per-weight ratio in remanufacturing is 27 times that of manufacturing a new car.

- **Labour-input per weight.** The labour-input per weight ratio of 6 man-hour/kg material input for remanufacturing is 240 times that of a new car (0.024 man-hour/kg).[14] The reverse material-input-per-man-hour ratio in remanufacturing (0.17 kg/man-hour) is 240 times smaller than in manufacturing a new car (40 kg/man-hour).

  The *higher* the labour-input per weight ratio is, the more man-hours of work are created per kilogramme of material consumed.

The labour-input per weight ratio[15] in remanufacturing is 240 times that of a new car.

These metrics are summarised in Figure 3.6.

The labour productivity of the Industrial Economy is put on its head in the Lake and the Loop Economy, as their objective is to substitute renewable resources – including manpower – for non-renewable ones. But despite the lower labour productivity, the remanufacturing cost is a fraction of the cost of a new car.

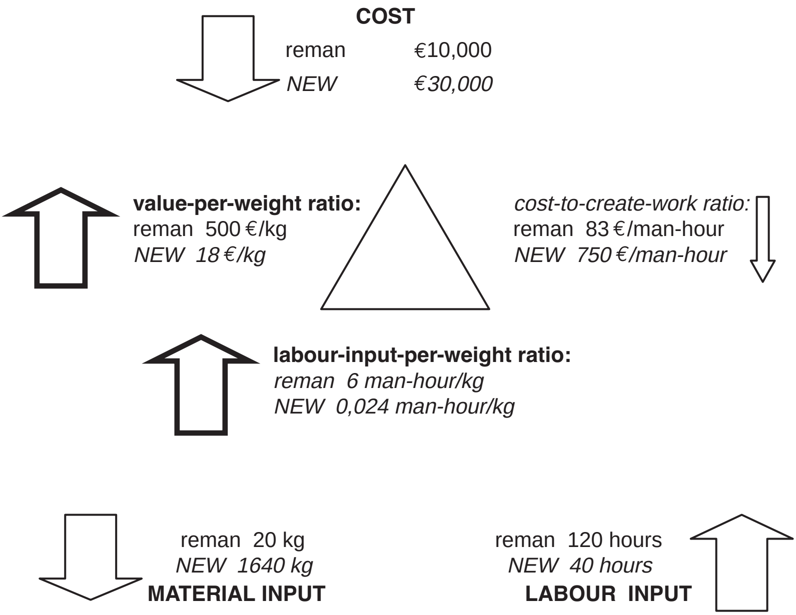

Figure 3.6 Comparing factor input ratios for remanufacturing components versus new production

Despite the lower labour productivity, the remanufacturing cost is a fraction of the cost of a new car.

In the metrics of the Industrial Economy, remanufacturing is equivalent to one fewer car sold and hence a reduced sales volume at the point of sale as well as a reduced economy of scale.

3.2.3.6 The issue of component standardisation

The standardisation of components offers numerous advantages in the manufacturing, utilisation and end-of-life phases of goods.

In manufacturing, component standardisation makes production cheaper and easier by avoiding duplication of efforts in design, reducing the quality control necessary in production and handling costs and preventing situations of both surplus spares and out-of-production service parts. Furthermore, component standardisation speeds up the time to market of goods and can open up saturated markets. (An example is the standardised Airbus flight deck that reduced annual cockpit crew costs by up to US$500,000 per aircraft.) It also improves product information to customers.

In utilisation, component standardisation greatly reduces the operating costs (such as training, stock and spare parts management); facilitates repairs and reduces their cost while simultaneously lowering the risk for potential mistakes in maintenance; encourages inter-operations on a systems level and enables adaptations to changing needs, including technological upgrading of goods and systems.

At a goods' end-of-life, component standardisation opens the market for a profitable remarketing of components and provides an economy of scale in remanufacturing activities. It also facilitates cannibalising parts and helps to avoid the situation of out-of-production service parts and thus the need for 'storob' (stores robbed) strategies.

Perhaps the perfect example of the advantages of component standardisation is the shipping container, which was invented in the mid-1950s by Malcolm Purcell McLean, a US trucking entrepreneur, to make transport more efficient. He began by transforming a used US Navy tanker into the first container vessel to demonstrate the inter-modal advantages of the 'container' concept, which had its breakthrough when it was adopted by the US Army during the Viet Nam War.

As the dimensions of the containers were based on US trucks, they could not be used on Asian and European roads. Worldwide adoption came only in the late 1960s, when the Geneva-based International Standardisation Organisation (ISO) published a worldwide standard for containers with new dimensions, reinforced corners to allow stacking and a twist-lock mechanism to connect the stacked containers. These new elements are 8 ft wide, 8 ft 6 inches high and 20 or 40 ft long.

In 2006, 70 per cent of all goods shipped worldwide were transported in ISO-standard containers. The high speed in changing from one transport system to another, the ease of tracking containers and the lower risks to the contents during transport are among the advantages of container shipping, which has also fundamentally changed the design of container vessels and the layout and management of port facilities.

3.3 The Lake Economy – Optimising the management of physical assets

The Lake Economy uses a business model of continued ownership (fleet management) equal to zero transaction costs, for example, *repairing* *goods, selling performance*. This gives it a strong economic advantage over the Loop Economy.

3.3.1 The shift from consumption to utilisation

The Lake Economy overlaps to some extent with the Functional Service Economy described in Chapter 2. In both cases, the vision is of an economic optimisation in an open-ended service-life perspective. Understanding the 'factor time' thus becomes a new factor of competitiveness, with fleet managers of durable goods as key economic actors.

But the Lake Economy and the Functional Service Economy differ in several ways.

- The Lake Economy includes manufacturers and fleet managers of durable goods outside the private sector but who as major actors are often drivers of technological innovation and progress, including:
  - state entities, such as the armed forces; public works; hospitals, museums and (national) heritage monuments,
  - academic and research institutions and
  - private entities and collectors of antiques, vintage vehicles, house owners and collectibles such as Stradivarius violins and teddy bears.
- The Functional Service Economy has a broader field of action. Its economic actors use efficiency and sufficiency strategies to exploit all types of goods, namely consumption, dissipative, catalytic and durable goods, while the Lake Economy focuses on durable goods and molecules.

Common to all business models of the Performance Economy is their cradle-to-cradle approach for goods, components and molecules.

Common to the Lake Economy and the Functional Service Economy of Chapter 2 is the focus on the efficient utilisation of goods, which opens up a number of profitable opportunities for innovative products and services that are of no interest to actors of the traditional linear Industrial Economy (letters refer to Figure 3.7):

- A long-life products and systems,
- M multifunctional goods,
- S system solutions,
- V commercial strategies, such as selling performance instead of goods, remarketing of used goods, shared utilisation of goods and using tools to determine the remaining service-life of goods.

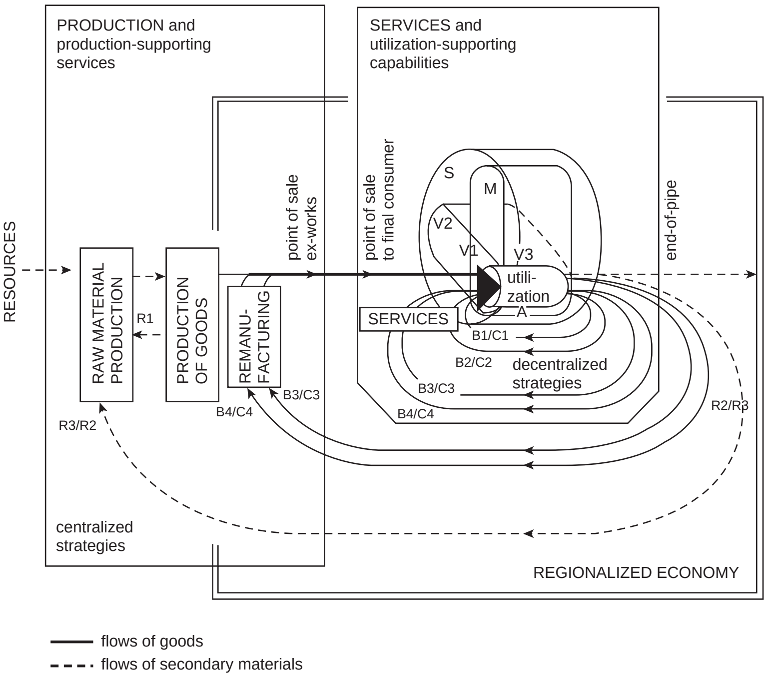

Figure 3.7 New strategies emerging from a utilisation focus for durable goods

This focus on the utilisation of goods (instead of production) also means that the *utilisation value* replaces the exchange value of the Industrial Economy as the central notion of economic value for actors of the Lake Economy. It also questions related concepts of the Industrial Economy, such as value depreciation over time in liability compensation, and is supported by a priority of *patrimony over dowry* as the basis of societal law.[16]

The optimisation of the product-life of goods that are part of a system – such as public transport, fisheries, forests or rental car fleet – demands an understanding of the quality and vulnerability of complex utilisation systems. For technical systems, the capability of continuously monitoring the qualitative 'state of the art' not only of the system as a whole but of every key component – such as an aircraft engine – is equally vital. The combination of understanding complex systems and quality monitoring results in minimised costs and maximised system availability. Redundancy and resilience, or 'slack',[17] further increases system efficiency, whereas in the Industrial Economy it reduces productivity.

3.3.1.1 Options of optimising utilisation

Service-life extension loops in the Lake Economy – and their typical goods – can be grouped as follows:

A. *Long-life goods*: Philips induction lamp, Ecosys printer.
B. *Product-life extension of goods*:
   B1. reuse: glass bottles,
   B2. repair: car windshields, punctured tyres,
   B3. remanufacture: retreaded tyres, renovated buildings, railway rolling stock,
   B4. technology upgrading: Xerox copiers, mainframe computers, ICE1 trains, insulating the envelope of exiting buildings.
C. *Product-life extension of components:*
   C1. reuse: refilling printer cartridges, reusing roof tiles,
   C2. repair: welding of broken machine parts, repairing broken windows,
   C3. remanufacture: engines and automotive parts,
   C4. technology upgrading: adapting combustion engines to meet new noise and emission standards, replacing old windows with high insulation windows.
D. *Remarketing and new products from waste* (product-life extension into new markets).

Some economists and engineers regard the Lake Economy as a second-class activity: economists because the management of physical assets is not part of the linear Industrial (or 'river') Economy that is considered to be the main producer of economic wealth; and engineers because service-life extension is seen as restraining technological progress.

Yet, the US' NASA space shuttle programme put to rest the notion that reusable goods are second-class technology already 30 years ago. Intelligent companies in many business areas have realised that the technological upgrading of goods and systems is the fastest way to market new innovative components of existing technical systems, witness the new jet engines for ageing aircraft.

Critics also overlook the technical innovation potential of the Lake Economy, including:

- the conception and design of goods as systems of functional modules;
- industrial design for component reuse and remanufacturing;
- mobile non-destructive testing equipment to measure quality changes over time;

- innovative remanufacturing processes for components and goods;
- operation-control components that protect goods against destructive abuse during utilisation;
- methods of optimising the service- and product-life extension activities themselves.

Further innovations include the development of:

- New methods for the life cycle cost optimisation of systems, goods and components.
- New technologies to optimise utilisation, such as self-curing spares. Creating new components that are fault-tolerant, self-curing or self-protecting against premature deterioration or willful misuse must be a priority in the utilisation optimisation of any system. The idea of 'self-maintenance' has been researched mainly in Japan.[18] Self-curing spares are components in, for example, a friction-reducing system that injects more lubricant when the temperature rises in the critical area. Tribology, invented in Vienna many decades ago, has been reborn in Japan.
- New processes to facilitate certain tasks in product-life extension, such as nuisance-free cleaning processes, spareless repair techniques, methods to refloat sunken objects and component standardisation across product lines. Xerox, a US pioneer of the last concept, calls it the commonality principle of components.
- New non-interruptive and spare-less repair methods.
- New products, such as non-production repair spares and zero-maintenance components.
- Instruments for quality monitoring, system self-protection, non-destructive testing and fault-finding diagnoses in complex operating systems.

The Lake Economy also initiates commercial and organisational innovations. An OECD report on product durability and product-life extension[19] concluded that the unavailability of spares and lack of markets for second-hand goods are the major culprits for premature waste through 'product-life abortions' long before the end of the technical life.

The unavailability of spare parts touches on an aspect of intellectual property rights dating from the Industrial Revolution. Spare parts are, in many countries, still regarded as patentable objects that cannot be copied for a certain number of years. While this protection has been reduced to one year in Italy and the UK and to five years in some other countries, France still maintains that a car, a work of art, should be protected for 50 years against illegal copying. The creation of a free market for spare parts would certainly result in reduced prices and an increase in regional repair activities.

An initiative by the General Insurance Association of Japan calling for reuse of car parts can be regarded as another step in this direction. The availability of non-production spares to simplify and lower the costs of repairs is a third approach to increase this potential (see Section 3.3.8 for an example of a repair research centre in the UK).

3.3.2 The Lake Economy of infrastructure and durables

Many experts have already realised that 'producing' a bridge or a sewer system is important if there are few bridges or sewers. In a near-saturated market (as is the case in most industrialised countries for infrastructure and durable goods), the husbandry of resources through maintenance activities, the improvement of existing systems towards easier and cheaper utilisation and their adaptation to changes in technology and demand become the new frontier.

However, few universities worldwide train operation and maintenance engineers to the same level of education as production-oriented engineers, or undertake R&D in this area.

In some cities, 50 per cent or more of the water that is treated and put into the distribution network is 'unaccounted for'; there are cases, not only in Third World countries, where reconditioning and proper maintenance could, through loss prevention, provide as much additional water as expensive new facilities.

> '*Maintenance itself must be considered a development priority*', said Michael Cohen[20] 20 years ago. '*The creation of assets that are allowed to deteriorate represents a serious undermining of the development process*'.

This also has repercussions on manufacturing. The ideal quality curve in the Lake Economy is shown in Figure 3.8. All products passing the factory gate should be as perfect as possible and not subject to breakdowns and problems during the use phase.

The actual curve is determined by the criterion of the shortest time to market, followed by corrections during use (product recalls, Microsoft's updates).

Optimising the utilisation of such equipment as marine diesel engines over many decades leads to the development of equipment according

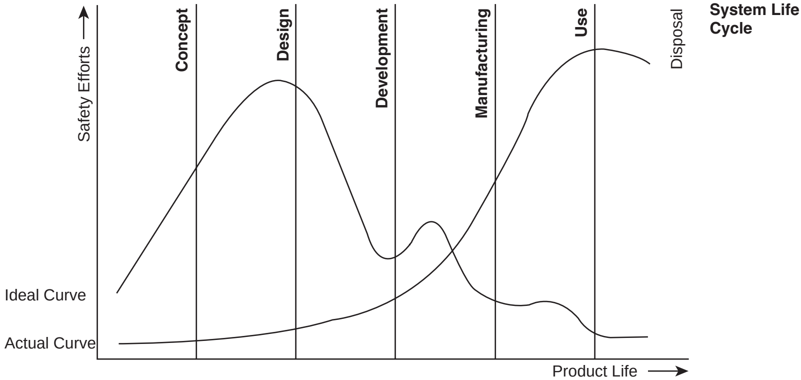

Figure 3.8 Safety and quality efforts during consecutive product-life phases

to the main criteria of ship owners: availability and reliability, low repair costs and planned maintenance schedules.

Figure 3.9 shows the economic impact of different degrees of maintenance on repair costs and reliability. Fleet managers of plants, vessels and vehicles have to decide on the risk management issue involved; depending on the use of equipment, unplanned shutdowns are acceptable or the higher costs for preventive maintenance are justified. Fleet managers can use this data to build a know-how that can be adapted for each product or system.

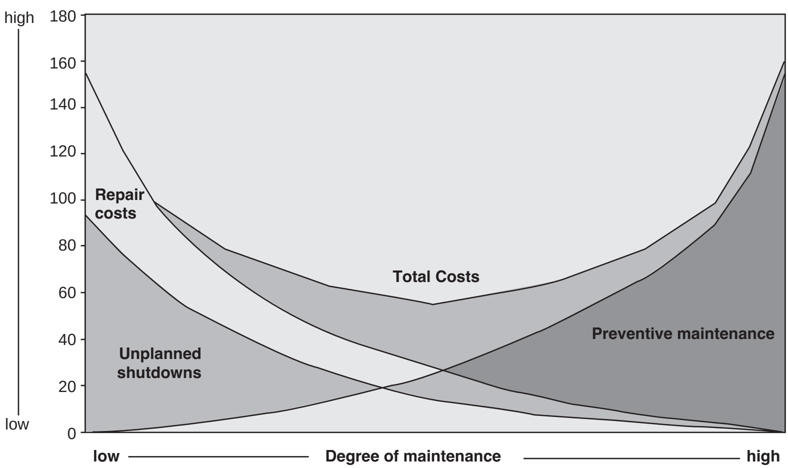

Figure 3.9 Total costs of operating equipment according to the degree of maintenance

As most infrastructure has a long life, technological upgrading of systems by replacing key components is an integral part of well managed systems. An example is the technological upgrading of turbines in hydroelectric power stations to increase the electricity production of existing installations. In 1999, the upgrading of the four turbines at the Birsfelden hydroelectric plant, situated on the Rhine River in Switzerland, increased the annual power production by 4.2 per cent, while leaving most of the plant untouched.

3.3.3 Fleet managers of the Lake Economy

Fleet managers are manufacturers and/or systems operators responsible for infrastructure or fleets of durable goods. They often have in-house remanufacturing capabilities as well as extended know-how in risk engineering and efficient maintenance.

Fleet managers also have the possibility to apply technological upgrading at a systems level. The remanufacturing of the first generation of German high-speed trains (see the ICE1 redesign example in Section 3.3.3.2) included equipping the remanufactured trains with new seats, each of which provides power and Internet connections to enable the easy use of portable computers. As the new seats are smaller – as in aircraft – seating capacity has been substantially increased, and so has potential income.

Major types of actors are:

- fleet managers outside the market economy, such as armed forces,
- fleet managers without manufacturing activities, such as airlines and hospitals,
- original equipment manufacturers (OEMs) as cradle-to-cradle innovators in the Lake Economy,
- independent economic actors in the Lake Economy and
- academic and research institutions.

3.3.3.1 Fleet managers outside the market economy

The pioneers and champions of this type of fleet manager include the following:

- **Landmarks: Golden Gate Bridge, San Francisco, USA.** The Golden Gate Bridge has few original parts other than the pillars and the main cables. The components of the bridge deck are periodically checked, repaired and remanufactured to keep the landmark safe and alive. A workshop near the bridge is responsible for fighting corrosion and wear on the bridge deck year round.

This approach is not different from that used by the old construction huts (*Bauhütten)* which have been used to guarantee the upkeep of medieval cathedrals for centuries. Teams of masons spend a lifetime repairing the stonework to check decay and prevent the eventual collapse of the landmark buildings and will continue to do so as long as the cathedrals exist.

- **Steam engines and electricity generators.** Steam engines and electricity generators have a service-life of up to 100 years. Many steam engines dating from the early 20th century are still in use: in Africa to pump water and on most Swiss lakes to power paddle steamers. The superb steam locomotives running in South Africa since the 1950s were technologically updated in the 1980s by the British engineer David Wardale. Their performance was increased by one third, while coal and water consumption was reduced by a third. In addition, steam engines can run on biomass and agricultural waste without converting them to biofuels. New Steam, a Swiss company, produces new steam engines for mountain trains that produce fewer emissions than modern diesel engines.

  Some electricity generators and water turbines have been in use in Swiss hydroelectric power stations for 75 years. The Handeck I power station, for instance, completed in 1932, still relies on its original turbines and generators, which are periodically overhauled and are now governed by modern computer systems. The hydraulic, mechanical, electrical and electronic systems are adapted regularly to the latest technology.
- **Innovation champions: armed forces.** The armed forces have been a major driver of innovation in a number of areas and technologies of the Lake Economy, with many of their inventions later adapted for civil use. In the 20th century, the US Armed Forces have often been in the lead, lately by developing mobile repair workshops for critical battle components. This brings up the question of global competitiveness: Is the European trend towards disarmament and a dissolution of the armed forces one reason why Continental Europe is lagging behind the US in development of innovative technologies for the Lake Economy? Japan may be different, as culture and traditions are strong drivers of keeping existing wealth, including temples, shipshape.
- **US Air Force's activated diffusion bonding.** The USAF has developed a number of spare-less-repair technologies, such as the activated diffusion bonding technique to repair damaged turbine blades of jet engines. With this method, new edges can be bonded on worn-out

surfaces of turbine airfoils, thus eliminating the need for numerous spares as turbine blades differ for each engine type.

- **Keeping the B52 bomber fleet in the air.** Since the B52's maiden flight in 1952, military demand, mainly by the Strategic Air Command (SAC), for these aircraft increased during the Cold War and then diminished when the military threats changed after the fall of the Berlin Wall.

  Yet after over 50 years of service, the B52 is still flying, also thanks to cannibalisation. Aircraft no longer needed are not scrapped but parked on an airfield in the dry Arizona desert, to feed parts to their flying sisters.

  Cannibalising a fleet of similar goods makes sense when demand decreases. It is possibly the most economic and resource-efficient strategy to fight the problem of out-of-production spares.
- **Mobile spare-less-repair units for fleet managers.** The unavailability of vital spare parts can be disastrous in emergency aid or on a combat mission on the other side of the globe. A better solution to flying in spare parts would be to produce them on the spot, using mobile repair centres that stock the digital data of the spares and are equipped with CNC equipment to produce them on demand. Data can be transmitted electronically and include up-to-date improvements.

  The US Army is studying a solution of mobile spare-less-repair centres. If commercialised, mobile repair centres could enable small- and medium-sized enterprises (SMEs) to become global service managers of their goods by providing support services to a network of local partners.

  Michelin, the French tyre manufacturer, has developed mobile repair units within its fleet management business model (described in Section 2.4.3.2).

  In the absence of spares, the only alternative left is sometimes the 'storob' (stores robbed) strategy of the UK's Royal Navy, described below.
- **The US Navy.** Periodic maintenance is one way to control system-inherent uncertainty. The US Navy uses the Service Life Extension Programme (SLEP), a two-year complete overhaul and upgrading procedure to extend the life of its major vessels, including nuclear-powered aircraft carriers, by 10–15 years. Such maintenance of a complex system has to be equally or even more sophisticated than its original manufacturing.

  Product-life extension activities can have a vital advantage in speed when compared to manufacturing. Who remembers today that all but two of the US ships sunk by Japanese aircraft at Pearl Harbour were refloated, overhauled and re-commissioned within a short period of time? The building of new ships would have taken a multiple of the time and required a shipyard capacity that was non-existent.

Mothballing surplus naval vessels in peacetime provides the redundancy needed in times of emergency at short notice.

- **The steamship Skibladner** on Lake Mjosa in Norway has been refloated several times. The ship was first commissioned in 1856 and today is the oldest steamship in operation. The ship has sunk several times under heavy snow loads at its winter mooring, and has been refloated and remanufactured on site every time because the transport of a new ship from the next shipyard in Sweden is economically not feasible. Without this service-life extension, the inhabitants around the lake would no longer have a ship to transport goods and passengers.

  A similar story also lies behind the steamship on Lake Victoria that became world famous through the movie 'The African Queen'.
- **NASA's space shuttle programme.** It is vital to recall that the maintenance of a complex system has to be equally (or even more) sophisticated as was its original manufacturing! The NASA space-shuttle programme finally put to rest the erroneous notion that reconditioning activities and reusable goods are associated with second-class technology or less-than-best solutions. It has on the contrary shown that such approaches will provide fresh technological and R&D impetus.

  Tragically, the need for the highest expert skills and judgement in maintenance and 'routine' rebuilding operations had been underestimated, leading to maintenance problems and finally to the explosion of the 'Challenger' on 28 June 1986.

  After the decommissioning of its space shuttle fleet in 2010, NASA will rely exclusively on buying performance services instead of hardware (see details of this strategy in Section 2.4.3.2).
- **'Storob' pioneer Royal Navy.** 'The Royal Navy is forced to "cannibalise" warships in a desperate attempt to keep Britain's fighting fleet at sea', defence chiefs have admitted. The practice of plundering one ship for spares to re-equip another is so widespread in the Royal Navy that it is officially known as 'storob', a contraction of the phrase 'stores robbed'.

  The dilemma arose in 2000 when the Royal Navy faced unprecedented operational demand, combined with a shortage of expensive spare parts for equipment, including radar and weapons systems.

Due to financial constraints, the Royal Navy could hold only a small stock of parts to ensure that the fleet would be serviceable under normal operating conditions, conditions it has not faced since the invasion of Afghanistan in 2001.

In 2004, for example, Campbeltown, a Broadsword-class Type 22 frigate, developed a problem with its air-defence missile tracking system. The ship was allowed to remain at sea in home waters where the air threat against Britain was regarded as low. A few weeks later, however, Campbeltown's captain received orders to sail to the Gulf area where the air threat, mainly from Iran, was considerably higher. But, before its departure, spares had to be reprieved from another ship.

The removal of a ship's fitted equipment or parts of it – storob – is normally used as a last resort to meet high-readiness operational commitments when other sources cannot provide the demanded items. Performance-based logistics (PBL), the Defence Industry's version of buying performance described in Chapter 2, will enable the UK Ministry of Defence to avoid the unavailability of service parts for out-of-production weapon systems in the future.

- **Innovation pioneers: Upgrading the Junkers Ju 52 of the Swiss Air Force.** A team of retired Swiss Air Force engineers converted the engines of the last squadron of Junkers Ju 52 aircraft to lead-free gasoline. This only surviving squadron of Ju 52s is in great demand from directors of films on World War II. The technical challenge of converting the engines was taken up by the Swiss engineers following little interest from car engine manufacturers.

3.3.3.2 Fleet managers without manufacturing activities

The pioneers and economic champions of dedicated fleet managers without manufacturing activities include the following:

- **Railway companies.** Railway companies manage a system with many components of varying service-lives. Parts of the track, with tunnels and bridges, may have remained unchanged since built over a century ago. Rolling stock – including engines, wagons and carriages – has a service-life of up to 50 years. Signalling equipment needs periodic technological upgrading, while rails and wheels may have to be remanufactured every year.

  Railways are part of the Functional Service Economy, selling the utilisation of their system to passengers as a logistics service to transport people and goods from A to B for a given price.

Periodically, railway companies have to choose between replacing ageing trains, keeping them running with increasing maintenance or re-designing their interior to modern standards. The impact of such a re-design of the first generation of the ICE1 high-speed trains in Germany is described below.

The 1956 first generation of Japanese Shinkansen trains were decommissioned in 2000, after more than 40 years of service. The service-life extension methods applied by the Japanese railway companies from 1956 to 2000 are unknown to the author.

- **Re-design: Remanufacturing of the German ICE1 high-speed trains.** A normal railway carriage has a service-life of 30 years, during which it travels about 15 million kilometres, or 375 times around the globe. Due to their higher speed and intensive use, the German ICE1 high-speed trains travelled the same distance in 15 years. In 2005, the 59 trains, each with 12 carriages and two locomotives, began a re-design process. This included a complete overhaul (remanufacturing) to give the trains a second service-life of 15 years and a new design of the interior, with modern seats to achieve a higher productivity due to more passenger seats per carriage. Re-design also included a technological upgrading of the trains, with each seat now equipped with individual power outlets and Internet connection.

  At any time, two trains were re-designed in parallel during a five-week period. In each train, 12,000 components were dismantled, cleaned, repaired, remanufactured or discarded. The material and embodied energy preserved in each 25-tonne carriage was over 80 per cent, while for the two locomotives, almost 100 per cent of material and embodied energy were preserved. This amounts to a preservation of over 300 tonnes of steel and its embodied energy and CO_2 for each train, or a total of 16,500 tonnes of steel and 1180 tonnes of copper, and the prevention of 35,000 tonnes of CO_2 emissions and 500,000 tonnes of mining waste (*Rucksäcke*).

> In total, 16,500 tonnes of steel, 1180 tonnes of copper were preserved, preventing 35,000 tonnes of CO_2 emissions and 500,000 tonnes of mining waste.

The €3 million cost of the re-design per train was a fraction of the €25 million that each new train would have cost. In addition, the ICE1 re-design saves social costs of €1 million on a global level, according to the Stern report.

The re-design was performed by 240 of the 320 workers at its Nuremberg railway workshop over more than three years. The first re-designed ICE1 left the workshop in autumn 2005; the last rolled off the line in early 2009.

- **Lufthansa Technik, SR Technics.** For safety reasons, aircraft and their key components must be overhauled regularly. The remanufacturing of engines depends on the number of hours of flight and the noise level, whereas the D-check of the aircraft fuselage depends on the number of take offs, landings and flight hours.

  The new business model of the jet engine manufacturers, selling hours of flying instead of turbines, will lead to an in-sourcing of remanufacturing services at the detriment of independent service companies.

  The general overhaul of the aircraft is called D-check and consists of a complete stripping of the interior and the paint work of the fuselage in order to detect any signs of wear and tear. It will continue to be done by airlines or service companies.

  Airlines that perform these activities themselves are among the technology leaders of the Functional Service Economy; leading the pack are the technical departments of the German carrier Lufthansa and the (former) Swiss Airline.

  An operation and maintenance process developed by Lufthansa Technik in its Hamburg workshop is used to strip the paint off aircraft by using water at high pressure in a closed loop. The water collected underneath the aircraft is filtered and reused; the old paint caught in the filter is disposed off as special waste.
- **Korean Air: Converting a passenger jumbo into a cargo jet.** Due to a shift in demand, in 2007 Korean Air transformed a Boeing B747-400SF passenger jumbo jet into its cargo version. Buying a new B747-400F jet would have cost US$150 million, while the remanufacturing cost was US$30 million, or 80 per cent cheaper than an equivalent new jet. The maximum take-off load of the remanufactured cargo jet is the same as that of a new one, while the maximum payload is 115 tons (versus 117 for the new jet) and maximum range is 7593 km (versus 8241). The big difference is thus the price.

> The remanufacturing was 80 per cent cheaper than an equivalent new jet.

- **Hospitals reusing disposable dialysers.** In 1990, Dr Kiss at the Cantonal Hospital at Liestal, near Basel, Switzerland, developed and built equipment to resterilise dialysers used in artificial kidneys up to five times. The resterilisation is a three-step process: chemical, natron acid and water purified by reversed osmosis. In Switzerland, 3000 out of seven million inhabitants require three weekly treatments for survival. As new dialysers cost €30 a piece, and resterilisation costs €3, the reuse enables a considerable reduction in treatment costs, saving about €4000 annually per patient.

New dialysers cost €30 a piece, resterilisation costs €3.

In some countries, such as Poland and the USA, resterilisation is a standard procedure to reduce health costs. In both countries, dialyser manufacturers also sell resterilisation equipment. Resterilisation as an outside service is offered by both third parties and dialyser manufacturers, such as the German Fresenius Medical Care, in countries subject to a strong competition, for instance in the USA.

3.3.3.3 OEMs as innovators in the Lake Economy

Only OEMs in the Lake Economy can optimise the full product-life of goods in a cradle-to-cradle approach, from design to manufacture, performance in utilisation and take-back of the goods for re-use, under condition that they retain ownership and internalise the costs of risk and waste.

Among the pioneers and champions of OEMs as innovators of the Lake Economy are the following:

- **Anonymous pioneers.** Flexibility and adaptability can be achieved through design, such as the plug-in compatibility of many electronic goods. Adaptability can also come through innovative service-life extension approaches, such as the transformation of a VLCC (very large crude carrier) tanker into a life stock carrier; or development of new technologies, such as plastic resin injections into components made of wood or concrete in order to improve their original performance (strength, impermeability).
- **Service-exchange system by Sony Computer Entertainment Europe (SCEE).** SCEE is responsible for sales, marketing, distribution and software development for PlayStation 2, PSP and PS3 video

games and multimedia consoles. SCEE imports the units from Japan and sells them to national distributors, which, in turn, sell them to retail outlets. From the onset, SCEE has used remanufacturing to enhance its customer services. Warranty returns were dealt with locally by Sony-approved retailers, which ordered parts on an individual basis and disposed of the defective parts. This system meant that customers with an expired warranty for their product were faced with a hefty bill for labour and parts, and a long wait until they arrived. As the repairs were costly, many customers simply discarded their unusable products.

To speed up repairs in the late 1990s, Sony's mobile phone sector began to operate a service-exchange system, whereby customers receive a remanufactured item in place of their faulty product. This system made use of centralised repair centres and allowed better quality control, economies of scale and smaller stocks of spare parts. The faulty components are then remanufactured and reused in repairs, replacing new parts shipped from the Far East (see case study at www.remanufacturing.org.uk).

Up to the 1980s, the German company Bosch had used a similar service-exchange system for its power tools with aluminium casing. When plastic replaced the aluminium, the system was abandoned as the casings could no longer be repolished in remanufacturing and looked unattractive to the next customer.

- **Manufacturers as innovative fleet managers – Zeppelin.** Some manufacturers became fleet managers to maintain their experience and capabilities as compensation after the loss of their traditional manufacturing activity. The Zeppelin Company at Friedrichshafen, Germany, developed and produced the famous Zeppelin airships of the early 20th century and still exists, despite the fact that its product disappeared from the market in the 1940s. Its new life began with marketing and servicing construction equipment and engines in Germany, Austria, Eastern Europe and Asia, as an exclusive partner of the US Caterpillar Inc. Part of this activity is the rental of construction equipment, vehicles and containers under the name of MVS Zeppelin. The rental activity is pursued as a franchising network in Germany, enabling Zeppelin to offer the appropriate machine or equipment to 120 rental stations (www.mvs-zeppelin.de).

  Further manufacturers-turned-fleet managers are active in the context of the Functional Service Economy. They include General Electric and Rolls-Royce selling hours of functioning jet engines;

Mercedes, now Daimler, selling hours of trucking; Xerox selling customer satisfaction and reusing 80 per cent of the components from the take-back of used equipment in the production of new machines; and CHEP renting wooden pallets and plastic containers to economic actors (see also Section 2.4.1.3).

- **Component standardisation by Airbus industries.** Airbus, a newcomer in an oversold market, picked up the idea of the commonality principle by using standardised major components in its products, such as a standardised flight deck that is built into all Airbus aircraft. The use optimisation obtained in this case includes lower operating costs, technical ease and flexibility in maintenance, reduced risks in maintenance and repairs as well as simplified pilot training and increased crew operation flexibility. It also led to cross-crew qualifications for pilots to fly all types of Airbus planes. For airlines, this directly translates into lower costs and increased competitiveness: airlines saved up to US$500,000 in annual operating costs for an Airbus, compared to aircraft by other manufacturers.

  Boeing later copied this strategy on its new 757, 767-200 and 767-200ER airliners, giving up the traditional philosophy of designing the best new flight deck for each aircraft. However, the traditional approach is still the norm in durable consumer goods, such as cars, electronic goods and washing machines.
- **Elevator upgrading kits by Schindler.** Elevators are complex technical systems that often live as long as the buildings in which they operate. Safety legislation that imposes strict maintenance standards, combined with the difficulties and costs to replace an elevator, has led to the development of component standardisation and availability of technological upgrading options.

  Schindler AG of Switzerland, for instance, offers its clients a number of standard technological upgrading kits, which include new double safety doors to replace single doors, electronic motor controls to speed up and smoothen elevator operation, and modern interiors, including emergency communication systems for old cabins. In 2008, when the credit crisis started, Schindler's sales of new equipment declined by over 10 per cent, while the market for modernisation remained stable.

  Several other lift manufacturers offer similar upgrading services for their equipment.
- **Lockheed.** The US' Lockheed has developed an advanced cleaning system that uses frozen pellets of carbon dioxide – dry ice – to blast and clean metal surfaces. After striking the target surface, the volatile

pellets quickly vaporise, and the vapour harmlessly dissipates. The process is low cost, can clean complex machinery without the disassembly needed for sandblasting, and can be used on anything from ships to electronic assemblies. Compared to traditional sandblasting, this process is clean and eliminates the costly task of separating the medium (sand) from the waste.

- **Sulzer marine diesel engines.** Sulzer Winterthur of Switzerland was once a world leader in marine diesel engine technology. Many of the giant ships ploughing the oceans were powered by engines from Switzerland, a small landlocked country. Yet the bigger the ship, the bigger the engines. And as shipbuilding in Europe declined after World War II, Sulzer engines were increasingly produced under licence in Asia. Today, the Sulzer engine factory in Winterthur no longer exists.
- **Long-life tools**. In the late 1990s, the German tool manufacturer Leitz produced a disk for cutting timber that lasts 60 times longer than conventional disks, and produces less noise. The disk's teeth have a hardened top that can be sharpened and are placed at irregular distances to lessen the high-pitched noise.

  Hitachi Tool Engineering Ltd, Japan, has developed a new coating technology that gives carbide-cutting tools longer lasting lubricity. The tool thus takes longer to heat up, and as a result, items like metal moulds and auto parts can be machined at higher speeds. The cutting tool itself lasts longer, too, and does not need to be replaced as often. The coating materials are ionised and injected from different sides of the furnace, where they vapour-deposit at the same time on the spinning cutting tip. The coating consists of alternative layers of two materials.

  The longevity of tools can also be improved after the point of sale, by innovations from independent actors specialised in the operation and maintenance optimisation of critical components.

3.3.3.4 Independent economic actors in the Lake Economy

Facility management is applied to both real estate and industrial plants. In both cases, its objective is the performance management of physical assets over time by operation and maintenance specialists. The two fields of expertise, which are both highly specialised and well developed, are presented here separately due to their different fields of application.

- **Maintenance and facility management of industrial plants.** For over 30 years, dedicated companies and institutions have pushed maintenance and facility management in Europe and the USA to a high degree of competence. The European Federation of National Maintenance Societies (VZW) today counts 20 European country organisations as its members; its objective is to improve maintenance and show its importance to trade and industry, the environment and public welfare and safety in Europe. The federation also organises an annual European Maintenance Congress.

In 2002, Associação das empresas brasileira de manutenção (ABRAMAN) organised the First World Congress on Maintenance in Bahia (Brazil), encompassing sectors of electric power, petroleum, metallurgy and mining.

Among the European leaders is Rheinhold & Mahla headquartered in Munich, Germany, offering construction and maintenance services for industrial plants, solutions for the shipbuilding industry as well as comprehensive services for technical noise control.

The Swiss company Eutectic-Castolin, which had developed similar processes to minimise the maintenance costs of tools, gave up its research activity at the end of the 20th century and is now a trading company.

- **Real estate managers.** Real estate management is characterised by a utilisation-focused fleet management approach and a system optimisation in a service economy, with few changes of ownership. This example is detailed in Chapter 2.

  Innovation is necessary to adapt buildings to changes in both technology and utilisation. Curtain wall constructions have been used in Europe since the 1960s and now have to be replaced, either due to corrosion effects or insufficient insulation characteristics. In cases where the buildings have been declared national monuments, their appearance must remain unchanged. Real estate managers, together with curtain wall manufacturers, have to develop a knowledge pool of balancing long-term operating costs versus the cost of technologically upgrading existing façade constructions to today's high insulating standards and the costs of replacing the existing façade with a new curtain wall.
- **Independent repair workshop: The case of a Saurer gearbox.** How do independent repair workshops differ from OEM workshops? This issue was researched when an independent lorry repair workshop in Berne, Switzerland, was taken over by a major European lorry manufacturer. A case study 'Product-life extension options[21] – remanufacturing the gearbox of a lorry' concluded that there is a choice between higher speed versus lower cost. For lorry owners,

Table 3.2 Two ways to remanufacture a gearbox

Alternative approaches to remanufacture a lorry gearbox:

(a) Fast remanufacturing of a gearbox according to manufacturer (OEM):

manpower input	23.5 hours
cost to client	CHF 16,000.-

(b) Economic remanufacturing of a gearbox based on workshop experience:

manpower input	59 hours
cost to client	CHF 10,400.-

Technical differences between (a) and (b) are:
(a) worn parts are replaced with new OEM parts
(b) worn parts are remanufactured where possible.

Result: a higher work productivity in the OEM's approach (a) means:
- considerably higher (53 per cent) invoice to the client
- shorter unavailability of the lorry to the client
- increased waste volume
- higher sales volume for OEM spares at the manufacturer's and
- 60 per cent less work in the workshop!

this choice exists only if independent repair workshops continue to exist (Table 3.2).

The current trend of takeovers of independent repair workshops by manufacturers thus deprives lorry owners of a choice between high availability at high cost and longer unavailability at lower cost. It also drastically reduces manpower input and increases financial cost and resource throughput.

> Different repair methods offer a choice between higher speed and lower cost.

- **Tyre retreaders for commercial equipment and vehicles.** Lorry tyres are regrooved and retreaded in the Lake Economy as a service for lorry owners. This implies no change of ownership and thus low transaction costs. The decision for retreading is based on utilisation-focused fleet management and system optimisation, namely, quality and cost/benefit considerations. Trust plays no special role as the client gets his own tyres back, or buys mileage from a tyre manufacturer. Lorry tyres are retreaded several times over their service-life.

  Similarly, aircraft tyres, which suffer heavy wear in landing, are retreaded up to 12 times, as are tyres of earth-moving machinery.

  The new business model used by Michelin, of selling performance instead of tyres (pay-by-the-mile), will reduce the volume of tyre retreading done by independent service companies (see page 122).

3.3.3.5 Academic and research institutions of the Lake Economy

The pioneers and champions of research institutions as innovators of the Lake Economy include the following:

- **Motor insurance repair centre.** Pioneers of research into product-life optimisation, such as the Motor Insurance Repair Centre in Thatcham, UK, have been motivated by *financial* savings in car repairs, not product-life extension or technical innovation.

  Yet, they have come up with highly innovative techniques, such as skin replacement panels that use more labour but greatly reduce repair costs and waste compared to traditional techniques. Instead of replacing a damaged car door, the door's contour is milled, which allows knocking out the damaged steel sheet. A new steel sheet is then glued onto the door frame of the car.

  Whereas, hitherto, production components had been used in repairs, the UK car industry has produced cheaper repair components for many years. Ways to reduce the costs of car repair – such as development of new repair spares, or the salvage of functional units from wrecked cars – has come exclusively from outsiders such as insurance companies. The concept of replacing a damaged door skin rather than the complete door itself is widely practised in the UK.
- **The Product-Life Institute Geneva** is the oldest consulting and research organisation on sustainable policies and strategies in Europe. Established in 1982 in Geneva, Switzerland, it is a virtual organisation working as a network of researchers to promote the sustainable opportunities of the Lake and the Loop Economy and their applications in the private sector. Publications and case studies are available on its website http://product-life.org.
- **University of Bremen's bridge-testing vehicle.** The special bridge-testing vehicle developed by the University of Bremen under a government research contract (BMBF) enables the measurement of the state-of-the-art quality and remaining lifetime of 'ceramic' road bridges, namely, those built of stone or concrete.

  After natural disasters, such as floods or earthquakes, many bridges are replaced 'to be on the safe side', as traditional quality methods cannot determine if the bridge can safely remain in use for a longer period. This leads to high costs, a huge throughput of resources with a very low value-per-weight ratio and unnecessary transport and waste – without increasing national wealth! The driver to replace bridges are often the repair subsidies available after catastrophes, not the hazardous condition of the bridges. The bridge testing vehicle may therefore not change the wasteful habits in place today, without adequate political support.

3.3.4 The Lake Economy of molecules

In the case of catalytic goods, the Lake Economy also functions on the level of molecules. The goods remain in the property of the manufacturer or fleet manager and are used in consecutive loops. Rent-a-molecule strategies are part of the broader business model of chemical management services dealt with in Chapter 2.

- **Deutsche Telekom: Managing its own copper pool.** Telecommunication companies are big users of copper wire for transmission cables that require periodic replacement. In the late 1990s, instead of buying copper and selling scrap, Deutsche Telekom began managing its own copper pool and contracting third parties to turn its scrap into new wires.

  The author ignores what happened to the Deutsche Telekom copper pool after the break up of national monopolies in the deregulation push at the beginning of the 21st century.
- **SafeChem: Rent-a-molecule in the Lake Economy.** Dow Chemical sells most of its chemical production, with some solvents are commercialised through chemical leasing (rent-a-molecule) by its SafeChem division. The advantage of such a leasing strategy is that the client has a record of how much was received and how much was returned. In countries with toxic release inventory (TRI) legislation, such as in the USA, this argument of accountability can be a competitive advantage as the rent-a-molecule strategy gives customers an additional benefit.

  But not all sold chemicals end up as waste or are incinerated. In many countries, a number of small companies are re-distilling solvents and other chemicals with a catalytic function, or recovering them for re-use: overspray of water-based paint, for instance, can be re-used as undercoat.

3.4 The Loop Economy – The art of reuse, remanufacturing and remarketing

The Multi-Loop Economy, particularly in remarketing goods and recycling materials, implies a *double change of ownership* equal to high transaction costs, which translates into higher costs than the Lake Economy.

3.4.1 The shift from cradle-to-nature to cradle-to-grave, then to grave-to-cradle

Before the Industrial Revolution, most goods were used as long as they could be repaired, or their materials reused, and then discarded into nature. This posed few problems when most goods were made from natural materials and their numbers were limited. In the first decade of the 21st century, the cradle-to-nature approach was still used for such inert materials as used optical cables, and satellites and other spacecraft abandoned in space, where they would eventually enter the atmosphere and disintegrate into smoke, or crash on planet Earth.

Since the 1950s the cradle-to-grave approach was the standard way to deal with public waste on Earth. Solid waste was collected and put into landfills or dumped into the sea. The highest mountain south of Maine on the US east coast, located in New Jersey, is still New York City's waste heap. The term cradle-to-grave appeared in the 1980s to 'upgrade' the image of the waste business which changed from 'Steptoe & Son' to professional waste managers.

As a reaction, Walter Stahel invented the term 'cradle-to-cradle' in the 1980s to draw people's attention to the potential advantages of a circular or Loop Economy, and to point out that the main interest of the consumer was actually the utilisation period for goods – the time between one cradle and the following one. The utilisation period as a focus of economic interest hardly existed when the Product-Life Institute was founded in 1982. (For further details, see http://product-life.org/cradletocradle.)

The Loop Economy starts at the end of a goods' utilisation. The objective of the Loop (or circular) Economy is to bring goods and molecules back into new use in a *grave-to-cradle approach*. This reduces both 'end of pipe' waste volumes (after utilisation) and the demand for virgin resources at the 'beginning of pipe' (base material production).

> The Loop Economy is a *grave-to-cradle approach* starting at the end of a goods' utilisation.

In the case of space waste, efforts were started in 2009 to force operators of satellites and other orbiting objects in orbit to declare details of their crafts and orbits, and to change the orbit of objects before decommissioning in order to reduce the danger of collision with other space objects and assure that the inactive object would fall into the atmosphere and 'disappear' in nature. However, some military operators to date refuse to disclose the details of their satellites and orbits. Down on Earth, Tokyo Electric Company started in 2005 to recycle optical fibre cables instead of putting them into landfills.

The Loop Economy consists of two distinct loops that differ fundamentally: one for products and one for materials and molecules (see Figure 3.4). Understanding each loop's characteristics allows economic actors to maximise their profits. The main difference between reusing goods (Loop 1) and recycling materials (Loop 2) is 'thinking money' instead of 'thinking waste'! Antique dealers who buy junk and remarket it as antiques exemplify this thought pattern!

> 'Thinking money' instead of 'thinking waste'!

Traditional economists and engineers feel comfortable with the Loop Economy as it maintains the *exchange value* of the Industrial Economy as the central notion of economic value. But the economic efficiency of the Loop Economy is curtailed for several reasons:

- Based on the dominating concept of *dowry over patrimony* as the basis of societal law,[22] the owner of a product in perfect working condition can decide to have it destroyed, rather than let someone else use it, shortcutting the law of the smallest loop to maximise profit. And the owner of a famous painting can choose to take it into his grave. (Figure 3.4 shows closing the product loop for goods and components, and closing the material loop for molecules.)
- The invisible hand of the free market often prefers material recycling to the economically more advantageous smaller 'product life-extension' loop. The reason for this lies in the familiarity of the Industrial Economy with both the throughput optimisation of recycling and its technology focus.
- Waste is not submitted to VAT and duties – incinerating old tyres or used oil is the cheapest energy resource for industry and individuals. The VAT should therefore be credited to the economic actors in the loop economy the same way it is done in the manufacturing chain.

Rethinking profit maximisation in remarketing, not cost minimisation in recycling, is therefore the recipe for profit maximisation in the Loop Economy for used goods. After having spent a fortune paying third parties to recycle its old aircraft seats, Lufthansa has recently discovered that used leather seats from First and Business Class can be *sold* very profitably to architects for reuse in, for instance, theatres.

> Profit maximisation in remarketing, not cost minimisation in recycling, is the recipe for profit maximisation in the Loop Economy.

3.4.2 The case for loop 1 – Product-life extension of goods

The Loop Economy of goods follows similar strategies as the Lake Economy but with two major differences:

- The Loop Economy suffers from higher transaction costs due to a double change in ownership at the 'grave' and at the next 'cradle'.
- The Loop Economy can only maximise profits during the reuse or recycling phase as it starts at the grave, after the utilisation phase.

The main service-life extension strategies for durable goods are: reuse, repair, remanufacture and technological upgrading, and any combination.

Reuse after quality checks to eliminate defective goods: *reusable bottles, rental goods, Lufthansa aircraft seats, secondhand clothes, building components such as sanitary fittings and windows and doors*.

Repair to recreate the original function after minor defects, accidents and wear-and-tear: *NASA space shuttle, shoes, cars, equipment*.

Remanufacture to bring it back to its original condition, as good as new: *oldtimer cars, combustion engines, structural parts, buildings, tyres*.
Similar terms are recondition, refurbish, restore and rebuild, used for specific applications.

Technological upgrading to bring goods up to state-of-the-art technology: *aircraft, ships, buildings, technical systems, Caterpillar diesel engines*. Technological updating is often done in combination with remanufacturing.

Additional strategies that can be applied are cascading, cannibalising and new products from waste. These strategies are generic; companies or individuals can apply them with little additional knowledge.

Cascading of goods and materials allows coping with uncertainty during long use. Cascading combined with periodic remanufacturing used to be common with for example, railway companies.

The original performance of a locomotive is maintained over a long period. The impact of a potentially growing risk of failure are gradually reduced by using the same locomotive in tasks of decreasing importance: for example, from express trains to goods trains to standby duty and finally to the shunting yard. Geographical cascading is an option for the leaders. 'Old' Swiss tramway and railway cars in working condition are regularly donated to low-income countries, such as Madagascar to replace technologically more outdated equipment.

Cannibalising to use existing goods as a mine for spare parts, avoiding the problem of out-of-production spare parts.
Scrap yards as spare parts supplier for automotive parts, 'storob' in the UK Navy, B52 bombers.

New products from waste, or reusing discarded goods adapted for another function, enables unemployed to become entrepreneurs.
Transform defective microchips into jewellery, glass bottles into mugs, textile waste into quilts, plastic sheeting into handbags.

Product-life optimisation does not necessarily mean product-life extension. Components that become obsolete due to technological progress are best recycled to recover the base materials or molecules, rather than reconditioned. Many cameras have become obsolete with the introduction of digital technology. Systems with a prototype character may not have a technical or production maturity that justifies extended utilisation except for display in museums; and goods damaged in fires or accidents may be in a state beyond repair.

On the other hand, hybrid materials, such as oil and timber, can have multiple uses: the same tree could consecutively be used as structural timber, planks, chipboard, fibreboard and fuel. Alternatively, the wood could be transformed into paper, recycled paper (even multiple cycles), cardboard, home insulation panels and fuel. Not exploiting these cycles is often a shortcut to facilitate production processes, such as turning trees directly into wood chips to facilitate the transport by pipeline to a distant chipboard factory.

3.4.2.1 The Loop Economy of durable goods and components

Of the main service-life extension strategies for durable goods: reuse, repair, remanufacture and technologic upgrading, only the first two are easily accessible to consumers.

Reuse is the preferred strategy for many consumers today, while previously reuse was restricted to such local activities as children's toys and clothes exchanges, garage sales and flea markets. Since the turn of this century, digital concepts such as e-bay and physical ones such as the fashion swap concept have become popular on a global scale. This activity makes more effective use of resources by providing a forum for people to exchange free of charge those fashion items (clothes, shoes, bags, accessories, etc) that they no longer use and that sit in their closets because, for instance, they no longer fit.

One example of a fashion-swapping event is the Swap-O-Rama-Rama, which started in the USA in 2005. People exchange clothing and attend workshops to learn how to alter second-hand clothes. In London, fashion swap events sponsored by a credit card company focus on the swapping of specific brands (www.swaporamarama.com).

Japan's first major fashion swap event, 'xChange', was held in September 2007 in Tokyo. These fashion swaps are promoted by the LOHAS movement (Lifestyle of Health and Sustainability) and are seen as alternatives to mass production, mass consumption and mass disposal (http://letsxchange.jp/english).

Some used products – such as sanitary equipment, timber elements and other building components – are traded on an individual level in many countries. In Switzerland, there are several exchanges for these products – including www.bauteilnetz.ch, www.bauboerse.ch, and www.ricardo.ch. E-bay has also started to get involved in this business segment, with the aim to create an exchange between craftsmen more than between individuals. This section also gives some examples of consumer goods successfully commercialised by their OEMs in the Loop Economy, such as single-use cameras by the US' Eastman-Kodak and Japan's Fuji.

On the industrial level, mobile goods such as ships, cars and aircraft are frequently sold for reuse. Thanks to easily exchangeable components, they are also suited for service-life extension in small workshops that can be located according to prevailing needs, conditions and demand.

Immobile systems such as buildings with exchangeable components require both on-site intervention and workshop activity. Their common characteristic is that the product-life extension activity is best and most cheaply performed where the goods and clients are.

As most product-life extension services have a limited economy of scale, their economic efficiency is greater when the economy of scale in the competing manufacturing process is low. The cost difference between new and remanufactured goods is thus highest for tailor-made goods produced in small numbers, such as railway carriages, ambulances, expensive cars and firefighting vehicles, and smallest for mass-produced goods, such as PCs and low-end automobiles. Collector's items and goods in museum that are part of the industrial heritage represent extremely profitable cases, as there is no competing supply of equivalent new goods.

The economic feasibility of some service-life extension activities in industrialised countries is threatened by mass-produced goods imported from low-cost countries, such as car tyres from China. This can be due to the new goods' cheap sales price jeopardising sales of the remanufactured goods, or a low-quality of the product that does not allow remanufacturing.

During the first decade of the 21st century, several countries have started to develop remanufacturing as an economic strategy, namely the UK and China. In the UK, the Centre for Remanufacturing and Reuse (CRR), in partnership with Envirowise, is the Department for Environment, Food and Rural Affairs' (Defra) point of contact for support for remanufacturing and reuse companies in the UK (www.envirowise.gov.uk, www.remanufacturing.org.uk).

CRR's work has confirmed that remanufacturing is a highly resource-efficient end-of-life activity, applicable to a wide range of products. UK companies that engage in remanufacturing are primarily driven by its economic advantages in comparison with waste and resource management, less by environmental factors. The rising recognition of CO_2 emissions as an accelerator of climate change has now shifted the emphasis to reducing energy and material supply chain inputs in the manufacturing process. Remanufacturing is a proven strategy for reducing these inputs and could thus play an important role in the recent drive of 'make and mend' to reindustrialise the UK with minimum resource consumption.

> UK companies that engage in remanufacturing are driven by its economic advantages.

In 2009, the UK also clearly defined the terminology of remanufacturing, reuse, recycling and reconditioning in the new British Standard BS887-2. In addition, CRR is sponsoring a remanufacturing and reuse category in the prestigious British Engineering Excellence Awards.

The Chinese Government is planning to allow – even support – automotive remanufacturing. Whereas remanufacturing of automotive components has virtually been banned under Chinese law for a long time, for fear of inferior quality, the winds have started to change. An early and strong signal of the government's intentions came in the autumn of 2006, when China's National Development and Reform Commission signed a letter of intent with Caterpillar Inc. under which both sides will 'join hands to promote the development of China's emerging remanufacturing industry'. These Chinese policies are summarised under the name of circular economy.

Economic actors in the Loop Economy of goods can be grouped as follows:

- innovative manufacturers,
- independent innovative service companies and
- academic and research institutions.

3.4.2.2 Innovative manufacturers active in the Loop Economy

Numerous manufacturers have been active at some point in time in the Loop Economy. With growing economic success, many of these innovators change into the industrial economy, for different reasons, as the following examples of pioneers and champions show.

- **Industrial Champion: Soichiro Honda**
  In 1991, Mr Soichiro Honda died, aged 84. He had founded Honda Motor, the motorcycle and car company that became a symbol of Japan's postwar industrial success. The son of a blacksmith, and a racing driver, Mr Honda began by fitting second-hand military engines to bicycles, creating a market for cheap motorcycles.[23]

  Mr Honda thus realised that the difference between unwanted goods and waste is the creativity to find new uses for discarded goods, and the courage to build an industrial activity on this belief. From 1948, Honda produced his own engines that were lighter and more efficient than the US engines. In the 1960s, the company began manufacturing small cars, first for the domestic market, and then for the USA in the 1970s.
- **The US remanufacturing sector.**[24] Remanufacturing started in the USA and the UK during World War II, when manufacturing industries were fully occupied in producing aircraft, tanks and other weaponry. While no private car or spare parts production existed during that time, remanufacturing offered the only way to keep cars on the road.

  In the mid-1990s, Professor Robert T. Lund[25] at Boston University undertook a study that for the first time analysed the economic importance of the US remanufacturing industry. The study found that this industry accounted for:

- more than 70,000 companies,
- over 50 major product categories,
- about US$53bn in annual revenue,
- some 500,000 direct employees and
- an average of about 25 employees per company.

According to the study, rebuilding and remanufacturing, a process that has been around for at least 60 years in the USA, has created hundreds of thousand of jobs in tax-paying businesses that: restore old products to like-new performance; save energy, natural resources and landfill space; and reduce air pollution by less re-smelting (namely, a reduced need for recycling scrap metals). The US remanufacturing industry has a number of professional organisations promoting its advantages in specific sectors.

Comparable sectoral studies in other industrial economies do not yet exist. While studies on remanufacturing capital goods and car components have been conducted in Europe,[26,27] the body of knowledge is smaller than in the USA. China is a hidden champion of the Loop Economy, as are many developing countries, for economic reasons. Japan is a successful leader for environmental reasons. Case studies can be found on the following websites:

- www.product-life.org,
- www.remanufacturing.org.uk,
- www.remanufacturing.org and
- www.oemservices.org.

- **Remanufacturing automotive engines.** A 2004 sectoral study[28] on restoring used automotive engines to a like-new condition showed much lower environmental and economic costs compared to manufacturing new engines. A life cycle assessment (LCA) model was developed to investigate the energy savings and pollution prevention achieved in the USA through remanufacturing a mid-sized automotive gasoline engine compared to an OEM manufactured one. The life cycle model showed that the remanufactured engine could be produced with 68–83 per cent less energy and 73–87 per cent fewer carbon dioxide emissions. The model also showed significant savings for other air emissions, with reductions of 48–88 per cent for CO, 72–85 per cent for NOx, 71–84 per cent for SOx and 50–61 per cent for non-methane hydrocarbons. Raw material consumption decreased by 26–90 per cent and solid waste generation by 65–88 per cent.

Remanufactured engines can be produced with 68–83 per cent less energy and 73–87 per cent fewer carbon dioxide emissions.

The economic survey of suppliers of new and remanufactured automotive engines showed a consumer price difference of between 30 and 53 per cent in favour of the remanufactured engine.

- **Remanufacturing Caterpillar diesel engines.**[29] In 1972, the US' Caterpillar Inc., a global heavy machinery and engine manufacturer, started remanufacturing its truck diesel engines supplied to a major OEM at the request of this client. At the time, engine remanufacturing was standard practice in trucking but Caterpillar doubted its economic feasibility and was largely unaware of its impact on the environment.

  Today, Caterpillar is sold on the economic feasibility of remanufacturing, which it feels has improved the quality image of its products. Economically, it makes good business sense. The environmental and social advantages of remanufacturing – versus manufacturing – are perceived but not yet measured.

  Manufacturing and remanufacturing are run as separate activities by Caterpillar, with engine design priorities still largely determined by the needs of the manufacturing process.

  Technically, Caterpillar's objective is to produce remanufactured parts of the highest quality, as good as new. In the process, the old engines lose their identity. After disassembly, components continue independently through an initial quality check and cleaning process onto the remanufacturing operation, which is done in batches of similar or identical components, in parallel lines. Remanufactured and new parts are then assembled into engines, each of which receives a new number and the same guarantee as a newly manufactured one. Compared to the remanufacturing of individual engines, this process is more efficient, enables the multiple remanufacturing of parts and components to the highest quality and allows adapting engines in the first loop to facilitate future remanufacturing.

  An average of 14 large truckloads of used engines and parts are delivered every working day to the Caterpillar plant at Corinth, Mississippi. The same trucks leave with remanufactured parts and engines, avoiding empty truckloads.

  Commercially, Caterpillar had to optimise the return logistics of used engines. In the beginning, old engines were bought back at scrap value and in competition with independent engine remanufacturers, and the remanufactured engines were sold at a discount. This provided no incentive to the owners of the used engines to return the engines to Caterpillar, nor to include all aggregates and in the best condition. Yet, the profitability of remanufacturing depends on a return of all aggregates and parts.

Today, a used engine is bought back for a price of up to 40 per cent of its original value, depending on its condition. Remanufactured engines are technologically upgraded and sold at the same price as new ones, under the condition that a used engine is traded in by the buyer.

The Caterpillar example has proven that the combination of manufacturing and remanufacturing does enable a company to develop an extended, or even comprehensive, stewardship for its products. Remanufactured engines and parts are sold exclusively through its parts distribution network (Caterpillar dealers). In exchange for this exclusivity, Caterpillar offers its dealers a variety of innovative product take-back incentives, ensuring that they return a large majority of its parts. These incentives include:

- a buy-back guarantee for unused (unsold) parts inventory,
- a deposit scheme on remanufactured parts and engines (a core deposit fee) as an incentive for dealers to return used parts to Caterpillar and
- a voluntary take-back of surplus used products at a price above the scrap value.

Caterpillar thus applies a policy of an extended producer responsibility to parts and engines that goes beyond 'from grave to cradle'. These voluntary, market-driven solutions also go far beyond any of the take-back legislation imposed by the European Union for used vehicles. Whereas the EU directive focuses on limiting environmental damage, the Caterpillar strategy maximises wealth! The next step might well be to sell performance instead of engines.

The managers and workers of the remanufacturing facility in charge of optimising the process have successfully used an approach that combines intuition with trial and error. But there is room to further exploit many of the synergies possible through an integrated design approach over several life cycles, following the concept of 'Managing and Designing for the Environment'. Caterpillar also has a policy of preferred procurement from suppliers that remanufacture their products, to encourage other component suppliers to also remanufacture their products – it is walking the talk!

Caterpillar plans to develop specific management and accounting tools that take into consideration 'physical asset management' and the cost and benefits of extended producer responsibility.

- **Remanufactured light vehicles from Retro Motors.** In 2005, the US company Retro Motors announced plans to supply completely remanufactured light vehicles in perfect mechanical condition with showroom looks and a limited warranty, as it believed that a remanufactured vehicle is the solution for 70 per cent of vehicle buyers who need an affordable, reliable, safe, low-maintenance transport. Retro Motors' vehicles were to be sold directly to the public through branded factory outlets that would offer same-day service for engine and/or transmission replacement. Individuals would have been able to buy a Retro Motors vehicle or contract with them to have their own vehicle remanufactured.

  The reasons why Retro Motors has abandoned its business plan are unknown. But as the cost difference between new mass-produced goods and remanufactured ones is small, the reason for the failure could simply be a lack of economic feasibility. The situation is different for the remanufacturing of oldtimer cars where the alternative of an equivalent new one does not exist.
- **Ambassador cars in India.** Ambassador cars have been manufactured and remanufactured since the 1950s in a Hindustan Motors factory located in Calcutta. Generally white or black, the car is a licence from the British Austin Company that no longer exists. The cars have a first service-life as vehicles for government officials and tourists. They are then remarketed for private drivers for a second service-life. When they are no longer roadworthy, Ambassador cars are returned to the factory to be remanufactured and adapted to technological progress, such as fitted with air conditioning, and resold as new. Hindustan Motors is part of Tata industries, which now also owns the Jaguar car company.
- **Jeepneys in the Philippines.** Jeepneys, the mini-buses in the Philippines, are in fact conversions of the Jeeps left by the US Army after World War II. Several companies, including Sarao Motors and Francisco Motors, have been producing Jeepneys for the last 50 years, and adapting them for use as mini-buses. Similarly to the Ambassador cars in India, most Jeepneys never die but are returned at the end of their life to the factory, where most of their components, such as axles, engines, gearboxes and transmissions, but also batteries and tyres, are remanufactured. The chassis is also remanufactured and the bodywork rebuilt and decorated by artists to make it a custom-made unique Jeepney.
- **GE Medical Systems' resource recovery.** In 1990, General Electric Medical Systems (GEMS) started a voluntary take-back of its own equipment in order to study the economics involved. After one

year, once profitability had been demonstrated, the pilot plant was transformed into a proper 'Resource Recovery' operation, which has made an annual profit since. GEMS then also started taking back equipment from other manufacturers. The revenue comes from selling second-hand remanufactured equipment and components. The main expense is the disassembly of goods and the recycling of the parts that cannot be reused; but these expenses are considerably smaller than the income from remarketing used parts and equipment for reuse.

In its first year in 1989, one million tons of materials were reused or recycled for a small profit. By the year 2000, GEMS' resource recovery centre had reached a stable level, with annual earnings of about US$4 million and about seven million tons of material being reused or recycled every year.

With this strategy, GEMS can offer high-quality medical equipment (as good as new) at a lower leasing fee or purchase price to hospitals in emerging and new markets that cannot afford new equipment, thus providing a market entry into these markets.

Another benefit comes from the storage of used third-party equipment in working order. These components are offered on a complimentary basis to hospitals that suffer equipment breakdowns but cannot afford to immediately buy new equipment. Experience has shown that in many cases, these hospitals will later buy from GEMS due to the service received in a crisis.

- **IBM's global asset recovery programme.** IBM started its global asset recovery programme for computers in 1999, following a pilot programme that showed it could profitably prevent 93 per cent of waste through product-life extension of components. Asset recovery encompasses end-of-lease equipment, manufacturing surplus and customer returns. Only 40 per cent of end-of-life equipment recovered is remarketed, the rest is sold to recyclers.

  In North America, Europe and Japan, IBM now offers its commercial clients product take-back programmes, most of which, however, charge a disposal fee.

  IBM Global Financing, the leasing company, has an in-house service that refurbishes computer systems for retail sale to large corporate customers, educational institutions and small businesses and resellers.

  In some countries, IBM also supports independent third-party reuse initiatives such as 'e-elders' in Japan, which collects and resells computers to elderly people.

- **Compaq, Dell, GE Capital, Stamford Computer and other leasing companies.** According to the IT Resellers Association, 65 per cent of leased computer equipment is re-leased or purchased by the original lessee. The remaining 35 per cent is returned to the lessor and remarketed by the leasing company. Leasing does not influence product design but guarantees a search for the highest price when goods are returned.

  Most computer-leasing companies remarket end-of-lease mainframes and PCs as retail resale, refurbished resale or spare parts to in-house maintenance departments. This brings in more revenue than if sold to wholesale brokers or recyclers.
- **NEC refreshed PCs.** NEC, one of Japan's major computer manufacturers, buys back used NEC PCs from ordinary users, and resells them as 'NEC Refreshed PCs' after checking and cleaning. In May 2004, NEC also started the practice of installing Office 2003 software in these computers, thus providing an upgrade on the original PCs and enhancing their performance.
- **Office equipment – A suitable case for the Loop Economy?**
  - **Fashion upgrades for office chairs by Sedus.** Sedus, a German manufacturer of high-quality long-life office chairs, offers a repair service for its chair. But as many chairs were returned due to frayed fabric covers, Sedus changed its strategy in the mid-1990s. Its chairs' textile covers are now sold with zippers or Velcro fixings for easy replacement; and Sedus manufactures and sells custom-made replacement covers as fashion upgrades, enabling its customers to use the chairs almost forever.
  - **Steelcase (US), Arthur Miller (US), Grammer (Germany).** Many European and US office chair manufacturers offer a take-back scheme, whereby the chairs are dismantled, components are reused as spare parts and the materials are recycled. This strategy makes sustainable sense mainly in a regional economy if dealers do not return the chairs to the plant for dismantling but do the work themselves, and if dealers apply the principle of the smallest loop: do not recycle what can be remarketed!

3.4.2.3 Independent economic actors as innovators in the Loop Economy

Outside the automotive parts sector, typical remanufactured equipment includes machine tools, industrial robots, vending machines, photocopying machines, electronic products and components and office furniture. Detailed examples can be found, for instance, in the book *Remanufacturing* by Rolf Steinhilper.[30]

Within the automotive sector, independent economic actors in some countries will adapt existing cars to cleaner technologies, such as compressed natural gas (see CNG example in Section 1.3.1).

The following are typical examples of pioneers and champions in the IT field.

- **Remarketing used PCs.** Reuse is more sustainable than recycling, and PCs are the products of the information technology industry, which claims to be state of the art. Yet PCs are often replaced when only one component is damaged or outdated – not a sophisticated approach. Independent workshops have started to remarket used PCs in many countries. The following are but a few examples.

  Fears that the remarketing business model for PCs could become a victim of the US$100 Third World X-O PC have been exaggerated. So far, this frugal X-O PC is not on sale in industrialised countries, for unknown reasons.
- **Flection International, reuse and remarketing of large IT assets.** A leader in the reuse of information technology (IT), Flection International maximises the residual value and minimises the risk for IT assets. It collects annually more than 300,000 surplus and obsolete IT units, and makes them suitable for reuse. Employing a combined workforce of 100 highly skilled professionals in the Netherlands, Belgium, France, Germany and Spain, Flection is one of the largest enterprises of its type in Europe. It uses latest techniques and software tools for the most efficient and effective refurbishment of IT assets and also manages the recycling of used and obsolete IT equipment. It provides a fast and high-quality asset management service to IT asset owners, which are defined as Large (global) End-Users (LEUs), IT leasing companies, IT manufacturers and original equipment manufacturers, distributors and service organisations.

  In desktop migration projects, Flection helps clients to implement hardware and software image standards and replication tests to ensure compatibility of the new equipment with the standards built within clients' organisations. To remarket redundant IT equipment, Flection uses its network in 60 countries to sell to retailers and distributors and its website (www.flectiondirect.com) to reach individual end-users. It also sells to businesses, schools and social welfare organisations. Clients' old, defective and unusable hardware are recycled according to the EU directive on waste electrical and electronic equipment (WEEE) that sets guidelines and targets for the responsible collection, reuse, recycling and recovery of electronic equipment waste.

- **ReUse Computer network in Europe.** ReUse Computer, a network of social enterprises in several European countries, remarkets used PCs, guaranteeing the highest quality standards to buyers. After being cleaned, repaired and upgraded if necessary, the used PCs pass an examination and receive a new serial number. PCs that cannot be reused are dismantled; their components that can be reused as spare parts are stocked and the remainder scrapped. The network's members have the technical knowledge, experience and skills in information technology and the desire to improve the quality of life of citizens and to reduce unnecessary electronic waste (For further details, see www.reuse-computer.org)
- **E-elder in Japan.** Another non-profit organisation, e-elder, collects used PCs from companies and donates the PCs to other non-profit organisations. Its members are also IT-specialists who use their expertise to support non-profit activities to help people overcome the digital divide in society.

  E-elder outsources the refurbishment to recycling facilities or welfare workshops. For the refurbishment process – which involves various fields of expertise – Microsoft provides the software, IBM Japan Ltd the replacement parts. The project's operating costs are covered by IBM Japan, Microsoft and PC donor companies.

The following are pioneers and champions of the Loop Economy outside IT:

- **Vetrum: Managing the reuse of glass bottles.** Weinflaschen-Recycling und Glashandel, Vetrum AG is the leading Swiss company to sort, wash and test wine bottles: 7000 bottles per hour, 16 million per year. More than 130 municipalities and organisations in eastern Switzerland send the wine bottles they collect from consumers to Vetrum for reuse. And more than two thirds of the bottles received can be washed and remarketed for reuse. Turnover increased from 1.2 million bottles in 1992 to 7 million bottles in 1998, and has tripled again since. Financial profit has doubled in the last five years. For one third of the bottles, remarketing is not feasible and they are recycled.
- **Retreading car tyres.** Retreaders are active wherever there are cars. Used car tyres are collected, retreaded and resold to new buyers. Transaction costs are therefore high due to a double change

in ownership. In emerging economies, workshops repairing punctures under the term 'vulcanisation' can in addition be found at most gas stations. In this case, costs are low because ownership is maintained.

Only few retreaders, such as Iceland's Green Diamond Company, technologically upgrade the retreaded tyres with an improved tread, giving them a qualitative advantage over new tyres.

- **Green Diamond Tires with a smart retread.** In contrast to new tyres that are manufactured from a single rubber mixture, retreads have the advantage that a componentised design is possible. In other words, a smart rubber mixture can be used for the tread – the rubber belt in contact with the road surface – which is different from the tyre structure.

  In 1995, New Industries Ltd of Reykjavík, Iceland, developed and patented a highly sophisticated technique for mixing hard silicon carbide granules into the material compound of a tyre tread. The high performance of these Green Diamond Tires is based on the thousands of small sharp-edged granules making firm contact with icy road surfaces, giving them superior traction without the hammering and damaging effect of studded tyres. Green Diamond Tires eliminate the two serious drawbacks of studded tyres – road wear and noise emission – while maintaining control effectiveness in slippery conditions and reducing tyre wear, thus extending its service-life.

  In manufacturing a Green Diamond Tire, the granules are distributed evenly throughout the rubber, which ensures that as the tyre wears down and granules are worn away, new ones are uncovered. Green Diamond Tires are particularly suitable for use with vehicles equipped with anti-lock braking systems (ABS) and have a superior, scientifically proven performance against other tyres in the most slippery conditions during freezing weather.

  As any other retread, a Green Diamond Tire also stands for waste prevention and a saving of three to seven gallons of oil for each tyre. Green Diamond Tires are an excellent example of an environmentally responsible, remanufactured product, which in addition is superior to the original product from which it is made. According to industry standards, only premium quality casings are used. Each used casing is exhaustingly examined using sophisticated test and inspection instruments and equipment. State-of-the-art new tyre technology is used to produce a product that has the quality and appearance of any 'major' manufacturer's but will out-perform any 'major' manufacturer's tyre on slippery surfaces.

Green Diamond Tires are an environmentally responsible remanufactured product, which is of superior quality to the original product from which it is made.

The success of Green Diamond Tires has been confirmed in Iceland by a rapid increase in market share. In Sweden, where production increased from 3000 tyres in 1998–1999 to 15,000 in 1999–2000, sales exceeded 70,000 in the 2006–2007 winter (www.greendiamondtire.com). In 2008, Green Diamond has set up factories in New York State and Colorado.

- **Freitag handbags.** An industrial version of 'new products from waste' was developed by two brothers in Zurich, Switzerland. Their Freitag Company transforms discarded polyvinyl chloride (PVC) lorry covers and car safety belts into expensive ladies handbags.

  An interesting aspect of these goods is that customers who refuse to buy a scratched CD cover will happily walk around with a scratched and dirty PVC handbag. And 'green' customers who demonstrate against the use of hazardous PVC in buildings generally do not object to buying a PVC product that will end up as municipal waste. Lorry covers, in contrast, are industrial waste that is properly recycled. Compared to leather, PVC handbags do not age and never develop a patina. Beauty is in the eyes of the beholder – and the marketing of the seller!
- **Military fortifications as data vaults.** In Switzerland, several entrepreneurs have bought decommissioned military fortifications and transformed them into data vaults, in one case even into a hotel. These underground military bunkers are extremely solid, often in secluded locations and with very limited access. Data stored here is thus safely protected even in the unlikely case of a nuclear explosion such as a second Chernobyl.
- **Anonymous solutions.**
  - **The Crazy ducks** that take tourists in Boston, Massachusetts, for a trip around the town and onto the Charles River are landing boats of the US Army that were used for D-day in June 1944 in France and are still going strong.
  - **DC3/Dakota water bombers in the UK.** Many of the DC3s and their military version Dakota, the aircraft with the highest production numbers ever, are still being used today in the Third World. In Great Britain, some of these aircraft from the 1940s have been converted to water bombers to spread chemicals on oil

spills in the sea, exploiting their capability to fly slowly at low altitude in any weather.

- **New products from waste**, or reusing discarded goods adapted for another function, enables people such as the unemployed to re-enter the economy by becoming entrepreneurs transforming, for instance, defective microchips into jewellery, glass bottles into mugs, textile waste into quilts and plastic sheeting into handbags. Stahel 1985.[31]

3.4.2.4 Academic and research institutions of the Loop Economy

Few academic and research institutions have looked at, or contributed to the Loop Economy so far. Among them are:

- **Battelle Memorial Institute.** The Battelle laboratories in Columbus, Ohio, developed a cost-saving process for making rigid polyurethane foam underwater in order to re-float sunken ships, aircraft or other objects.[31] The self-contained system is small enough to be flown into a salvage site for quick response. In-line process heating allows the system to also be used in cold waters.
- **Design Pioneer: Victor Papanek's Design for the Real World.**[32] New products from waste need an innovative jump to make them sellable. The novelty can be of an artistic nature, such as the creation of jewellery using the aesthetic properties of discarded microchips; of a technical nature, such as cutting tyres into sandals or filling tyres with concrete to hold up umbrellas; or of a commercial nature, such as offering door-to-door repair services.

  New products from waste require individual creativity instead of specialised skills. Waste, the main resource, is free. And so this 'business model' is open to the unemployed without revenue, who can sell the resulting products at flea markets or door-to-door, again without any special skills.

  Useful 'waste' includes empty bottles, cans, tyres, textile and leather cut-offs, scrap metal and. One's imagination is the limit.[33,34]
- **The Product-Life Institute Geneva** is the oldest consulting and research organisation on sustainable policies and strategies in Europe. Established in 1982 in Geneva, Switzerland, it is a virtual organisation working as a network of researchers to promote the sustainable opportunities of the Lake and the Loop Economy and their applications in the private sector. Some publications and case studies are available on its website http://product-life.org

3.4.3 The case for loop 2 – The Loop Economy of molecules

Loop 2 activities – material recycling as a service-life extension of molecules – includes physical molecules but also qualitative conditions such as heat and cold. They can be grouped as follows:

- **Recycling production waste**, called primary recycling, has the advantage of easy collection, clean mono-material waste, small transport distances and often no change of ownership.
- **Recycling end-of-life products**, called secondary recycling, is a grave-to-cradle business models with high collection and sorting costs, often involves mixed or contaminated waste, has long transport distances and offers a choice between several types of recycling processes.
- **Natural cycles**, such as water and CO_2 cycles, which are part of nature, a non-monetary system without time constraints, labour costs or pollution issues. Biomass as a renewable energy resource is an industrial use of the natural CO_2 cycle.

Due to high collection and sorting costs, secondary-waste recycling in industrial countries faces a cost disadvantage over virgin resources (Junction 2 in Figure 3.4 in Section 3.2.2).

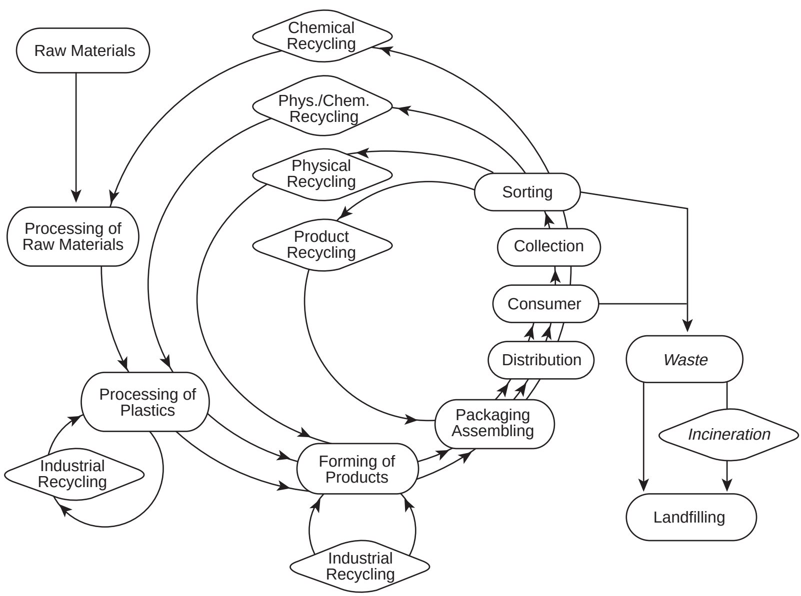

Figure 3.10 Industrial loops of materials and molecules

Figure 3.10 gives an overview of the loops, which allow the reuse of molecules. The reuse of goods (Loop 1) is here called ‘Product Recycling’; primary recycling is referred to as ‘Industrial Recycling’.

3.4.3.1 Recycling industrial wastes (primary recycling)

Profit maximisation in material recycling demands marketing skills as well as innovation into new processes adapted to specific waste streams and the re-use of secondary resources:

- Reusing molecules in the Loop Economy generally demands an understanding of dissipative systems with a high entropy (that is a low concentration distribution of its parts in a thermodynamic equilibrium), in order to recover the pure resources of high value. New processes are needed to recover raw materials or molecules available in dissipated form in heterogeneous products, such as in recycling small disposable batteries.
- Processes to recover some materials have existed for a long time, such as molecules in metal smelting and remelting, fibres in paper recycling or monomers in certain plastics, such as polymethacrylate (Plexiglas). These are the low hanging fruits of material recycling.
- New processes are being developed to recover monomers from engineering plastics, such as Nylon. Fibre manufacturers focus on depolymerisation processes to recover the pure monomer, while fibre users, such as Interface Corporation, are searching for shorter and cheaper loops to recover the plastic material.

The primary recycling of clean production waste also includes waste heat and wastewater that may be reused in another function. This strategy is promoted by the *Industrial Ecology* concept that uses the waste of one plant as resource for another. This ecologically based concept started over 100 years ago, when urban slaughterhouses where forced to find non-offending alternatives to simply dumping their waste into rivers and landfills. Bones, fat and blood were profitably turned into sellable products such as candles, soaps and cosmetics. Modern Industrial Ecology relies on the organised structure of industrial parks, the best known of which is Kalenborg in Sweden.

As in any chain manufacturing system, Industrial Ecology carries a high vulnerability when one or several chain links are lost. A well-known illustration of the latter is the crash of the first national economy organised according to these principles, the German Democratic Republic. Its economy collapsed within a few years after opening the market to competition and the subsequent 'cherry picking' by foreign companies. A similar effect can happen if waste prevention in the originating production process is applied: the waste-equal-resource for the following process step disappears, sufficiency killing efficiency.

2.4.3.2 Recycling end-of-life products (secondary recycling)

The resource efficiency of secondary recycling, that is, of end-of-life waste, is strongly affected by the 'Factor Time' – the inclusion of time in economic optimisation – which is illustrated in the example of an aluminium beverage can.

One limitation of material recycling is the imperfection in the recovery process of any material, including collection; management can influence this. Another drawback that cannot be influenced is the Second Law of Thermodynamics, whereby a certain part of material and energy is lost in each technical process.

Expensive materials such as gold are often used in minute quantities, such as in surface coatings of glass or other metals. Recovering this dissipative use of the metal is expensive or even impossible. Other gold objects have a long life, but may be buried with their owner, and are hence not recoverable. Overall, only about 50 per cent of the gold mined is recovered and recycled.

Gypsum is a rare example of a cheap material that is partly made from waste (from coal-fired power stations) and can be taken back after use and reintegrated into the production of new gypsum. The Austrian Rigips company, a subsidiary of Saint-Gobain Gyproc, for instance is actively involved in collecting gypsum waste from do-it-yourself house improvement activities by individuals, through the Waste Collection Centres (ASZ) in Oberösterreich, one of the Austrian states actively engaged in economic waste reduction.

The pure porcelain (China) used to produce the industrial insulators needed in electricity substations and to support the overhead wires of railways, could be directly reused in manufacturing if take-back logistics were in place. As these goods are exclusively used in industrial applications, a system of reversed logistics should not be difficult to install – but who should do it, the manufacturer or the user of the goods?

Cheap materials, such as aluminium or steel used in packaging, can have a very short service-life. As only 5 per cent of the original energy to produce aluminium is necessary to recycle aluminium, the collection and recycling of waste aluminium makes economic sense in many countries. But recovery can be hampered by several factors:

- a short service-life makes it impossible to prevent a rapid loss of resource, even with a recycling rate of 90 per cent of cans sold. The relative loss over time is different for, say, an aluminium car engine with a service-life of 10 years.
- the geographical location of the waste can make collection uneconomic, for instance in the case of the aluminium oxygen cylinders thrown away by mountain climbers in the Himalayas.

Table 3.3 shows the amount of metal available at each recycling loop for recycling rates of 50, 75 and 90 per cent of the cans sold. Even the hypothetical recycling rate of 90 per cent results in a loss of the total resource within two years. A reusable glass bottle by comparison, goes into its first recycling loop after 27 service-lives, or almost two years!

The following are some of the pioneers and champions of the Loop Economy of Molecules:

- **Gordon Battelle and Marine Mining Company.** Gordon Battelle, an American chemist-turned-industrialist, made a fortune around 1900 by developing a novel process to extract tin from low concentrate deposits. He then bought tin mine heaps all over the world and recovered half the tin still in the mining waste stored around tin mines. When he died in 1929, the money from his estate was donated to the Battelle Memorial Institute, which he had set up in Columbus, Ohio, the first not-for-profit foundation and the nation's first contract research institution.

  In the late 1970s, the Marine Mining Company in the UK started a similar activity off the coast of Cornwall, remining the waste of the ancient Roman tin mines that had been washed into the sea over centuries by the Cornish rivers.
- **Japanese cell phone manufacturers.** Japan's Telecommunications Carriers Association (TCA) and the Communications and Information network Association of Japan (CIAJ), jointly recycled some 11.72 million cellular phones (a service unique to Japan) in 2003, an increase of 348,000 units from the previous year. The collection rate was down by five percentage points to 24 per cent. The resource recovery rate – the percentage of metal content in cell phones – was 19 per cent.

Table 3.3 The 'Factor Time' in the Loop Economy of molecules: Recycling Coca-Cola cans

Example : Coca-Cola can in the US				
Cycle time: three weeks (from factory to disposal)				
Recycling rate in per cent of cans sold	50	75	90	
Share of recycling material at the end of the				Total loss after
1. Recycling loop	50	75	90	
2.	25	56	81	
3.	12.5	42	73	
4.	6.3	32	66	
5.	3.1	24	59	
6.	1.6	17.8	53	
7.	Negligible	13.3	48	1/2 year
8.		10.0	43	
9.		7.5	39	
10.		5.6	35	
11.		4.2	31	
12.		3.2	28	
13.		2.4	25	
14.		1.8	23	
15.		1.3	21	
16.		1.0	18.5	
17. Recycling loop		Negligible	16.7	1 year
18.			15.0	
19.			13.5	
20.			12.2	
21.			10.9	
22.			8.9	
23.			8.0	
24.			7.2	
25.			6.5	
26.			5.8	
27. *By comparison, the average reusable glass bottle in Europe lives for 27 loops, one and a half years*				
28.			5.2	
29.			4.7	
30.			4.3	
31.			3.8	
32.			3.4	
35. Recycling loop			Negligible	2 years

- **Interface's Cool Blue recovery process.** Interface, the world's largest manufacturer of modular carpets, is probably also the world's most forward-thinking company in its field. Its aim is to free itself from oil to make its goods. At the centre of its efforts lies a robust campaign to make use of recycling and remanufacturing, reclaiming used materials and putting them back into the production cycle. And Interface hopes that its reliance on reclaimed materials will also help it to smooth earnings volatility.

  Interface's operation to reclaim the old carpet is called 'ReEntry 2.0' and includes reverse logistics, take back and processing. A separation process called 'Clean Separation' mechanically separates the Nylon fibre from the carpet backing that leaves the post consumer Nylon fibre clean enough to be remelted, filtered in the melt stage and then extruded into new carpet fibre. This mechanical process is the lowest energy, lowest cost route to take post consumer fiber to new fibre. Interface incorporates up to 40 per cent into new carpets; the reused content varies by colour, since the company uses mostly solution-dyed fibre.

  The old, waste carpet backing is ground and densified in the 'Cool Blue Process', a mechanical process to convert waste carpet backing into a new carpet backing sheet, which is then laminated to the new face cloth to form the finished web, which is cut into tiles. Cool Blue has a capacity of 6 million square yards of carpet per year.

  In this perfect grave-to-cradle approach, Interface accepts all types of carpets and backing but recovers only the PVC backing and Nylon 6,6 fibre for its own use. Nylon 6, PP and other fibre streams are sold to third parties for reuse in other markets such as engineering resins for automotive parts and composite lumber. But Interface also sells performance through its 'Green Lease' programme presented in Chapter 2, in a cradle-to-cradle business models which internalises all costs of risk and of waste.
- **A sewage treatment plant as a new gold mine**. In February 2009, officials at the Suwa sewage treatment plant in the Nagano perfecture in Japan reported that they are extracting significant amounts of gold from processed sewage. The concentration was 1.890 kg of gold per ton of incinerated sludge, which is considerably higher than most gold mines. The Hishikari mine in Japan, for example, yields 20–40 grams of gold per ton of ore. Officials believe the gold is from IT manufacturers in the area.
- **Insurance for recovery and recycling expenses at the end of product-life.** First Solar of Phoenix, Arizona, in May 2005 com-

pleted a long-term agreement with a major international insurance company to fund the estimated future costs of reclaiming and recycling First Solar modules at the end of their life. This constitutes a built-in economic incentive to explore all reuse and remarket options at the end-of-life stage.

This Reclamation and Recycling Reimbursement Policy assures owners of First Solar modules that funds will be available from the original purchase price to pay the estimated costs of transporting First Solar modules to a recycling centre and recycling them into new products or disposing of them as prescribed by law. This insurance programme is compatible with the Integrated Product Policy of the European Union. But in addition, it assures that economic optimisation will be sought, as there is an economic actor – insurance – interested in maximising its profit.

- **Reusing porcelain insulators**. In many technical applications, such as transformation stations and overhead wire support of electricity supply to railways, big porcelain insulators are used. These insulators suffer from sand storms, hail and frost and require periodic replacement. In situations where there is a take-back logistics, manufacturers can grind the old insulators and reuse the material to manufacture new ones.
- **Used generator brushes recycled into mechanical pencil leads.** Since 2005 Tokyo Electric Power Company (TEPCO) and Tombow Pencil Company have been jointly developing mechanical pencil lead recycled from generator brushes used in TEPCO's thermal power plants. Generator brushes are made from highly pure graphite (over 97 per cent) and are crushed to form graphite particles.
- **Recycling optical fibre cables.** Tokyo Electric Power Company has also started recycling used optical fibre cables into drums for storing these cables. It is pursuing this in cooperation with Furukawa Electric Company. This is the first electric utility to recycle optical fibre cable. Tokyo Electric Power formerly buried all collected optical fibre cables, treating them as industrial waste.
- **Reusing water in a closed loop for paper recycling.** The Duesseldorf-based paper producer Julius Schulte Söhne has developed a water-regeneration method, which enables it to operate in a closed loop system. In the past, the company consumed 260,000 tons of drinking water per annum to recycle wastepaper, and discharged the same quantity as wastewater. The closed loop cleaning process is based on a triple treatment to filter all impurities out of the water. This is

also an example of a successful sufficiency strategy, reducing water consumption to zero.

- **Reusing wool waste instead of plastic film.** Wool runs on grass: by eating grass, sheep produce wool that reflects the ingredients of the soil, and thus constitutes an ideal fertiliser.

  In modern agriculture, the black plastic film used to protect seedlings against cold and drought ends up as contaminated waste that cannot be recycled. A similar protection can be achieved by using a non-woven film made from second-hand wool, which at the end of its life is simply ploughed under, a perfectly balanced fertiliser returned to nature.
- **Japanese research group generates hydrogen from bread waste.** Sapporo Breweries Ltd, Shimadzu Corp. and Hiroshima University have jointly developed the world's first technology that can efficiently generate hydrogen and methane from bread waste. On 7 October 2004, their research group announced that their small-scale experimental system had run successfully for over six months. The National Institute of Agrobiological Sciences, an independent administrative institute in Japan, has commissioned and sponsored this research.

3.4.3.3 Biomass as a renewable energy source[35]

The process of turning biomass into hydrogen is a new industrial activity with a potentially bright future, as this is the most efficient way to produce hydrogen. The following examples of producing bio-diesel and ethanol from plants, to replace diesel and gasoline refined from crude oil used in combustion engines, are more traditional and have historic precedents. Cars running on ethanol, for instance, have existed for a long time. In the 1930s, Ford and Mercedes-Benz already produced cars that could run using ethanol alcohol as fuel. In recent years, the market introduction of the so-called bio-fuels has accelerated; industrial production worldwide has doubled; and sales of ethanol-powered cars are booming. In Brazil, several car manufacturers sell flexible fuel vehicles (FFVs) that run on a mixture of gasoline and ethanol.

European developments are driven by EU legislation, which imposed a bio-fuel content of 2.5 per cent for both diesel and gasoline in 2007, and of 5.75 per cent from 2010 onwards.

Smart bio-fuels can be produced from a multitude of wastes, as shown in the following examples:

- **Turning dairy waste into diesel fuel.** Whey is a waste product from dairies that is rich in protein and used to produce baby food or medicine. The leftover watery solution – 10 million tonnes annually in Germany – goes into sewers and thus ends up in sewage-treatment plants, where it has to be eliminated at considerable cost.

A process developed at Stuttgart University separates the lactose (sugar) from the water, using an enzyme found in the effluent pipes of US wastewater treatment plants. Within five days, the microbes transform the fat into single-cell oil that can again be separated into a vitamin-rich feedstuff and the single-cell oil Triglycerid. Using another yeast (enzyme), this can be transformed into Sophorose-lipid, which can be used to drive diesel engines, similar to rapeseed oil.

Compared to rapeseed oil, the new product does not need agro-chemicals or arable land to grow, its production is not seasonal and the production cost is considerably lower.

- **Abengoa: Turning AOC wines into ethanol fuel.** Abengoa Bio-energy, a subsidiary of the Abengoa industrial and technological company, is a €1.5bn holding company headquartered in Seville, Spain (www.abengoabioenergy.com).

  Abengoa Bioenergy is Europe's first and the world's second producer of ethanol, which it transforms from such renewable biomass as grains, corn, grass, wood and even surplus wines, including *appellation d'origine contrôlé* (AOC) ones that you may drink at lunchtime. Its typical customers include refiners, blenders and marketers of gasoline for use as a fuel additive that allows gasoline to burn more completely and with fewer emissions. Another area of activity is grain distillers' co-products, which are obtained after the extraction of ethanol by fermentation and distillation of grain feedstock. When fed to livestock, such as beef and dairy cattle, it is a valuable source of protein and energy.

  The fifth largest ethanol producer in the US, Abengoa Bioenergy operates its five US corn-based facilities with a total production capacity of 365 million litres from its headquarters in Missouri. In Spain, its annual production capacity of 320 million litres was expanded in 2006 with the going onstream of an additional plant to produce 200,000 tons of biodiesel, using crude vegetable oils, in collaboration with the Cepsa energy company. Its subsidiary Abengoa Bioenergy R&D focuses all efforts and resources on biomass and fuel cell activities to further advance the production of bio-ethanol products worldwide.
- **Turning wood waste into fuel.** A nanotechnology unit of Mitsui & Company now operates a plant that makes high-grade ethanol fuel from low-grade ethanol created through the fermentation of wood

scraps. Developed as part of a biomass energy-efficient conversion technology project of the New Energy and Industrial Technology Development Organisation (NEDO), the process raises the purity of ethanol from 8 to 9 per cent to at least 99.6 per cent. By adding it to gasoline, it can be used as automotive fuel in normal engines.

Other processes to turn wood into fuel exist. Choren Company, located at Freiberg in Germany, annually produces 13,000 tons of 'bio-fuel' from wood, using a gasification process followed by a Fischer-Tropsch synthesis.

- **Turning rapeseed into bio-diesel.** Eco Energie Etoy (EEE) is a Swiss company that started in 1995 to produce 'bio-diesel oil' from rapeseed. At the end of 2004, EEE produced 18 million litres of bio-diesel and 2150 tons of glycerine.
- **Turning cereals into bio-ethanol fuel.** A bio-ethanol plant recently built in Zeitz, Germany, has the capacity to produce 260 million litres of bio-ethanol and 260,000 tons of feedstock per annum through fermentation of cereals – such as wheat and corn – and sugar beet. Agricultural products containing starch undergo fermentation in order to produce sugar, which is not necessary for sugar cane.
- **Cane-based ethanol.** Cosan, Brazil's largest sugar and ethanol company, produces an annual 2.3 million tons of sugar (number-two worldwide behind Südzucker in Germany) and is the world leader in sugar cane-based ethanol, producing 825 million litres and exporting 298 million litres. (See also Section 1.2.2 for other science-based examples of green life sciences.)

However, as previously mentioned, a number of questions remain open. There is an ethical question about using foodstuff to produce car fuel in a world where hunger is still largely present. This question is of less importance in projects to transform agricultural and wood waste into car fuel, as they transform waste into a sellable product.

And there is a question of economic feasibility. Many new projects were started in a time of ever rising oil prices – forecasts predicted an oil price of US$200 per barrel for the end of 2008. But in July 2009, crude oil prices fluctuated around US$60 per barrel, and many drivers switched back from ethanol to the now cheaper gasoline. Ethanol producers suffer from the fact that they have high fixed production costs. If these are higher than the oil prices, they can no longer sell their bio-fuels in the open market.

One alternative is to transform biomass directly into hydrogen, as in the above example of the Japanese research group generating hydrogen from bread waste. According to Jeremy Rifkin,[36] this would prevent the CO_2 emissions responsible for climate change. And it could open the door to a green energy future for Industrial Ecology.

3.5 Change drivers

The most prominent change drivers listed below can promote change in favour of a better management of performance over time, but sometimes can also work against it.

Among them are economic competitiveness, science and technology, commercial and cultural innovation and a wish for a higher autarky.

3.5.1 The quest for the highest competitiveness

There is no rush in policymaking to change course from the industrial throughput to the more competitive Lake Economy and Loop Economy, with the possible exception of new UK and China initiatives. And this despite the fact that the examples of Honda (Japan), Lufthansa (Germany) and Caterpillar (US) show that in all industrialised countries, economic actors have followed the most profitable roads, creating wealth and jobs and preventing waste.

Recent legislation focusing on waste instead of economics – such as the EU directives on end-of-life vehicles and waste electric and electronic equipment (WEEE) – promote the Loop Economy of Molecules at a considerable cost to the consumer and by ignoring the best available solutions.

There is no rush by economic actors either to exploit the considerable difference in economic competitiveness between goods on one hand and molecules on the other, or to exploit a 'sustainability bonus' from the considerably higher value-per-weight ratio and labour-input-per-weight ratio in the reuse and remanufacturing of goods compared to material recycling.

Competitiveness also depends on the speed of change. GEMS started its take-back initiative of medical systems in 1990 with a pilot plant under the threat of the EU's WEEE directive, to find out if 'we can make money that way'. Most European companies waited another 15 years until WEEE entered into force and then delegated the take-back and resource recovery to third parties, thus waiving the most profitable routes of reuse and remanufacturing not open to third parties.

In changing course, the most efficient method has proved to be 'learning by doing'. Xerox, Caterpillar and GE Medical Systems developed their 'design for environment' tools on the shop floor in order to develop better manufacturing solutions to maximise profits in the Lake and the Loop Economy. The US approach of 'learning by doing' has a clear advantage in speed and cost over the feasibility-study approach in Europe, Learning by doing often opens the door to the development of new technological areas, better industrial design and innovative production methods that have so far been invisible, whereas feasibility studies tend to be based on existing manufacturing know-how, which is of limited use to optimise product-life extension activities.

3.5.2 Science and technology innovations

Technological progress and quantum leaps in science have several influences on the Lake and the Loop Economy.

- Advances in technology can lead to technical obsolescence of components, products or even systems and thus to an abortive end of a product's useful life,
- Jumps in technology also open new fields of activities in recovering dissipated resources in the Loop Economy of Molecules,
- Innovations in material sciences (see Chapter 1) can considerably improve the feasibility of the Lake and the Loop Economy. New materials and methods applied to extend the service-life of existing goods have, for example, made concrete bridges impermeable against salt water in cold climate areas or strengthened old wooden structures with carbon fibres.

The smart materials described in Chapter 1 should blossom in the Lake and the Loop Economy. As some of them can be reused with little effort, their manufacturers may change today's business model in order to retain ownership and profit financially over the full service-life of their molecules.

But in many cases, appropriate processes and methods still need to be developed and perfected for the Lake and the Loop Economy. This is the experience of Michelin, Rolls-Royce and others that have made the shift to selling performance recently. Once developed, they increase the company's competitive advantage.

Most product-life optimisation activities are services, and thus typical children of the Service Economy: they lack homogeneity, must adapt to complexity, cannot be stored and have to be provided locally. For immobile systems, such as sewers or railway tracks, and clients on the run, such as the armed forces, mobile remanufacturing units are needed that can perform on the spot where and when the need arises.

Some manufacturing technology may be inappropriate for the Lake and the Loop Economy, especially when its equipment cannot cope with the slight tolerances in reused goods. Filling reusable glass bottles needs 'tolerant' bottling equipment and distributing used bank notes needs 'flexible' automated teller machines (ATMs). The order of component assembly in goods production may be a fundamental obstacle in disassembly for maintenance, for example, car instrument panels. This can be avoided by including ease-of-maintenance in the product design stage.

Technological progress can also hinder managing performance over time. Up to the 1980s, the German company Bosch had used a rental and service exchange system to market its power tools with aluminium casing. When plastic replaced the aluminium, the system was abandoned as the casings could no longer be repolished in remanufacturing and looked unattractive to the next customer.

3.5.3 Commercial innovations

In a growing number of countries, a key driver has become the public and private sectors' acceptance of service-life extension as an economic base to preserve national heritage and industrial archaeology. Old industrial buildings including unused churches are transformed into expensive flats and luxury restaurants (St Catherine's dock and the South Bank in London, for example). Collecting and driving classic cars is seen as a sign of wealth and snobbism, not poverty. But keeping monuments without exploiting their utilisation value will increasingly become a financial burden for society and lead to innovative new uses of existing physical assets. One extreme example are the Swiss Army's decommissioned nuclear bomb proof shelters in the Alps that are being transformed into data storage vaults!

In the case of mobile durable consumer goods, such as cars and computers, the link between owner-users and remanufacturers is often missing and has to be created by the latter through commercial innovations. If an individual cannot find a workshop to rebuild his car, there will be no rebuilt car.

Many economic actors in the Lake and the Loop Economy could profit from cooperation and partnership, mediated through an independent third-party organisation. In the USA, an organisation that fulfils this role is the OEM Product-Services Institute, which is part of The Remanufacturing Institute (TRI), a global all-volunteer, non-profit organisation headquartered in Lewisburg, Pennsylvania. This body can build trust between supplier and customer and ensure that the model is successfully implemented. A similar body is lacking in Europe. A broker organisation acting as a catalyst, similar to the Chemical Management Systems detailed in Chapter 2 and the incident-reporting organisation in disaster prevention presented in Chapter 1, could increase the competitiveness of the sectors and actors in the Lake and the Loop Economy.

Manufacturers are slowly discovering the oldtimer market. Bosch, a global manufacturer of automotive, industrial and consumer goods, in November 2005 inaugurated its 'Bosch Automotive Tradition' service that offers spare parts for and information on oldtimer cars. The new service is part of Bosch's Automotive Aftermarket Division and is based in Karlsruhe, Germany. As oldtimer cars have the characteristic of a Stradivarius violin rather than a teddy bear, many will survive their owners, providing a lasting and price-insensitive market for spares.

Consumers and legislators are suspicious of some new materials and technologies of the Performance Economy. Commercial innovations can overcome these fears, such as an operational leasing strategy (for example, Xerox's commercial launch of photocopiers in the late 1940s) or an unlimited manufacturer's performance guarantee. This would considerably speed up the market introduction of many innovations. Insurers can also give a performance guarantee (see the example of First Solar). In most cases, this constitutes a shift to the new business models that are detailed in Chapter 2.

3.5.4 Cultural innovations: The 'caring' index

The Lake Economy can serve as an index of 'caring', or of applied sustainability. This caring index can be defined as the ratio between the fleet size of goods of mature technology and the ratio of 'senior' goods within this fleet. As this ratio differs in the different industrialised countries, for instance for buildings and cars, it gives an indication of the culture of caring by both individuals and society. Table 3.4 shows the 'caring' index for automobiles in three European countries with a similar culture and a common language, German.

Differences in car culture and legislation on older vehicles influence these figures. Japan is an extreme case, as ten-year-old cars must pass a severe quality test often entailing expensive repair costs. Most Japanese thus prefer to buy a new car instead; most used cars are then exported to other Asian countries where they are operated for many more years.

Table 3.4 The 'caring' index for automobiles in German-speaking Europe

	Fleet of cars	Of which young-timers (20–29 years)[1]	% of fleet	Of which old-timers (30 plus)[2]	% of fleet	% over 20 years	Popu-lation
Austria	4.1 million	Included in old-timers		125,000		2.7	8.2 million
Germany	45 million	500,000	1.1	425,600	0.9	2.0	82.7 million
Switzerland	3.9 million	84,000	2.1	60,000	1.5	3.6	7.7 million

[1]Youngtimer cars are 20–30 years old.
[2]Oldtimer cars are older than 30 years,
classic and vintage cars are subcategories of oldtimer cars.

Oldtimers are rare on Japan's roads and can be admired only in manufacturers' museums.

The caring index is hampered by the fact that most national statistics are a mirror of the dominating Industrial Economy's focus on throughput. Production statistics abound but data on stocks (physical wealth) hardly exist.

In Germany, several organisations specialise in tracking down older cars. One of them, the German Automobile Association (ADAC) has done extensive research and in June 2009 published its first statistics on vehicles older than 30 years in Germany (in the following called old vehicles):

- The total number of old (including vintage) vehicles in Germany on 1 January 2009 was 803,000, of which 53 per cent (425,600) were cars and 47 per cent motorbikes.
- Two thirds (539,000) of the old vehicles were still being used under normal conditions.
- Most of the other 264,000 vehicles were equipped with red number plates for occasional use at antique car rallies (54 percent), exhibited in museums (19 per cent) or under repair or restoration (27 per cent).

ADAC estimates that the number of Germany's vehicles over 30 years old increased 11 per cent in 2008, which is thus a sign not only of a population's growing 'caring' attitude but also of a rising economic factor! However, the trend may not continue for long for a number of reasons:

- Germany's strict environmental legislation demands that second-hand cars be upgraded to new emission standards when sold. As the cost of the upgrading is higher than the residual value of the car, many used cars are scrapped, except if there is no change of ownership.
- To promote new vehicle sales, Germany in 2009 began paying hefty premiums to owners of cars over 10 years old if they scrapped their car and bought a new one. This policy is disguised as climate-friendly but is really an attempt to revive the car manufacturers of the Industrial Economy. A Life-Cycle Analysis (LCA) shows that a positive climate impact will happen only once the new car has been driven for several hundred thousand kilometers! This policy was 'invented' in the 1990s by the French Government. By 2009, it had spread to 13 European countries and the USA, under President Obama's 'cash for clunkers' law, despite the fact that environmentalists and many economists agree that it does not make sustainable sense.
- Electronic equipment in cars normally cannot be repaired – and spare parts are either out of stock or extremely expensive to replace. Vehicles built after 1980 may therefore never reach the age of 30 years – and thus never become oldtimers.

Other countries with a long tradition of caring for automobiles include the UK, Austria and Switzerland. But the highest percentage of oldtimer cars may well be found in regions with a benign climate, such as Kenya and California, and countries with strict import restrictions, such as Cuba.

The caring index can also be measured on national level, for instance by the number of natural and cultural heritage sites listed in the UNESCO World heritage list.

3.5.5 Autarky as driver

The Industrial Economy relies on an efficient global transport and logistics network to supply manufacturing plants just-in-time with raw material and semi-products. This manufacturing system has a high inherent vulnerability for any disruptive events, such as pandemics, natural catastrophes or sudden rises in raw material and energy prices.

The key strategy to combat this vulnerability has always been regionalisation of the economy, namely, stockpiling strategic resources or building back-up facilities. The Lake Economy can be regarded as a giant stockpile of goods, materials and embodied energy in a geographic distribution that corresponds to society's needs; the Loop Economy as the equivalent resource base available at short-term for manufacturing. But most governments have yet to exploit the disaster management aspect of the fleet management inherent in the Lake and the Loop Economy.

Some authorities have recognised the potential of the Lake and the Loop Economy for future economic growth and autarky. Cultural differences, however, determine the details, as is visible in the following two examples in the USA and Europe.

In the USA, the Golden LEAF Foundation, administrator of half of the money received by North Carolina from its settlement with cigarette manufacturers, has made US$9.3 million in grants available to the newly created N.C. Aerospace Alliance to help citizens get into the business of manufacturing out-of-production service parts for ageing military aircraft. This enables OEM suppliers to extend the life cycle of products and continue obtaining revenue past the product's planned economic life. The Alliance provides entrepreneurs of manufacturing structural components, electrical parts, engine components and hydraulic systems with assistance in certification and engineering, workforce training and access to capital. Golden LEAF's objective is to help create new industries at a time when North Carolina is making the transition from a tobacco- and textile-based economy to a new industrial base. State officials are making concerted efforts to keep in North Carolina the two major facilities for overhauling aircraft – at Cherry Point naval air depot and in Elizabeth City's US Coast Guard air centre – by making their operations more productive.

In the EU, the European Commission presented on 8 February, 2006, a strategy to promote biofuels, outlining a range of market-based legislative and research measures to boost biofuel production and increase competitiveness. In 2007, an energy crop credit was extended to farmers in all Member States on the condition that crops used for biofuels meet standards of environmental sustainability. Member States are being encouraged to grant biofuel tax exemptions or biofuel obligations requiring fuel suppliers to include a given percentage of biofuels in the total amount of fuel they place on the market. The EU's biofuel strategy is driven by energy, environmental, agricultural and development policies as well as rising oil prices, the uncertainty of uninterrupted natural gas supplies from Russia and the need for the European Union to reduce its dependency on fossil energies and its CO_2 emissions under the Kyoto Protocol.

3.6 How to overcome obstacles

The original inventors of 'sustainability' are the Prussian gentleman foresters of the late 18th century who managed their forests by caring for the capital 'forest' and living from the dividends (timber, but also game). All decision power was in one hand, and there was a clear acceptance of 'caring', prioritising the management of existing physical assets over maximum timber production. (see also Chaper 4).

Today, these conditions are not given, for instance after floods and other natural disasters. The 'victims' are municipal authorities, and the money comes from national governments. These often pay for the replacement of damaged structures even if they are not damaged beyond repair. This leads to a huge throughput of resources with a very low value-per-weight ratio and unnecessary transport and waste – without increasing national wealth! Innovations such as the bridge testing vehicle of Bremen University (in Section 3.3.3.5) and their scientific opinion are not welcome and may therefore not change the wasteful habits in place today, without adequate political support.

3.6.1 Creating the missing tools

In the modern world, the Prussian gentleman foresters' approach must be adapted to include physical assets – other than trees – in order to develop incentives and the necessary supporting and monitoring tools and structures. One of the first such incentive that has been created is the new remanufacturing and reuse category in the prestigious British Engineering Excellence Awards. This category was created in 2009 and is sponsored by the UK Centre for Remanufacturing and Reuse (CRR).

The British Standards Institution (BSI) in 2009 also provided a supporting structure in its new BS887-2 standard that clearly defines end-of-life terminology, including remanufacture, reuse, recycling and reconditioning. In the next phase, BSI will develop an umbrella standard to set out remanufacturing protocols to guarantee as-new performance. This standard can then be adapted to various industrial sectors and products.

The missing monitoring tools to measure changes in the quality of stock over time are perhaps the most limiting factors in the Lake and the Loop Economy today.

- There are no statistics to measure if the overall health in a country's population has increased or decreased over the last ten years. But we know how many people have been treated for ill-health, and how much has been spent for the health system – which is in reality a illness system.
- We do not know if today's students have a better comprehension of what they learn and a better capacity for applying that knowledge than students ten years ago. What we do know is how many students have passed an examination and how much this has cost.
- In accounting terms, we have the annual statement of income and expenditure, so we know how much we have spent and what for, but we do not have a balance sheet, so we do not know if, as a result of this expenditure, we have become richer or poorer.
- The situation is much the same in technology. We know how many cars are on the road and how many cars have been produced in the last year, but we do not know the state of the stock of cars, their remaining technical life or if they correspond to their drivers' needs.
- Even for a single piece of equipment, we often lack the tools that would allow measuring the quality and remaining utilisation value of components, either on a theoretical basis (such as basic research into such subjects as relative failure modes of wear versus fatigue of railroad rails) or with regard to a specific product (such as what is the condition of a car engine, and how many more miles will it run before the end of its useful life).

In national accounting, we have no instruments to measure the activities of the Lake and the Loop Economy. The EU market for 'products as services' in 1998 was estimated at €700–800bn, or 10 per cent of GDP. Within this figure, selling the function of products (fleet management) accounted for six per cent of GDP, remanufacturing services for 4 per cent.[37]

The shift to a successful adoption of the Lake and the Loop Economy will be accelerated by the development of these tools on all levels so that we can have instruments to optimise the management of physical assets, and the quality management of functioning systems, over long periods of time.

3.6.2 Creating the missing support

The business activities linked to product-life optimisation are examples of the sudden simultaneous and unrelated emergence of the same idea in many different places. This means that many innovators are not aware of the progress by colleagues elsewhere nor of possible synergies that could be developed. It also means that most activities in this area have the character of a craft. A multitude of auxiliary functions have to be carried along, even developed alongside, the primary activity, by each economic actor, a characteristic also typical for many SMEs in the manufacturing sector. Due to the lack of specialisation, most enterprises do not reach a size where they can afford to undertake R&D efforts that would enable them to proceed further. Robots to renovate house facades without putting up scaffolding and without dust are but one example in the building industry.

Activities that are close to manufacturing technologies – such as remanufacturing combustion engines or in-house remanufacturing by fleet managers – are no exception. The majority of activities in the Lake and the Loop Economy suffer from a lack of research, appropriate equipment, services and other support. If unavailable in the marketplace, such support must be developed in-house or the activities will lack competitiveness.

In the USA, networking between remanufacturers is concentrated mostly around the annual American Production and Inventory Control Society (APICS) conferences and the research programme on Environmentally Benign Manufacturing (EBM) by the National Science Foundation. In Japan, regular conferences on inverse manufacturing have a similar function.

A large untapped potential to create new innovative structures also exists in many fleet management operations. Tapping these resources needs an awareness that the knowledge carriers of remanufacturing and reuse are the workers and engineers doing the maintenance work as well as the workers on the shop floor in remanufacturing plants, not the engineers involved in design and manufacturing.

There are a number of tools to tap this potential:

- Quality circle discussions and other exchanges of experiences between the different departments involved in product design, production and remanufacturing activities within a company will greatly enhance corporate competitiveness, as shown by the examples of Caterpillar and GE Medical Systems.
- Improvement proposal systems in corporations enable any employee to submit ideas that are then checked for their economic and technical feasibility. Successful systems range from
  - DuPont de Nemours' annual 'Sustainability Awards' primarily attributed to teams of workers and supervisors in large production plants, to

- the Germany Railways' '*DB Vorschlagswesen*'. The latter's rolling stock maintenance workshops are the national champions with regard to the number of proposals per hundred workers (26.6 proposals in 2008), the ratio of implementation and the economic profit realised: over €99,000 per maintenance worker and €13,250 per employee at the corporate level in 2008!

In all German corporations surveyed in 2008 by the Central Ideas Management Organisation (DIB – *Dachorganisation für Ideenmanagement*), 1.4 million improvement proposals were submitted in 2008, 70 per cent of which were realised and resulted in annual savings of €1.55bn.

3.6.3 Creating incentives for product reuse and remanufacturing

Incentives can be created to overcome resistance at political and institutional level and to overcome industrial and consumer resistance.

In some cases, the elimination of hidden subsidies to create a level playing field would have the biggest effect. Waste, for instance, is not submitted to VAT and duties – incinerating old tyres or used oil is the cheapest energy resource for industry and individuals. VAT should therefore be credited to economic actors of the loop economy, the same way that this is done in a manufacturing chain.

3.6.3.1 Overcoming political and institutional resistance

Many policymakers regard the Lake and the Loop Economy with suspicion as they jeopardise today's concept of wealth creation through manufacturing by reducing the throughput, economy of scale and productivity of the Industrial Economy. The fact that the Lake and the Loop Economy conserve overall wealth, reduce waste, resource consumption and CO_2 emissions and create skilled jobs is ignored, as there are as yet no statistical tools to measure these changes.

The economic misjudgement of the Lake and the Loop Economy is due partly to the 'depreciated value' concept used in tax estimation and liability compensation. A seven-year-old automobile, for instance, is fully written off from a taxation point of view. It has become a zero-value product, despite the fact that it has a technical life of 20–30 years, and independent of its qualitative state of the art (its utilisation value). If the replacement value concept used for production tools and buildings was used for car accidents, the insurance company of a faulty driver would have to replace a destroyed seven-year-old car of the innocent driver with a car of a utilisation value similar to the car destroyed, rather than payment of a symbolic sum (the depreciated value being zero).

The replacement-value concept is today imposed by few authorities, an exception are the Courts in Belgium.

3.6.3.2 Overcoming industrial and consumer resistance

The regionalisation of economic activities in the Lake and the Loop Economy contradicts present strategies of centralised global mass production and local sales commissions. A car dealer who gets a mark-up of more than 20 per cent on a new car sale cannot get the same 'return-on-effort' when repairing or remanufacturing a car. Other disincentives to product-life extension from manufacturers, legislators and consumers include:

- maintenance obstacles: built-in design features to prevent cheap repairs and planned obsolescence in the form of components with a limited service-life,
- economic confiscation: third-party compensation by legislation and courts that value a product at its depreciated value rather than at its utilisation value,
- psychological obstacles: 'bigger-better-faster-safer' publicity that creates a belief that 'new is superior' rather than 'old is resourceful', and
- discontinued production of spare parts, such as paper bags for vacuum cleaners and rubber joints for refrigerators.

Maintenance obstacles are quickly eliminated in selling performance and the manufacturing of goods used in the Functional Service Economy of Chapter 2, when the cost of operation and maintenance is borne by a fleet manager who is paid for performance of the goods being used.

Economic confiscation can be overcome by introducing utilisation or replacement value in legislation ruling third-party liability. Many insurance contracts already stipulate 'new or replacement value' to insure production equipment and personal belongings and 'reconstruction value' for fire losses of buildings.

Overcoming consumer resistance and the psychological obstacles within ourselves may be the most difficult part, at least for consumer goods. A lack of caring by users has a negative impact on the Lake and the Loop Economy. Destruction by users when operating goods can be prevented by technology that safeguards the interests of the fleet manager of a long-life product, for instance by attaching RPM governors to the engines of rental cars. Sufficiency solutions can be taken or ignored by the user of, say, a car but influenced by incentive payments. 'Car glass' franchises offer drivers a repair solution for damaged windscreens that can be repaired by a fast intervention, and drivers are rewarded by their insurance company if they prevent a loss.

Easy quality monitoring is crucial to avoid waste due to consumer insecurity. If there is no easy way to determine the remaining power in a small disposable battery in say a film camera, one cannot prevent people from throwing away almost unused batteries in order to be 'on the safe side', except by promoting the use of rechargeable batteries and charge checkers.

Psychological resistance is linked to the syndrome of 'keeping up with the Jones's' and a belief that used goods, even if properly cared for, are a sign of poverty, not of good husbandry and resourcefulness. This is not a new phenomenon! In Arthur Miller's play 'The Death of a Salesman', when Willy finds his wife Linda mending stockings, he angrily shouts:

> 'I won't have you mending stockings in this house! Now throw them out!'

This is a proud statement from a bankrupt salesman. And a wise attitude of his wife: Linda puts the stockings in her pocket. But do-it-yourself repairs have their limitations, also in producing spare parts which are no longer on the market.

3.6.4 Creating the missing university curricula and educational support

Most remanufacturing activities, including such options as the technological upgrading of goods, suffer today from isolation due to an absence of outside innovation and stimulus provided by outside players, including universities and consultants.

Do not count on researchers at universities for product-life statistics! Most economics professors do not include the Lake or the Loop Economy in their lectures, and do not know the rare figures published. Most statistics in this chapter are based on data collected by operators and fleet managers of goods and communicated to the author as a courtesy.

The best technical schools in industrial countries continue to exclusively train technical experts for the manufacturing industry and marketing specialists for the Point of Sale. It is important to educate

- 'life-cycle-cost engineers' specialised in cost optimisation of complex systems – such as hospitals, motorways or water and sewer systems – over longer periods of time, and

- 'utilisation marketers' who can develop marketing tools to sell the lower unit costs of long-life goods, compared to disposable goods, and the advantages of reused goods.

Then, the Lake and the Loop Economy will become a concept accepted by the technical and scientific elite, and researchers will study new fields of science relevant to a system utilisation optimisation over long periods, such as 'tribology' (an interdisciplinary subject integrating friction, wear, corrosion and lubrication).

The economic and engineering basics of operation and maintenance activities, as well as the importance of product and system skills for these activities, should be part of the curriculum of every technical school. 'Operation and maintenance' engineering should be introduced at all levels of technical education. Innovations such as mobile workshop or intervention units to carry out these activities should receive special attention, as should methods to determine the remaining service life of equipment, structures and bridges. In addition, actors in the Lake and the Loop Economy need skilled manpower to execute testing and evaluation as well as the activities themselves, and the Industrial Economy needs experts to integrate the lessons learnt from utilisation optimisation into the manufacturing process.

> Operation and maintenance engineering should be introduced at all levels of technical education.

In the UK, a number of universities have started to study the opportunities of the Lake and the Loop Economy. In Germany, Professor Rolf Steinhilper was nominated in 2004 to the first chair for remanufacturing (*'Lehrstuhl für umweltgerechte Produktionstechnik'*, or chair for eco-production techniques) at the University of Bayreuth.

With regard to loops of molecules, the study of dissipative systems not only in biology but also in techno-economics and waste streams should be given as much weight as the study of the exploitation of highly concentrated natural resources – see the example of gold concentrations in a Japanese waste treatment plant on page 246.

3.6.5 Creating incentives for innovation – The role of framework conditions

Xerox, Michelin, Rolls-Royce and Caterpillar are examples of companies that exploit an extended service-life as an economic opportunity.

Their voluntary, market-driven take-back solutions go far beyond any legislation proposed by the European Union for used goods. Whereas the EU directives focus on limiting environmental damage, the strategies of the four firms maximise wealth and job creation! This indicates that it is better to leave the choice between the different business models (presented in Chapter 3) to the market, rather than to legislate the government's view of waste. Where other framework conditions are more efficient to achieve the desired result of economic, ecological and social efficiency, waste leadership could turn into economic stagnation. The economic policy thinking that could support these new concepts is still in an embryonic stage.

Courts can hinder the Lake and the Loop Economy, too. In the USA, car parts became a major issue after an Illinois court decided that the State Farm Insurance Company defrauded customers in 1999 by allowing the use of generic parts for repairs without telling them and slapped the company with a substantial fine – originally over US$1bn – that was however reduced after appeal.

Prior to the Illinois court decision, the use of non-OEM parts was common practice. After the stunning ruling, many insurance companies, not even parties to the litigation, discontinued the use of non-OEM parts because of the litigation risk.

The National Conference of Insurance Legislators (NCIL), at their 2002 conference, again took up the issue of repairing damaged cars with parts not made by OEMs. They proposed endorsing the certification of aftermarket parts by third-party organisations, such as the Certified Aftermarket Parts Association (CAPA), which would require disclosure as to the use of such parts. One key issue of the debate was over the safety of certified aftermarket crash parts often used by OEMs to 'block out' the competition. The issue pits auto manufacturers against producers of aftermarket crash parts with the interest of the insurance industry to maintain competition.

Government policies to foster Lake and Loop innovations include:

- promoting free market safety nets rather than legislation and mandatory standards in order to speed up innovative solutions (First Solar's insurance for recovery and recycling expenses at the end of its products' lives is an alternative to national take-back legislation),
- rewarding an extended product responsibility and closed-loop strategies by OEMs, especially for 'chewing-gum goods' that are used once and then thrown away,

- taxing what is undesirable, such as production of waste and consumption of non-renewable resources, instead of taxing renewable resources including manpower,
- giving preference to pragmatic 'do it' approaches, such as learning by doing, over scientific studies, even in research funding,
- promoting the diffusion of innovation through public procurement policies (UK firms have invented cheap car repair methods that 30 years later are still unknown outside the UK),
- building the 'Factor Time' into consumer protection legislation, by specifying long-time warranties instead of forbidding the use of remanufactured components in (new) goods, and by defining quality as a guarantee of long-time system functioning rather than as zero-fault manufacturing,
- rewarding the prevention of waste and emissions through the Lake and the Loop Economy (waste is not free, it has a negative value equal to the waste disposal costs paid for by the community),
- rewarding the prevention of CO_2 emissions in the Lake and the Loop Economy on equal terms with the CO_2 emission reductions of the Industrial Economy, by changes in the successor of the 1992 Kyoto Protocol,
- adopting performance standards and systems specifications, rather than product standards,
- cutting the link between the time an equipment is used and the time it is written off, to avoid the 'depreciation' waste of perfectly functioning equipment for tax reasons,
- replacing the residual value concept in third-party liability legislation by the 'replacement or utilisation value' concept already used for production tools and buildings, and
- introducing a labelling of the 'renewable resource content' of goods and services on invoices and in annual accounts.

3.7 How to measure it!

The new measure of managing performance over time in the Performance Economy is the part of the economic value that is created by using renewable resources including labour.

Value creation from renewable resources, measured as:

(a) **labour-input per weight** (manhours per kg),
(b) the cost of the renewable resource content as per cent of total cost (percentage).

Similar to environmental and social issues, such as use of clean technologies and absence of child labour, consumers can only use these metrics at the point of sale if each product's label shows separately:

- the labour-input in man-hours,
- the percentage of total cost for renewable-resource inputs including manpower (or alternatively the percentage of total cost for non-renewable resource inputs).

This is the case today for some repair service bills but unknown for manufactured goods.

The Lake and the Loop Economy are competitive and sustainable because they enable the creation of skilled jobs with a greatly reduced consumption of materials and energy. But this fact is not publicised and cannot be verified by the buyer.

The Lake and the Loop Economy introduce the Factor Time into economic optimisation and act as a virtuous circle: the longer a product is used, the higher the effect of substituting manpower for non-renewable resources becomes.

The Lake and the Loop Economy create higher value-per-weight and higher labour-input-per-weight ratios than the manufacturing industry.

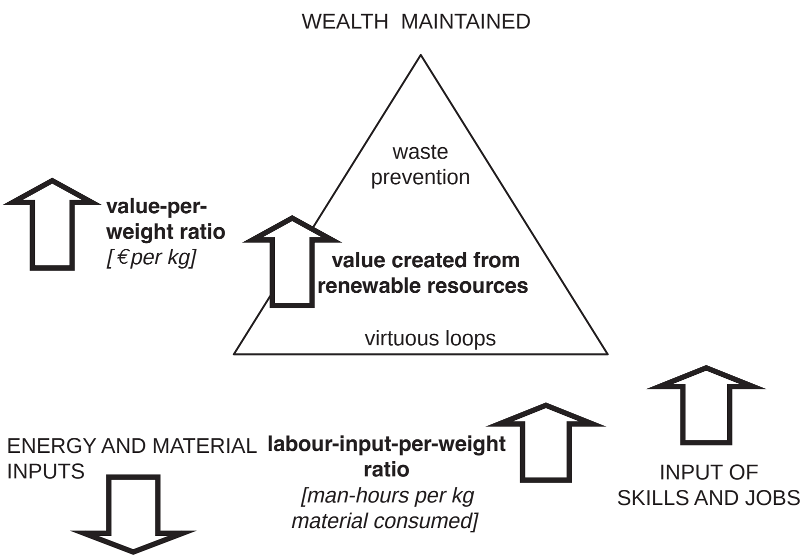

Figure 3.11 The objectives and metrics of managing performance over time in Chapter 3

As non-renewable resources – both energy and materials – become scarcer and hence more expensive, value creation from renewable resources becomes doubly profitable as both national policy and corporate strategy! (Figure 3.11).

Corporations can show this metric in their annual report or corporate sustainability report (CSR). No CSR or sustainability rating today uses this yardstick, except for energy costs (percentage of energy from renewable sources). Including the metrics presented in this book would complete the analytical picture and guide sustainable investments. A first such attempt to develop a Resource Efficiency Index (REI) is under way by the author in cooperation with the University of Surrey, where he is a visiting professor.

Despite the higher labour input, the asset management of the Lake and the Loop Economy is competitive as it follows two self-centred economic reasons:

- exploiting the fact that the cost of remanufacturing a product is inherently cheaper than the cost of manufacturing an equivalent new product, by an average of 40 per cent, and
- rewarding laziness by maximising the residual value of existing wealth: do not throw away what can be resold, do not remanufacture what can be repaired and do not repair what is not broken.

Physical asset management in the Lake and the Loop Economy is sustainable because it substitutes renewable resources, such as manpower, for non-renewable resources, such as virgin raw materials and energy throughout the economy.

4
Sustainability and the Performance Economy

4.1 In praise of chaotic self-regulating systems

The dominating concept of sustainable development encompasses three dimensions of welfare – economic, environmental and social. It has its origin in forestry management and is of a static nature.

Most systems with a lasting success, by contrast, are of a dynamic nature and based on self-regulation or chaos as the main principle – witness the market economy, nature, democracy and innovation.

4.1.1 The market economy as a dynamic self-regulating system

The market economy self-regulates itself through numerous consumers choosing from what is offered in the marketplace by the numerous butchers, bakers and candlestick-makers going about their business offering their individual wares in competition against each other – the invisible hand of Adam Smith.

However, many industrial and service companies inherently tend towards concentration, growth and monopoly where there is a higher 'return on effort' (the monopoly rent) than in competitive markets, and their lobbyists try to restrain the uncontrolled development by demanding 'foreseeable politics', which is another term for order. Yet, the stability sought must lead to an abrupt discontinuity later on, according to Nobel Prize Laureate Ilya Prigogine;[1] therefore, politicians and economic actors alike should resist order.

Agreed, there is a delicate balance between strict regulation and self-regulation with checks and balances. The credit crises, or financial bubble, of 2008 happened despite a high degree of regulation, partly because the supervisors and regulators did not use their powers, with the exception of Lebanon. Its banking supervisor was the only one to ban investments into sub prime and other toxic papers, and as a result the financial centre of Beirut sailed through the storm largely unhurt. Could the application of regulation be more important than 'perfect' regulation?

The Performance Economy leads to a more competitive *and* sustainable development of societies by focusing on economic incentives for self-regulation of economic actors. It creates a path towards a sustainable future by favouring the internalisation of the costs of risk and waste, systems solutions and sufficiency over product efficiency, virtuous loops over vicious loops and innovation over incremental improvements. But it may not be immune to regulation.

4.1.2 Nature as a chaotic self-regulating system

Nature's strategy is based on entropy and decentralisation, diversification and recombination and on permanent change and innovation. Nature is a truly chaotic system in which attractors can develop at random because the system is biased towards diversity and entropy. Ilya Prigogine showed in his research that if nature's chaotic order is frozen by strong attractors, this stability heralds abrupt discontinuity and danger. Nature will always survive because it has no leadership. When the renowned physicist Alfred Einstein realised this, he complained that 'God plays with dice'. Yes, chaos means eternal life! Are politicians' efforts to protect the environment through detailed legislation motivated by a distrust for chaos more than by a desire to increase people's quality of life through radical innovation? Ecology – the science of nature as it is – is increasingly replaced by ecologism, a view of nature as experts think it ought to be. One sign of this are the hundreds of eco-labels meant to guide consumers but creating confusion instead of clarity.

4.1.3 Society as a dynamic self-regulating system

Society is, in principle, also chaotic. Most policymakers therefore see their role in creating order through top-down regulation (see Section 1.3). Yet, most regulations lack adaptability because they specify technical details instead of stipulating desired performance. Legislators generally prefer centralised command-and-control solutions and short-term goals even if they cannot impose them. And they distrust the long-term creativity of chaotic systems, such as the Swiss direct democracy with its preference for subsidiarity – decision taking at the lowest possible level. The subsidiarity principle, not centralisation, has been the European Union's objective, but evolution goes the opposite way.

There is some discussion if democracies or enlightened dictators are more efficient to rule emerging economies – the evolution of China versus India is a case often quoted in this respect.

The crucial factor for dynamic systems to self-organise is time, a lack of speed. Political leaders can react instantly; parliaments need more time; direct democracy is even slower. Understanding the 'Factor Time' is thus crucial for sustainable politics. If a nation wants trees for shade along its roads, it has to plant them a decade before it will need them, as Napoleon explained to his generals.

4.1.4 Innovation as a chaotic self-regulating system

Innovation is again unpredictable and uncertain. Its results are unexpected and thus cannot be planned or foreseen, similar to the success of a new business model in the market, a windstorm or a public vote. Yet, there is the phenomenon of the unrelated simultaneous emergence of the same idea in different places, indicating a short-term order within the chaos, or one of Prigogine's strong attractors.

Nature, the market economy, democracy and innovation are successful examples of highly diversified, decentralised and dynamic systems, which may be 'inefficient' in the short term but durable and resilient in the long run. By contrast, specialisation and order are efficient in the short term but often not durable! Sustainability has become a global static rule more than a guiding concept over the last decade; this raises the question if a dynamic self-regulation concept of sustainability would not be more compatible with today's scientific innovation and technological progress.

4.2 The concept of sustainability

The 1987 book *Our Common Future*, published by the UN World Commission on Environment and Development under the chairmanship of Gro Harlem Brundtland, published the most common definition of sustainability, that the present generations should not used up the resources of future generations.

Agenda 21 of the 1992 UN Declaration on Environment and Development at Rio de Janeiro then urged countries to 'develop indicators of sustainable development' in a way that would 'contribute to a self-regulating sustainability of integrated environment and development systems' – what this book calls virtuous loops.

The 2003 UN Marrakech Declaration on South–South Cooperation formulated five objectives as a follow-up to Rio and Johannesburg. Two of these are to uncouple economic growth and resource consumption and to create a circular economy.

The Performance Economy provides the tools for these two Marrakech objectives, showing business models of how to achieve a higher value-per-weight ratio and how to optimise the Lake and the Loop Economy. The corresponding metrics provide an easy means for consumers, economic actors and nation states to judge individual products and services, factories, corporations and regions, with regard to the two Marrakech objectives above.

The common definition of sustainability as a triple optimisation of ecological, social and environmental performance can be shown as a triangle (see Figure 4.1).

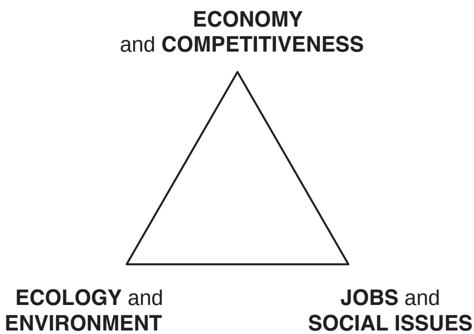

Figure 4.1 The key dimensions of the sustainability triangle

The Performance Economy translates these abstract terms into units and metrics that can be applied to the activities of economic actors. Two pictures can explain how the Performance Economy, and its objective of achieving higher competitiveness in a sustainable way, fits into the present discussion on promoting a more sustainable development: 'The sustainability triangle of the Performance Economy' in Figure 4.2 and 'The Quality Cube' that defines quality as performance optimisation over longer periods of time.

A higher sustainability means to achieve more from less: an increase in wealth and jobs to guarantee a decent quality of life for all, combined with greatly reduced resource consumption in industrialised countries. The Performance Economy has the business models to achieve this, and the metrics to measure the progress of change.

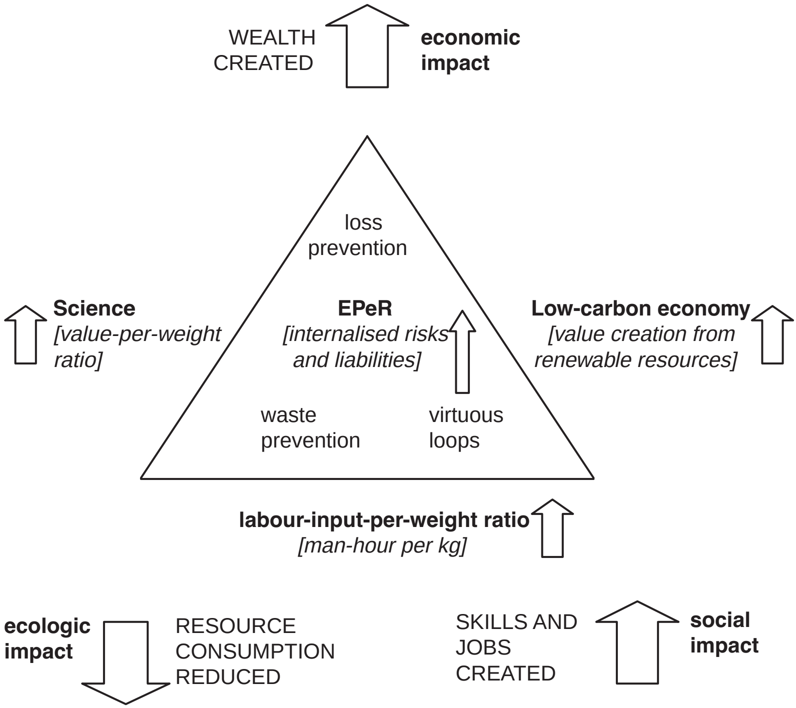

Figure 4.2 The sustainability triangle of the Performance Economy

4.2.1 The Quality Cube of the Performance Economy

The second picture to explain the link between the Performance Economy and the concept of sustainability is the Quality Cube, defining quality as product-system optimisation over longer periods of time (Figure 2.1). Each of the three goals of the Performance Economy corresponds to a plane of the Quality Cube (Figure 4.3).

The Performance Economy can thus also be defined as business models to create a new Quality based on a triple optimisation of Time, Efficiency and Prevention, using Science, Job Creation and an Extended Performance Responsibility (EPeR) as drivers.

4.2.2 The OECD's decoupling and composite indicators[2]

The metrics in the sustainability triangle of the Performance Economy constitute decoupling indicators, each combining two issues, with the desired factors of wealth and jobs increasing and resource consumption shrinking. According to the OECD, decoupling indicators are useful in

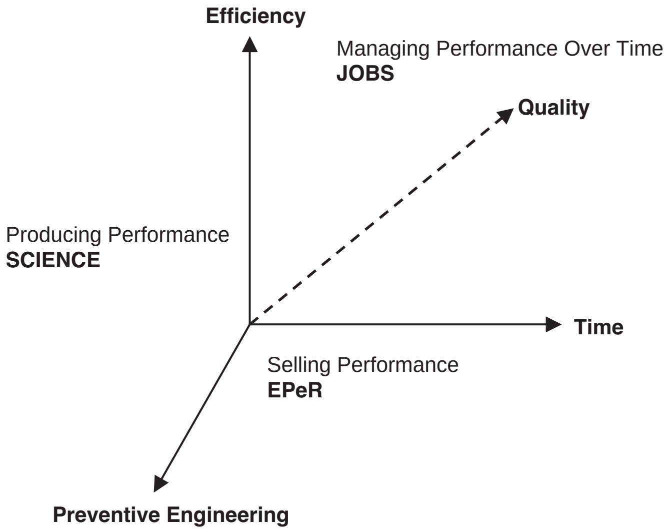

Figure 4.3 The Quality Cube of the Performance Economy

helping policymakers understand the interface between developments in two different spheres.

In the OECD's decoupling *environmental* indicator (DEI), the term decoupling refers to breaking the link between 'environmental bads' and 'economic goods'. It refers to the relative growth rates of a direct pressure on the environment and of an economically relevant variable to which it is causally linked. Decoupling occurs when the growth rate of the environmental pressure (EP) is less than that of its economic driving force (DF) over a given period. There is a distinction between absolute and relative decoupling. Decoupling is said to be absolute when the environmental variable is stable or decreasing while the economic variable is growing. Decoupling is relative when the environmental variable is increasing but at a lower rate than the economic variable. (See http://caliban.sourceoecd.org/vl=686377/cl=48/nw=1/rpsv/factbook/ for the OECD's 2008 statistics panorama. Click on 'show all indicators' for the detailed table of contents.)

The metrics proposed in this book are decoupling *sustainability* indicators (DSIs) not yet considered by OECD. The value-per-weight ratio compares an economic variable with an environmental (resources) variable; the labour-input-per-weight ratio compares a social variable with an environmental one; and the value-from-renewable-resources metric indicates the environmental quality of the economic variable (considering man as part of nature). These decoupling indicators of the Performance Economy can be used on a micro- (local), meso- (regional) and macro- (national) level.

On a multinational level, the OECD has defined composite indicators, which are synthetic indices of groups of individual indicators used to compare and rank countries as to environmental performance and sustainable development. They integrate large amounts of information into easily understood formats for a general audience. However, there are serious questions regarding the accuracy and reliability of composites, particularly in ranking country performance.[3]

4.2.3 World resource consumption

The Industrial Revolution has enabled poor countries to turn a scarcity of goods into an abundance of goods and to create goods for the masses. Resource consumption (ecology) and jobs (social) were at the base of wealth creation (economy) during the Industrial Revolution. Many emerging economies that still have a subsistence economy therefore rightly dream of their own industrial revolution.

Global resource consumption clearly reflects the evolution of industrialisation: the top 20 per cent of the world population living in industrialised countries consume 80 per cent of the world's resources,

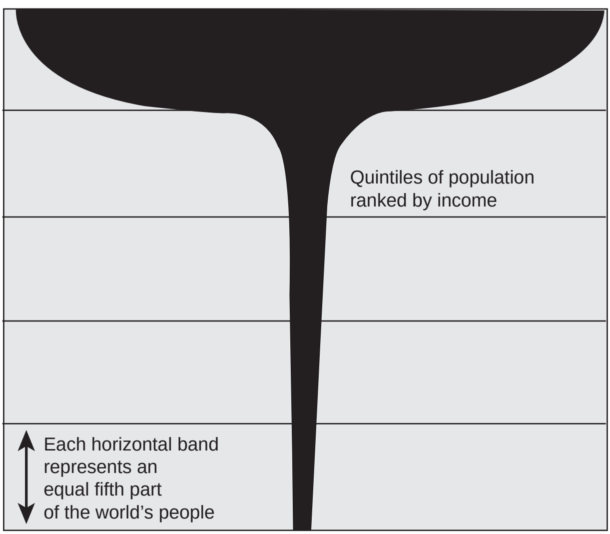

Figure 4.4 Distribution of world resource consumption by income groups today

as shown in Figure 4.4 of a Champagne glass.[4] The population in industrialising countries and emerging economies, the lower four fifths, consume a minor part of world resources, and a minute part if calculated per capita. World resource consumption is thus hugely imbalanced between different countries and their populations.

Spreading the concept of the Industrial Revolution, and bringing with it a globalisation of the material throughput of industrialised countries, would soon produce a demand for resources corresponding to the equivalent of several Earth planets. This situation, represented by the large glass in Figure 4.5, is hardly feasible as we have only one Earth.

A future in balance with Earth's resources, where all people have equal access to resources, corresponds to the *inner pillar* of Figure 4.5. For the industrialised countries, the top fifth of the figure, this signals a need to reduce their present resource throughput ten-fold, namely, by a Factor Ten[5] equivalent to a 90 per cent decrease.

'Resource trading rights', similar to 'pollution rights' and the proposed CO_2-emission or carbon trading, could balance the regional per-capita under-consumption and over-consumption of resources. Industrialised countries would then need to buy resource consumption

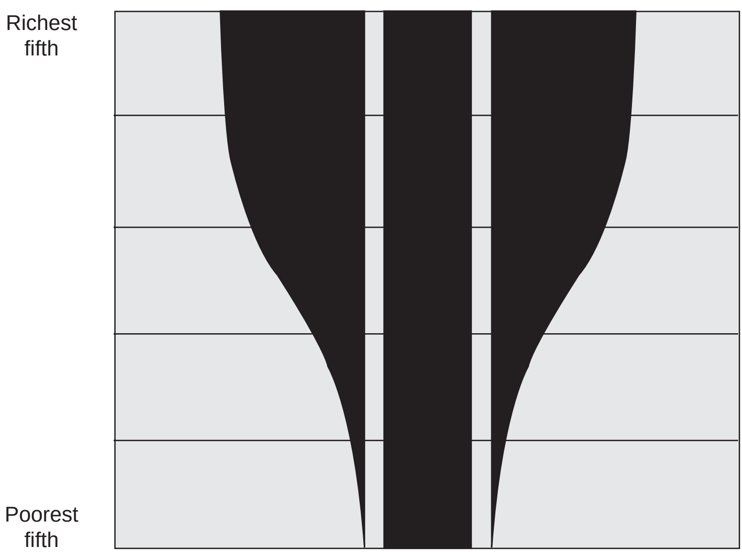

Figure 4.5 Alternative distributions of world resource consumption by income groups in future

rights from less-developed countries, which could replace present development aid and eliminate feelings of guilt or inferiority. Resource trading rights would not suffer from the ethical problems of carbon trading, which is based on an abuse of a Global Commons, the atmosphere.

Alternatively, industrialised countries could tackle the problem with an entrepreneurial attitude. Instead of selling goods cheaply, say ten tons at €1 per ton, they could learn to sell them at a much higher value-per-weight ratio of €10 per ton! This latter approach reduces resource throughput ten-fold, while maintaining the revenue base of both enterprises and national economies (Figure 4.6).

A potential resource scarcity caused by the industrialisation of emerging economies could thus be avoided by a greatly reduced resource consumption of industrialised countries. The pillar of a sustainable resource consumption that replaces the large glass in Figure 4.5 represents this balanced situation. This solution corresponds to the Performance Economy and is a sustainable strategy that will, however, need new business models of qualitative growth in industrialised countries.

OECD work on resource consumption is based on developing accounts in physical units comprising the extraction, production, transformation, consumption, recycling and disposal of different types of materials. Priority is given to accounting for high volume flows

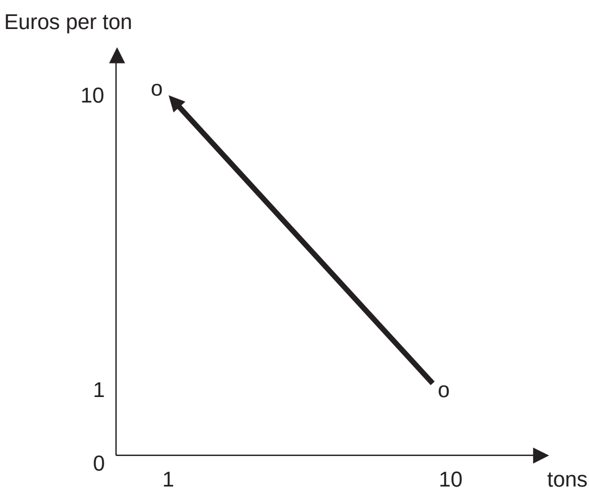

Figure 4.6 Dematerialising the Industrial Economy 10-fold without loss of revenue

(metals, wood, fish) and toxic flows (chemicals, pollutants). The aim is to develop a common accounting framework within which countries can collect data and fashion indicators on material flows.[6] The data will help to understand but not to solve our problems.

4.2.4 Sustainability benchmarks and metrics

Definite benchmarks are needed to focus efforts on sustainable solutions. One such benchmark exists for mobility. Any solution that enables people to move further or at a faster pace than a pedestrian, with a unit of energy, is sustainable. Man is thus the point-zero of mobility. Bicycles, elevators and possibly sailing boats are among today's few technologies that offer a more sustainable mobility than a person on foot.

Plus-energy buildings are a clear benchmark in the construction industry. But zero- or plus-energy buildings will also change the role of life-cycle analysis (LCA), as the energy embodied in materials now becomes the new challenge: maintaining physical assets over time takes on a central role in sustainable solutions of buildings (see Chapter 3).

But for many other sectors of activity, we have no benchmark to guide the technological and organisational development of new solutions. However, a number of the examples shown in Chapter 1 are pointing to new sustainable solutions.

Sustainability benchmarks should also help to stop subsidises for unsustainable solutions. According to a recent study, Germany subsidises activities with a negative impact on the environment with €30bn per annum. Stopping these subsidies would save money and save the environment and, in many cases also create local jobs.

4.3 The relevance of the Performance Economy to emerging economies

Per-capita resource consumption is small in most less-developed countries (LDCs), better referred to as 'emerging economies'. To overcome a scarcity of goods, the Industrial Economy has been and still is a proven strategy to produce large volumes of goods with decreasing unit costs to achieve sufficient stocks of goods. This is the case for most LDCs. Yet, the Performance Economy still has some strong messages for emerging economies!

- '**Exploiting SCIENCE**' in the Performance Economy enables emerging economies to leapfrog those industrialised countries characterised by a risk-averse attitude towards scientific progress, and jump ahead in international competitiveness.

If the convergence of sciences is accepted as a starting block in the education systems of emerging economies, rather than the traditional scientific disciplines, their advances could become durable.

- **'JOB Creation'** in an asset management economy is already the case in many emerging economies. Especially waste and loss prevention through proper operation and maintenance are of high relevance for emerging economies! Many countries could gain more by focusing on proper operation and maintenance of their infrastructure – such as water-supply systems, waste-treatment plants, power-supply networks and railways – rather than on building new ones. But the number of existing goods may be insufficient for a fleet-management approach and the quality of many goods and infrastructure may be inadequate (see Figure 4.7).

  Other job opportunities come from accessibility solutions. Today, emerging economies still greatly rely on customer mobility. No access to mobility is then equivalent to no access to goods and services. Developing key capabilities based on accessibility, including mobile units, can help in both economic development and creation of new jobs. The first tool successfully used in this sense is the mobile phone.

Quality high	**RENTAL ECONOMY** sale of fashion and function in a multi-option society or for short time use (clothes, uniforms, equipment)	**PERFORMANCE-ECONOMY** sale of performance and results in system solutions in the sense of physical asset management (infrastructures, investment goods)
Quality low	**INDUSTRIAL ECONOMY** sale of (replacement) goods to keep the throughput economy (and GDP) going (clothes, cars, electronics)	**THIRD WORLD** the dilemma of a scarcity of resources, goods and money (equipment, vehicles)
	short product-life	**long product-life**

Figure 4.7 The economic quality dilemma of manufacturing: Quality and durability of consumer goods

- **'Promoting EPeR'** (extended performance responsibility) makes good sense for many emerging economies. Rather than 'buying' power stations or railway systems of the most efficient and latest technology, for the operation and maintenance of which there is no local base, governments can buy such performance as 'kWh delivered' or 'transport capacity provided' by following Private Finance Initiative (PFI), build-operate-transfer (BOT) or build-own-operate (BOO) strategies – see Section 2.4.3. With these strategies, the risks of financing and operating the new infrastructure remain with the manufacturer supplying the new technology for some decades to come. In its own interest to maximise profits, the contractor trains locals to properly operate and maintain the new technology. The EPeR approach can be applied to all product groups, and national economic actors can compete by offering indigenous solutions.

  The traditional commercial term BOT or PFI today is often replaced by Private-Public Partnerships (PPPs). Yet, PFI is clearly an entrepreneurial strategy of selling performance by supplying customer satisfaction without 'ifs' and 'whens' in the context of the Performance Economy. Political newspeak should not blur the key issue of the extended performance responsibility and the economic feasibility involved in PFI projects, but not necessarily in PPP![7] PPPs often limit the liabilities in order to foster public goods, as exemplified by an international agreement to limit the losses from accidents in civil nuclear-power plants. This possibly first international PPP limited the liability from nuclear accidents to initially US$200 million and the national territory of where the accident occurred. The Chernobyl nuclear plant meltdown showed the meaning of the agreement: the USSR could not be held liable for losses in other European countries. But without the agreement, civil nuclear power stations would probably never have been built, as the risk was considered uninsurable at the time.

4.4 The relevance of the Performance Economy to industrialised countries

The Performance Economy will enable industrialised countries to overcome some of today's most pressing problems:

- A **SCIENCE** PULL enables wealth creation and economic growth without resource consumption in a market economy and with minimal state intervention, within the limits of insurability of risks, in the best cases.

- MORE SKILLED **JOBS** will reduce local unemployment in regional economies and ease the pressure for an early retirement of able workers. This will increase private spending, decrease public expenses, lead to smarter exploitation of renewable resources (including human labour and knowledge) and lower consumption of non-renewable materials and energy. The OECD's range of *social* indicators is broad and grouped under four policy objectives: 1) enhancing the independence of individuals; 2) promoting equity in social outcomes; 3) improving the health of populations and 4) securing social cohesion.[8] The impact of the Performance Economy on these indicators has so far not been studied.
- **EPeR** (extended performance responsibility) reduces the expenditures of nation states for waste elimination, clean-up, technical disasters and natural catastrophes – the public sector's hidden part of the iceberg. Furthermore, the internalisation of social and environmental costs by economic actors reduces the need for national legislation and eases the burden on state budgets.

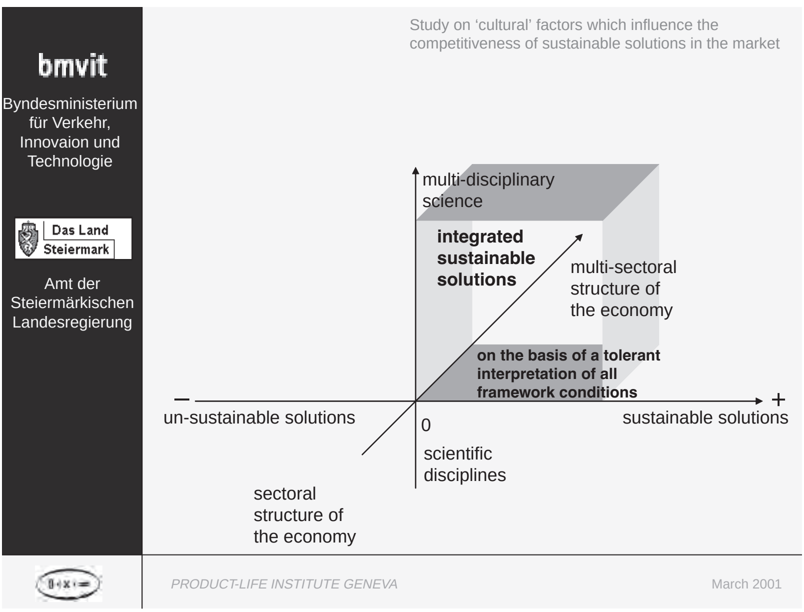

Figure 4.8 The 'cube of tolerance' to foster sustainable solutions

4.5 What are the drivers of change?

The Performance Economy, as most sustainable solutions, is of a trans-sectoral and trans-disciplinary nature. With regard to the benchmarks in Section 4.2.4, tolerant framework conditions are needed for many solutions to the right of point-zero in order to foster sustainable solutions. Sustainable solutions need a 'borderless' interpretation (tolerance, fuzzy logic, system focus) of framework conditions (legislation, rules of economic structures) in order to blossom. (see Figure 4.8.)

4.5.1 Interdisciplinary solutions

The present trend of converging sciences will eliminate many of the obstacles in scientific thinking that hinder the application of the Performance Economy today, if its progress is not stopped by traditional discipline thinking.

Future drivers of change may well be shortages of resources – such as clean drinking water – which have not yet been considered in the Performance Economy. The new concept of virtual water allows computing metrics such as value-per-ton of water, similarly to the value-per-weight metric presented in this book.

The new metrics of the Performance Economy can be used to measure the sustainable performance of national economies, regional economies, enterprises and goods – at the level of macro-, meso- and micro-economics. But the opposition from economists and academia defending their scientific disciplines, their turf, is programmed.

4.5.2 Intersectoral solutions

The Performance Economy cannot overcome the structural problems of the public administrations in most industrialised countries, which are generally organised in sectoral departments that are discouraged from cooperating. The Performance Economy optimises goods and services over the full product life cycle; it would greatly benefit from an administrative organisation of budgets and people responsible for performance delivered over time, in a multi- and trans-sectoral structure.

4.5.3 Sustainable investments

The new metrics of the Performance Economy provide fund managers investing in eco-efficient, sustainable or socially responsible companies with a common denominator for their assessment, which is lacking today. The metrics are based on qualitative criteria and enable comparisons between countries at different stages of development, and between enterprises active in different sectors – 'comparing apples and pears' is possible within the Performance Economy, as the new common denominator is performance, not cost.

Work on developing a Resource Efficiency Index (REI) to guide sustainable investors was started in 2009 by the author together with Professor Gary Stevens, CEO of Gnosys, a spin-off of the University of Surrey and should be available in 2010.

4.6 The link between performance, culture and sustainability

Different cultures have used different definitions of sustainability over the last centuries; some are dynamic, some of a static nature. Some concepts are based on the preservation of values, others on preserving the environment. A unified global definition of sustainability, imposed for instance by the UNO, may therefore become an obstacle in promoting sustainable development and wealth creation.

4.6.1 The five pillars of a sustainable society

The Prussian foresters' philosophy of the late 18th century, which is the foundation of the 1987 UN report 'Our Common Future', was based on husbandry and conservation of forests, with the aim of living from the 'interests' while preserving the capital stock for future generations. This view recognised the need for an interdisciplinary approach to manage forests as natural systems.

Modern day sustainability must be based on several independent but interrelated systems, or pillars, which also include technology and culture; they are listed below. Each pillar is essential for human survival,[9] there can be no argument over priorities nor speculation on which of these pillars humankind can afford to lose first (in fact, it cannot lose any one).

- The first pillar – '**nature conservation**' – recognises the need to conserve nature and the natural environment as a base for life on Earth. Man's life is based on the resources supplied by the global eco-support system of the planet (for example, biodiversity, the atmosphere and seas), and the regional carrying capacity of nature with regard to populations and their lifestyle (including the water cycles, land-use patterns and waste assimilation). A lack of water, for instance, can lead to mass migrations.

- The second pillar – '**limiting toxicity**' – recognises the need to conserve the individual health and safety of people and animals, which are jeopardised by man's economic activities. This is a qualitative issue that involves measuring the presence of toxic agents (such as mercury, lead, nickel, DDT or thalidomide) in tiny quantities (nanograms) as well as nature's absorption capacity.

  The above two pillars are based on command-and-control, but solving the issues of the next pillar needs creativity and innovation:
- The third pillar – '**resource productivity**' – is based on the need of industrialised countries to dematerialise their lifestyle in order to allow the material development of industrially less-developed countries. This is a domain of innovation, creativity and corporate strategies that lead to higher resource productivity over long periods of time. A reduction of resource consumption by a factor ten is needed to prevent a radical change towards re-acidification and/or climate change that could threaten man's life on Earth. In addition, this is a factor of disequilibrium between over-industrialised and less-industrialised countries.

  Achieving the objectives of the first three pillars will create a sustainable economy. However, in order to reach the objective of a sustainable society, nations will also need to tackle the following pillars of social and cultural ecology:
- The fourth pillar – '**social ecology**' – encompasses the fabric of societal structures, including peace and human rights, dignity and democracy, employment and social integration, security and safety, the constructive integration of female and male attitudes. Keywords here are: the commons, 'prisoners dilemma', sharing and caring, barter economy.
- The fifth pillar – '**cultural ecology**' – comprises education and knowledge, ethics and culture, attitudes towards risk-taking, values of 'national heritage' and other assets, at the level of the individual, the corporation and the state.

  The fifth pillar carries the idea of a sustainable society.[10] It encompasses the broader objective that, besides the natural resource problem, includes the question of the longevity and sustainability of our societal and economic structures. This insight was at the basis of the movement that re-coined the English term 'sustainability' in the early 1970s. But the 'green' movement, which emerged later, missed the broader perspective of a sustainable society by not considering full and meaningful employment and quality of life in its interpretation of 'sustainability'.

4.6.2 Sustainability is also a competition of cultural models

Sustainability as a concept has a number of different faces and interpretations that depend on the underlying cultures and traditions. The common denominator is sustainability as a synonym for happiness, quality of life and health. The six nations of the Iroquois Confederation in North America defined sustainability with the following principle:

> *In our every deliberation,*
> *we must consider*
> *the impact of our decisions*
> *on the next seven generations.*

This definition is dynamic and allows to integrate the contributions that scientific innovation and technological progress have brought to our modern world.

In Eastern cultures, it is common to define happiness as a balance between two 'opposing' trends, such as the 'ying and yang' of Buddhism. In Hinduism, it is believed that the supreme power is 'Aadi Shakti' (Power Forever), the creator of Lord Shiva, who subsequently created Lord Vishnu and later Lord Brahma. The role of Shiva is of a Destroyer: when evil becomes supreme, he provides opportunity for a new beginning, by complete destruction; the role of Brahma is to create new life after destruction. In Hindu mythology, Brahma is believed to have created the entire Universe (called Brahmand in Hindi). The role of Vishnu is one of a preserver or operator. And the cycle goes on. In God, Hindu mythology finds representation of all three: G for Generator, (Brahma); O for Operator (Vishnu); and D for Destroyer (Shiva). Ganesha, a son of Shiva and his wife Parvati, is also a symbol of a good beginning. So in Hindu mythology, each good work begins with the worship of Ganesha, because he is considered auspicious at that point and prevents failure. At this time, Hinduism is in a transitory stage dominated by Shiva – namely, a time of turmoil and change, not of preservation, which may be why Western efforts towards sustainable development find limited reception in many parts of Asia.

In Japan, the buzzword of the 21st century is LOHAS – Lifestyles of Health and Sustainability – a concept derived from the 'cultural creatives' idea developed by the American sociologist Paul Ray. LOHAS has replaced green consumerism as a much broader and more accessible marketing and lifestyle concept.

4.6.3 The need for a dynamic model

In its definition of an ecologically, socially and economically viable society, the 1992 UN conference on sustainable development in Rio de Janeiro has seemingly taken a neutral position. But dominated by 'green' European thinking and biased towards preserving the environment, its interpretation is based on the Prussian principle of conserving present natural capital. This attitude may still be valid for society's contact with nature, but it is inappropriate for dealing with scientific progress.

The 19th century overthrew the then existing situation but most definitely left a positive impact on the next seven generations, including you, the reader. A quick analysis shows this. Starting off with horses and candles, the scientists, engineers and industrialists of the 19th century left a large number of innovations that, according to Iroquois thinking, had a decisive impact on mobility, energy, telecommunications and printing for the following seven generations (see Section 1.2.2).

The static Prussian foresters' philosophy of the late 18th century, based on husbandry and conservation of natural resources, would not have placed much value on these innovations. There is thus a need to adopt a dynamic model of sustainability to include technical, social and organisational progress.

The evolution continued in the 20th century with the discovery of new sciences, of which life sciences and nanosciences are the most prominent. The future will tell if the legacy of the 20th century will be regarded as wealth or burden, but the modern European attitude of risk aversion so far is not supported by an historic analysis of the changes brought about by Western scientific and technological progress.

An assessment of the scientific success stories of the 20th century will also reveal a new balance in innovation between Europe, North America and Asia. In the context of the Performance Economy, the scientific competition is wide open on a global level, driven to a large extent by cultural factors, including the regional interpretation of the vision of sustainability and of attitudes towards risk acceptance and risk aversion.

In Europe today, there is still too little awareness of these cultural and other geopolitical differences. For example, in 1900 Europe represented 25 per cent of the world population, while this figure dropped to 5 per cent by 2000. And yet some people would like to stop progress, as if everything useful has already been invented. What is certain, however, is the need for new business models in industrialised countries, as the present Industrial Economy:

- cannot provide wealth without resource consumption,
- can no longer provide a sufficient number of jobs locally and
- cannot provide the incentives for an extended performance responsibility over the full life cycle of physical goods.

The Performance Economy shows three paths of sustainable development towards overcoming these problems through innovative strategies driven by economic actors. But it is useful to recall its foundations:

- The Performance Economy will complement, not replace the manufacturing economy. But economic competitiveness and power – especially in industrialised countries – will increasingly shift towards the Performance Economy.
- Doing the right things does not distract attention from doing things right. Environmental issues and the greening of industry to alleviate toxicology and pollution will continue to be taken seriously in both emerging economies and industrialised countries. But smart systems innovation will dominate in providing more wealth and welfare from substantially less resource consumption.
- Doing the right things will increasingly influence the competitiveness of companies and nations. The business models and metrics of the Performance Economy will help to achieve the vision of becoming a wealthy low-carbon resource-miser society.

Notes

Introduction

1 See the Four Pillars of Sustainability in Chapter 4.
2 Schmidheiny, S. (1992). *Changing Course: A Global Business Perspective on Development and the Environment*, MIT Press, ISBN 0-262-69153-1.
3 See also: Stahel, W.R. (2001). From 'design for environment' to 'designing sustainable solutions'; in M.K. Tolba (ed.) *Our Fragile World: Challenges and Opportunities for Sustainable Development*, Forerunner to the Encyclopedia of Life Support Systems, UNESCO and EOLSS Editors, Cambridge UK, pp. 1553–1568.

1 Producing Performance

1 See also: Stahel, W.R. (1997). The service economy: 'wealth without resource consumption?', *Philosophical Transactions A, Royal Society London*, 355 (June), 1309–1319.
2 The hidden material rucksack of the Stone Age Economy is small, so there is little difference between gross and net value per weight. Exceptions are diamonds, with a huge 'rucksack' of hidden material flows and mining waste. The gross value per weight of diamonds, in an overall calculation of all material flows involved, is a fraction of the net value.
3 'Material Input Per unit of Service', MIPS was strongly promoted in the 1990s by the Factor 10 Club and its president, Prof. Friedrich Schmidt-Bleek. A number of publications are available on MIPS.
4 The hidden material flows are considerable for most goods of the Industrial Economy. Gross value-per-weight ratios are about half way between the Stone Age Economy and the net value-per-weight ratio of the Industrial Economy.
5 The new technologies of the Performance Economy have small material rucksacks; net and gross value-per-weight ratios are therefore similar.
6 Prof. Ryoichi Yamamoto researches and teaches at the University of Tokyo, Institute of Industrial Sciences. E-mail – yamamoto@iis.u-tokyo.ac.jp.
7 See also Section 2.4.2.
8 See also Section 2.4.2.
9 For a good overview of books and articles, see the *Journal of Industrial Ecology*, 7 (3–4), Summer/Fall, 2003, published by MIT Press.
10 See *Innovation & Technology Transfer*, vol. 3/98, EU Commission Brussels, May 1998, p. 20.
11 See also Section 1.2.4.
12 'PhilRice goes back to aggie dep't', *The Philippine Star*, July 10, p. B-10, 2003.
13 Data kindly supplied by Roderick Parker, Agricultural Information Services Ltd, London SW6 2AP.

14 Based on information by Prof. Charles P. Enz, University of Geneva. See also Enz, C.P. (1996). Review of the physics of high-temperature superconductors, in Zygmunt Petru et al. (eds) *From Quantum Mechanics to Technology*, pp. 143–160.

15 See also Section 3.4.3.

16 See Chapter 2 for details.

17 The term ‘functional nanotechnology’ was first proposed by Dr Margarethe Hofmann, Lausanne.

18 For a more detailed explanation, see e.g., *Nanoscience and Nanotechnologies: Opportunities and Uncertainties*, The Royal Society and The Royal Academy of Engineering, RS Policy document 19/04, July 2004, ISBN 0 85403 604 0, Price £25. This report can be found at www.royalsoc.ac.uk <http://www.royalsoc.ac.uk> and www.raeng.org.uk <http://www.raeng.org.uk>, p. 116.

19 A useful website on the history of nanosciences is www.sciencemuseum.org.uk/antenna/nano.

20 Information received from Ing. Serge Bourquard, LAC laboratories, Geneva, Switzerland.

21 According to studies by Prof. Ryoichi Yamamoto, see note 6.

22 *Source*: *Science*, 310, 1793–1796, 2005.

23 This information was kindly supplied by Prof. Olga Golubnitschaja, PhD, Head of the Division of Molecular/Experimental Radiology at the Friedrich-Wilhelms-University, Bonn, Germany and Secretary-General of EPMA, Brussels.

24 John Kletz on 16 January 1989, at the ETH (Swiss Federal Institute of Technology) of Zurich. Published in *A Life-Cycle Engineering Approach*, Bernold, T. (ed.), 1990.

25 HSE (1993). *The Cost of Accidents at Work,* Health and Safety Executive London, HMSO, booklet HS(G)96, ISBN 0 11 886374 6.

26 *Source*: Sustainable production, challenges; see note 30.

27 Research reported in *New Scientist*, April 9, 23, 2005.

28 Hartmann, K.M., Goetz, S., Market, R., Kaufmann, T. and Schneider, K. (2003). ‘Photocontrol of weed germination: Lightless tillage and variable memory of the seed bank’, *Aspects of Applied Biology*, 69, 237–246, 2003.

29 A detailed analysis is given in Figure 3.5, page 198.

30 Sustainable production, challenges and objectives for EU research policy, July 2001. *Report of the Expert Group on Competitive & Sustainable Production and Related Service Industries in Europe in the Period to 2020*, EUR 19880, European Commission Brussels.

31 Swiss press quote from 1882 at the opening of the Gotthard rail tunnel.

32 Or £/kg, $/kg, Yen/kg and so on.

33 Stahel, W.R. (1997). The service economy: ‘wealth without resource consumption?’, *Philosophical Transactions A of the Royal Society London*, 355 (June), 1309–1319. The idea to uncouple economic success and resource consumption has since been integrated into the Marrakech declaration of the UNO.

2 Selling Performance

1 Wysiwyg, what you see is what you get. This was an early promise by Microsoft’s modern software that what the user of a PC could see on the

screen is what the printer would deliver. What today sounds obvious was a dream for many in the early days of PCs, which were as recent as the mid-1980s.

2 The framework of the United Nations Monterey Consensus adopted in 2002 emphasised the critical role of private investment in achieving development objectives, including the Millennium Development Goals. In January 2006, the OECD published the draft text of the Policy Framework for Investment, a new initiative to help countries attract more investment to boost economic growth and development.

3 This figure, under the title of 'Das Konzept der Zurverfügungstellung von Gütern', was first published in: Börlin, M. and Stahel, W.R. (1987). *Economic Strategy of Durability*, Researched for the Swiss Bank Corporation, Basel, Bankverein-Heft Nr. 32, 77 p.

4 See: Stahel, W.R. (1997). 'The functional economy, cultural and organisation change', in D.J. Richards (ed.) *The Industrial Green Game: Implications for Environmental Design and Management*, Washington DC, National Academy Press, pp. 91–100.

5 Referring to Engel's Law in Giarini Orio, see note 6.

6 Giarini, O. and Stahel, W.R. (1989/1992). *The Limits to Certainty: Facing Risks in the New Service Economy*, Dordrecht, Boston, Kluwer Academic Publishers, London, ISBN 0-7923-2167-7, Translated into French, Italian, Rumanian, Japanese and German.

7 Stahel, W.R. (2004). 'The E-Factor', *Resource*, May–June, 32–34.

8 Lessons learned from 4 Times Square. (1997). The Durst Organisation, New York, NY 10036.

9 For a full account of the beginning of Xerox, see *The Battelle Story*, available from the Battelle Memorial Foundation, Columbus, Ohio.

10 Xerox: Design for the Environment, Harvard Business School case study N9-794-022, 7 January 1994.

11 *Chemical Management Services Industry Report 2000* (2000). Chemical Strategies Partnership, San Francisco.

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13 Votta, T., Broe, R., White, A. and Johnson, J.K. (1998). Using environmental accounting to green chemical supply contracts, *Pollution Prevention Review* 67 (Spring), 68.

14 *Chemical Management Services Industry Report 2000* (2000). Chemical Strategies Partnership, San Francisco.

15 Energie-profis (2000–2002). die besten Beispiele fur Energie-Contracting; Available from OEGUT-news, Hollandstrasse 10, AT-1020 Vienna, Austria.

16 Delivering resource productivity: The service solution, *A Report by Green Alliance*, London SW1W 0RE 2003, ISBN 0 9543813 4 3.

17 Goldman, C., Osborn, J., Hopper, N. and Singer, T. (2002). *Market Trends in the U.S. ESCO Industry: Results from the NAESCO Database Project*, Ernest Orlando Lawrence Livermore Laboratory, Berkeley, CA.

18 Today Novartis AG in Basel, Switzerland.

19 Now Novartis AG, Basel and Stiftung für Zusammenarbeit mit Entwicklungsländern in Basel.

20 This is one of the objectives of the UN Millennium agenda of 2000.

21 A term coined by Amory B. Lovins, founder of the Rocky Mountains Institute, Snowmass Colorado.
22 Chesshire, J. (ed.) (2000). From electricity supply to energy services: Prospects for active energy services in the EU, *Report Prepared for the European Commission – Directorate General Energy and Transport – and Union of the Electricity industry*, Brussels. Available from public.eurelectric.org/Content/ Default.asp.
23 Available from www.chemicalstrategies.org/csp_manual.htm.
24 See http://www.blueprint-network.nset – Blueprints for an Integration of Science, Technology and Environmental Policies, or contact r.kemp@merit.unimaas.nl.

3 Managing Performance Over Time

1 See also Stahel, W.R. (1982). The product-life factor, Mitchell Prize Competition, The Woodlands, Texas. The objective of a circular economy has in the meantime become one of the five objectives of the UN Marrakech declaration, but corresponds to 'The Loop Economy of Molecules' of this chapter. The skilful management of existing assets – a caring attitude – also corresponds to the original definition of sustainability by Prussian foresters 200 years ago.
2 See Giarini, O. (1980). Dialogue on wealth and welfare, an alternative view of world capital formation, *A Report to the Club of Rome*, Pergamon Press, Oxford, ISBN 0-08-026088-8.
3 The figures are based on the life cycle costs of the author's car, a 1969 Toyota Corona Mk II.
4 According to a press communication by Wofgang Bernhard, Head of VW division at Vokswagen AG Wolfsburg, workers at VW need 50 hours to build a car, while the industry average is 25 hours.
5 See also Stahel, W.R. and Reday-Mulvey, G. (1976/1981). Jobs for tomorrow, the potential for substituting manpower for energy, *Report to the Commission of the European communities, Brussels and Vantage Press*, NY.
6 Steinhilper, R. (1998). *Remanufacturing: The Ultimate Form of Recycling*, Fraunhofer IRB Verlag Stuttgart, ISBN 3-8167-5216-0. Also published in German, French and Japanese.
7 See Chapter 2 for details.
8 Smith, V.M. and Keoleian, G.A. (2004). The value of remanufactured engines, life cycle environmental and economic perspectives, *Journal of Industrial Ecology*, 8, 1–2, 193–221.
9 *Source*: Stahel, W.R. and Reday-Mulvey, G. (1976/1981). Jobs for tomorrow, the potential for substituting manpower for energy, *Report to the Commission of the European Communities,* Brussels/NY, Vantage Press.
10 Such as inverse manufacturing in Japan.
11 See also Robertson, J. (1978/1983). *The Sane Alternative: A Choice of Futures*, ISBN 0 9505962 1 3.
12 This data comes from a case study of remanufacturing the engine of one of the author's cars.
13 Value-per-weight ratio, see Chapter 1.
14 Annual man-hours divided by number of cars produced in a manufacturing plant.

15 Man-hours of work per kilogram of resources consumed.
16 See note 2.
17 'Slack' is a term coined by Beatrice Otto at the WBCSD.
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19 OECD. (1982). *Product Durability and Product Life Extension*, Paris, OECD.
20 Michael Cohen, Division Chief in the World Bank's Water Supply and Urban Development Department.
21 A case study by Dr Willy Bierter, The Product-Life Institute, Geneva, 1997.
22 See note 2.
23 Obituary in *The Economist*.
24 More details on www.remanufacturing.org.
25 Lund, R.T. (1995). *The American Edge: Leveraging Manufacturing's Hidden Assets*, Manufacturing Engineering Dept, Boston University.
26 Grey, D. et al. (1995). Untersuchung und Bewertung der Möglichkeiten zur Abfallvermeidung und- verminderung durch verbesserte Instandhaltung und Modernisierung im Maschinen- und Anlagenbau; Abschlussbericht des Forschungsprojektes des ZEUT Zentrum für Energie- und Umwelttechnik Rostock für das BMBF Bonn, Projektträgerschaft UBA Berlin. Förder-Nr 1490881, Juli 1995. Zusammengefasst in: IH schont Ressourcen, Ökologie als Argument für die Instandsetzung; in: Instandhaltung Nov. 1996, S. 22–24, Kennziffer 202.
27 See note 5.
28 Smith, V.M. and Keoleian, G.A. (2004). 'The value of remanufactured engines, life-cycle environmental and economic perspectives', *Journal of Industrial Ecology*, 8 (1–2), 193–222, published by The MIT Press.
29 The full case study is available on the website http://product-life.org.
30 See note 6.
31 Foam to refloat sunken ships, *Battelle Today*, 46, February 1986.
32 Papanek, V. (1971). *Design for the Real World, Including Less Developed Countries*, London, Thames and Hudson.
33 Stahel, W.R. (1985). Study for YEA, the Youth Employment Agency, Dublin, by the Product-Life Institute, Geneva.
34 See also Vogler, J. (1981). *Work from Waste: Recycling Wastes to Create Employment*, Published by Intermediate Technology Publications and Oxfam, ISBN 0 903031 795.
35 See also the *Report by the Royal Commission on Environmental Pollution, Biomass as a Renewable Energy Source*; enquiries@rcep.org.uk, www.rcep.org.uk.
36 Rifkin, J. (2002). *The Hydrogen Economy*, Tarcher Putnam, ISBN 1-58542-193-6.
37 Products into Services in the EU to 2010. (1999). *A Report to the European Commission, Brussels*, The Product-Life Institute, Geneva.

4 Sustainability and the Performance Economy

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2 See also OECD Statistics Brief No. 10 (2005). On Measuring Sustainable Development.
3 OECD (2002). *Aggregated Environmental Indices: Review of Aggregation Methodologies in Use*, Paris, OECD.
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