2

Resource Flow and Product Design

2.1 The Environmental Dilemma of Resource Flows

2.1.1 Resource Use and Product Design

Resources are used to produce products, and all product design processes have to develop and deal with a resource policy. To accomplish an ecodesign a clear understanding of environmental consequences of the resource use is necessary. In subsequent chapters in the book we will discuss in some detail how to deal with material choice, product function and product recycling, all of them important for resource flow. In this chapter we will describe why resource flow constitutes a dilemma, which designers will have to deal with.

2.1.2 Categories of Resources

There are different ways to group resources. A commonly used one distinguishes the following seven categories [Hillary and Jolly, 2001]. These all have their specific properties from the point of view of the environment.

1. **Bulk material** is material extracted from the *pedosphere*, the uppermost layer of the ground. Bulk material is abundant. The problem with its use is not the amount but the fact that the ground from where it is extracted is disturbed or destroyed.

2. **Macro nutrients** – nitrogen, phosphorus and calcium – are used in large quantities in agriculture but also in a long series of chemical compounds, such as phosphorous in detergents, and nitrogen in various plastics. Nitrogen compounds are mostly produced by reduction of atmospheric nitrogen into ammonia, a process that requires large amounts of energy, while phosphorous is mined. Nitrogen is thus available in practically unlimited quantities, while phosphorus is a non-renewable resource. The present layers are large, however, and will last more than 200 years, at the present rate of extraction.

3. **Minerals** are compounds extracted from the *lithosphere*, the bedrock. They are used to produce metals. Metals can be characterised according to their technical use. Iron is in a class by itself. Metals used mainly as alloys with iron, called ferro-alloy metals, include chromium, nickel, titanium, vanadium and magnesium. The traditional non-ferrous metals are aluminium, copper, lead, zinc, tin and mercury. Metals are of course by definition non-renewable. Iron and aluminium, how-

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ever, which are very abundant in the surface of the planet, will not be depleted by present levels of use. All other metals are being mined at a rate of about one order of magnitude larger than the natural weathering. Some rare earth metals are already almost depleted from known sources [Karlsson, 1997].

4. **Stored energy resources** include lignite, black coal, oil and gas. Coal, oil and gas, which were formed hundreds of millions of years ago, are *fossil*. The fossil fuels are *non-renewable*. They are presently used at a rate that is millions of times larger than their eventual renewal. Peat is formed on the time scale of thousands of years. Some consider peat fossil since it is not at all reformed at the rate we might use it, while others do not include peat in the group of fossil fuels.

5. **Flowing energy resources** refer to resources which depend on the sun. *Direct* solar energy resources include solar heat, solar electricity and photosynthesis. *Indirect* solar energy – sometimes referred to as *streaming* resources – includes waves, wind or flowing water. These are used in wave energy (which is technically difficult), wind energy and hydropower.

6. **Environmental resources** are what we and all life forms depend on every day and minute for our lives, the air we breathe, the water we drink and the soil we walk on. This is also referred to as the *ecosphere* or *biosphere* of the planet. The environmental resources provide what is called *ecological services*. This refers to the support of life forms, and the absorption of emissions from these processes.

7. **Biotic resources** are biomass to provide food and fibre for our livelihood, and a long series of other products, such as pharmaceutical substances, landscape. These resources are *renewable*, but, of course, limited. The production rate of the biotic resources are referred to as the *carrying capacity* of the area considered.

2.1.3 The Large Size of the Resource Flow

The resource flow on our planet is very large (see further the discussion in the Introduction). Material Flows Analyses, MFA, carried out in several countries in Western Europe show that flow of solid material is about 60-80 tonnes per capita and year (see Introduction, Figure 6). The figure is slightly smaller in e.g. Poland (about 50 tonnes) but much larger in the USA (about 80 tonnes). Materials in the largest amounts are bulk material (for building purposes), fossil fuel (energy purposes) and macro nutrients (mostly agriculture).

An estimate of the material flows on the planet as a whole [Schmidt-Bleek, 1994; The Global Footprint Network, 2005] indicates that it is about 35% more than the carrying capacity. This over-use of the resources corresponds to the use of fossil fuels, deforestation, over-fishing and so on. Resource use has increased during the entire history of mankind, but was far below the available resources up to about 100 years ago. During the 20th century resource use increased about 20 fold in many categories, for example, energy, and much more in some, for example, macro nutrients [MacNeill, 2000]. The carrying capacity of the planet was passed probably around 1980.

In 1995 the American environmentalists A.B. and L.H. Lovins together with E.U. Weizäcker, Direcor of the Wuppertal Institute, published the book *Factor Four: Double Welfare – Half Resource Use*. The title indicates that we need to reduce resource use by a factor of two, but if we can use the resources twice as efficiently we do not need to lose any welfare.

Box 2.1 Categories of Resources

1. Bulk materials such as stone, sand and gravel
2. Macro nutrients: nitrogen, phosphorous, calcium, and sulphur
3. Mineral resources, metals
4. Stored energy resources, fossil fuels
5. Flowing energy resources, solar energy, hydropower etc.
6. Environmental resources, soil, water and air
7. Biotic resources, biodiversity and sylvi-cultural products (wood, fish, etc.)

Figure 2.1 Oil society. *Today fossil fuel – coal, oil and gas – dominate both the energy market and the chemical industry. World-wide, fossils account for some 80% of energy provisions. In the Baltic Sea region, the eastern countries, e.g. Poland and Russia, have an even larger dependency on fossils, while Sweden is on a level of 40% fossil dependency. For product design it is important to produce products that are energy efficient and when possible use renewable energy sources. Also in manufacturing petrochemical processes, the use of oil as raw material dominates. Here the challenge is to find alternatives, building on so-called green or sustainable chemistry. The oil tankers on the Baltic Sea, increasing in number drastically, also constitute a threat of a major accident that would be a disaster for marine ecosystems. Photo: Norsk Hydro ASA.*

Factor four was meant to be a global policy. But resource use is not equally distributed over the planet. The industrial countries use far more resources per capita than developing countries. One might conclude that one essential task for our industries is to reduce resource use drastically. In fact it is possible to estimate that if resource use in the world as a whole were to decrease by a factor of two and resources were to be used equally in all countries, the industrial countries would have to reduce by a factor of close to ten. This is due to the fact that industrialised countries use 80% of the resources but have only 20% of the global population. The concept of *Factor 10*, meaning that material flows should decrease by a factor of ten, may seem extreme, and of course it builds on a simplified calculus [Spangenberg and Schmidt-Bleek, 1997] but it has been accepted as a policy goal in several countries and in the European Union.

2.1.4 The Environmental Consequences of Large Resource Flows

Material flows should decrease not only because resources are over-used but because resource flows as such lead to severe environmental problems. Most material flows in industrial countries are *linear*. The material flows directly, so to speak, from the sources to the waste heap. The material set in motion accumulates in the environment and cause problems. The most severe of these include:

- Global warming caused by accumulation of carbon dioxide from fossil fuel combustion in the atmosphere.
- Eutrophication due to accumulation of nitrogen and phosphorous from agriculture in water bodies.
- Acidification of forests and lakes due emission of sulphur oxides from combustion of fossil fuels.
- Toxic effects of metals accumulating in the environment, e.g. mercury and lead.
- Toxic effects of man-made substances accumulating in the environment, such as PCB.

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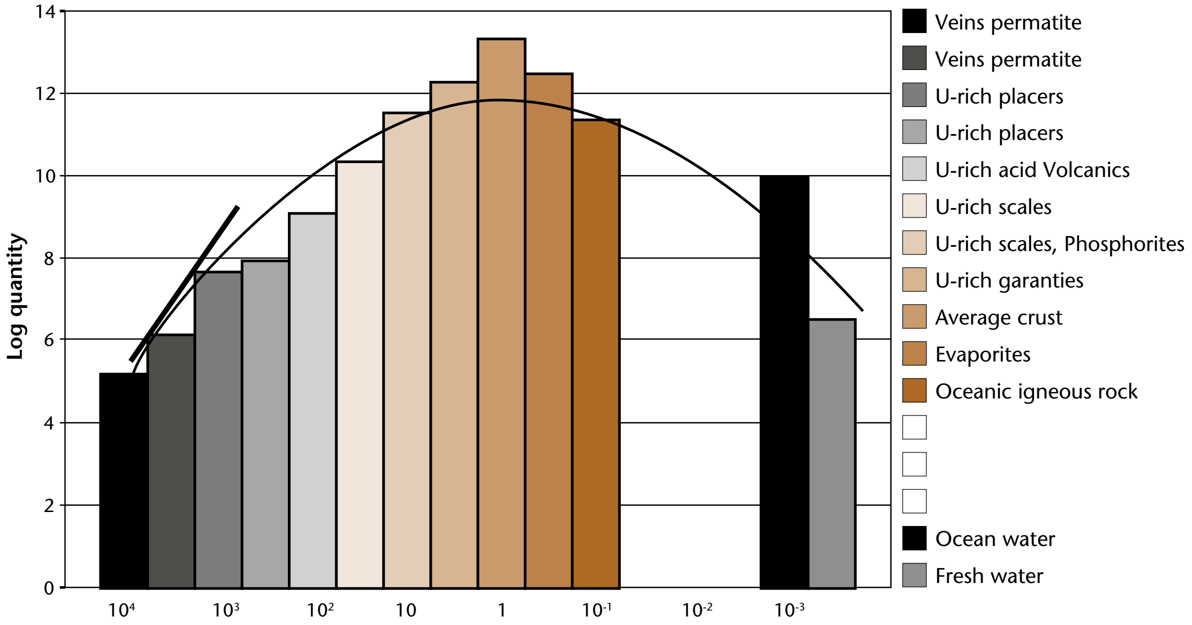

Figure 2.2 Distribution of uranium over the world's crust. *The grade on the horizontal axis ranges from 50,000 to 0.0005 parts per million; every two bars is one order of magnitude [Deffeyes, 1964]. In the same report Deffeyes also presents data on the distribution of other resources.*

Box 2.3 Materials Management Strategies for Improved Material Flows

I. Reducing the flow – use less material for a service

1. *Use the material more efficiently.* By raising the transmission voltage in a copper wire it is possible to reduce the amount of copper needed to transmit a certain current.
2. *Increase the quality of the material.* By increasing the strength of a metal, e.g. by using an alloy, less material can be used for the same purpose. It has been estimated that the Eiffel Tower in Paris today could be built with one seventh of the steel content it actually has.
3. *Miniaturization – use smaller equipment.* By making equipment smaller, less material is used. Computers, now based on miniaturized electronic components, such as silicon chips, provide a dramatic example. A much smaller computer serves the same functions as a large machine earlier.
4. *Multi-functionality – Let the equipment serve several purposes.* Multi-functional use of products offers another opportunity for reducing the need for materials for a given function. For example, a roof-mounted solar collector can also function as roofing.

II. Slowing down the flow – make the material last longer

5. *Improve the quality to make the equipment last longer.* By making the products last longer, for example, with increased quality, the same amount of materials can provide services for a longer period, therefore reducing the amount of materials for a given service.
6. *Protect the material in the equipment better.* Materials can be protected from wear or corrosion. Modern cars last much longer than those from before due to better protection of the surface.
7. *Better maintenance.* By regular maintenance and by using equipment that can be maintained properly, the equipment or material can be used longer.
8. *Reparability – Make the equipment easier to repair.* Reparability, for example, through a modular construction of equipment, will increase the longevity of the materials used.

III. Closing the flow – use the material again

9. *Reuse the goods themselves.* Most goods or equipment are of course used more than once. In some instances a proper strategy is required to make this happen, as with glass bottles that may be refilled.
10. *Recycle materials in production processes.* Many different strategies are applicable in the industrial production process to reduce material intensity. This is part of waste management strategies. Thus manufacturing waste can fed back into earlier material-processing steps, as when for example copper scrap in the manufacturing of copper wires is fed back into the process.
11. *Recycle materials in consumer goods – true recycling.* Materials in consumer goods may be recycled. This is particularly important for materials that are toxic, such as heavy metals, or materials that are expensive to produce, such as aluminium. Important cases are thus recycling of the metal in aluminium cans and the lead in lead-acid batteries. Recycling of the material to the same use once again is true recycling.
12. *Cascading or down-cycling of materials.* In many cases there is an inevitable loss of quality in materials when they are used. However they may be suitable for a different use requiring less quality. This is down-cycling or cascading. The typical example is paper where the fibres in the paper itself go through a wearing process, which limits the use to about six cycles. The chain might start with high quality paper going over newspaper to cardboard paper. The chain or spiral ends when the material is used for energy production in combustion.

IV. Substitute the flow – Use a different, less harmful, material

13. *Substitute a less harmful material for a harmful one.* Transmaterilization means that one material is exchanged for another. An important aspect is when a hazardous material is replaced by a less harmful one. The exchange of mercury in a number of applications, from barometers to tooth repair, belongs to this category as does the exchange of many solvents used for painting.
14. *Substitute a less scarce material for a scarce one.* Sometimes it is important to find a less scarce material for a particular use. Replacing copper wires in telephone connections with fiberoptic cables is one example.
15. *Substitute a renewable material for a non-renewable one.* The non-renewable materials will in the end necessarily be exchanged for renewable ones. An important example is when fossil fuels are exchanged for renewable fuels, such as biomass. An important case is the replacement of petrol in cars with alcohol from biomass.

Source: Reproduced from Karlsson, 1997.

As a rule the flow of non-renewable resources causes environmental problems long before they are depleted at the source. The environment is not able to handle large amounts of a substance that is not part of the normal set-up. As the resource flow continues, it leads to an accumulation of the substance, and sooner or later it will become detrimental to the environment. The large anthropogenic material flows of resources are not similar to the natural flows. Ecosystems, as a rule, recycle resources and all material are used for new purposes.

2.1.5 Sustainability Principles for Improving Resource Management

Good material management should obey a few simple rules, included in the so-called *physical principles for sustainability* [Holmberg et al., 1994], adopted as the systems conditions in the Natural Step Foundation:

- Do not cause the accumulation of material from the lithosphere in the ecosphere. (Material from the lithosphere (bedrock) includes metals and fossil fuels.)
- Do not cause the accumulation of man-made substances in the ecosphere.
- Do not cause the systematic destruction of the productive capacity of the environment (e.g. by ongoing extraction of material and thus depleted land use, as in erosion).

To live up to the basic rules, materials need to be recovered and reused rather than ending up in the environment. *Recycling* is thus a basic strategy. *Dematerialisation*, that is, slimming the material flow, is also basic. Non-renewable materials should not be used unless it is possible to ascertain that they are recycled. Thus recycling will make it possible to continue to use metals although they are non-renewable. However fossil fuels will not be acceptable in the longer term since it is not possible to recycle them, except to a limited degree.

Today material flows and energy flows are mostly coupled. We thus see the need for a different energy policy that says that energy flows need to be *de-carbonised*, uncoupled from the carbon flows, the use of fossils.

Total material flows are in practice coupled to toxic material flows, that is, flows of toxic materials are roughly proportional to material flows. Here, too, there is a need for a different materials management policy, one that avoids toxic material.

Resource use will have to be reduced, and some resources abandoned all together. A summary of materials management strategies supporting this goal are found in Box 2.3.

2.2 Resource Availability

2.2.1 Minerals

In the geo-statistical model for minerals, it is generally accepted that the distribution of concentrations of mineral resources is log-normal if we plot quantities against grade. This phenomenon has been described, for single deposits, as Laski's law. There is wide agreement amongst resource geologists that log-normal ore grade distribution is a reasonable approximation also for the world-wide ore occurrences of a large share of minerals. Although real proof for this relation is not easy

Table 2.1 Fossil fuels sub categories *[Eco-indicator 99, 1999].*

Category	Sub-Category	Remarks
1. Oil	1.1 Conventional Oil	1.1.1 All currently produced oil, which easily flows out of large wells
	1.2 Unconventional Oil	1.2.1 Tar sands
		1.2.2 Shale
		1.2.3 Secondary oil (produced from existing wells with steam injection
		1.2.4 Tertiary oil (oil from infill drilling, reaching pockets that were originally bypassed)
2. Gas	2.1 Conventional Gas	2.1.1 Wet gas, associated with an oil accumulation
		2.1.2 Dry gas, unrelated to oil fields
	2.2 Unconventional Gas	2.2.1 Natural gas liquids (condensed gas)
		2.2.2 Gas from coal-beds
		2.2.3 Gas from tight reservoirs
		2.2.4 Others, like mantle gas from deep in the earth crust
		2.2.5 Hydrates: gas in ice-like solid concentrations in oceans and polar regions
3. Coal	3.1 Conventional Coal	3.1.1 Open pit mining (Anthracite or Lignite)
		3.1.2 Underground mining

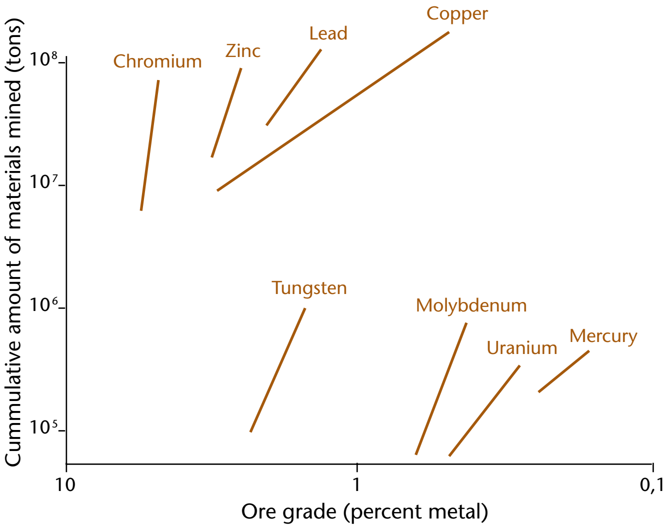

Figure 2.3 Slope of availability against grade for metals. *If the slope is steep, much more resources are found as a lower grade ores are mined [Chapman and Roberts, 1983].*

to provide, an illustrative example for the case of uranium is available from Deffeyes [Deffeyes, 1964].

Deffeyes has determined the average concentrations of uranium in different types of rock and in water. This data, combined with data on the world distribution of rock types has been combined (Figure 2.2). The grade varies in this graph from 50,000 to 0.0005 parts per million. From the graph you can see that the size of the resource stock is completely dependent on the grade, which we are willing to mine.

Chapman and Roberts refer to the work of Deffeyes and base their analysis of the seriousness of mineral extraction on data from Deffeyes [Chapman and Roberts, 1983]. Figure 2.3 (taken from Chapman) shows the relation between resource availability and the concentrations. If the slope is steep, the resource availability increases sharply as the concentration decreases slowly. The quality of minerals with a steep slope decreases relatively slowly when extraction continues.

2.2.2. Fossil Fuels

For fossil fuels the term “concentration” is not a very good indicator for the resource quality. The processes that have produced and distributed the fossil fuels are quite different from the processes that have caused the log-normal distribution in the earth crust. This means that the log-normal distribution of resource concentration is not directly applicable to fossil fuels.

Basically three types of fossil fuels can be distinguished. These three types can be differentiated in a number of sub categories (Table 2.1). The brief overview demonstrates that apart from the conventional sources there are several alternative (unconventional) sources for oil and gas. As in the case of minerals, until now only conventional sources are used, as these can be extracted with the least effort.

Quite unlike the case of minerals, the effort of exploiting a resource does not decrease gradually when the resource is extracted. As long as sufficient conventional oil can be found, the effort to extract the resource does not increase significantly, as long as the oil keeps flowing.

Only when conventional resources become really scarce will mankind have to start to explore unconventional resources. In this case the effort to extract the resource does increase. In the example of oil this could mean that additional drilling and pumping or even steam injection is needed.

So instead of a continuous decrease of the resource quality, you can observe a stepwise resource decrease, while between these steps the effort to extract is basically constant.

Conventional oil (and gas) has been formed during certain distinct periods in distinct places. For instance the huge oil resources in the Middle East, the North Sea and Siberia were formed in

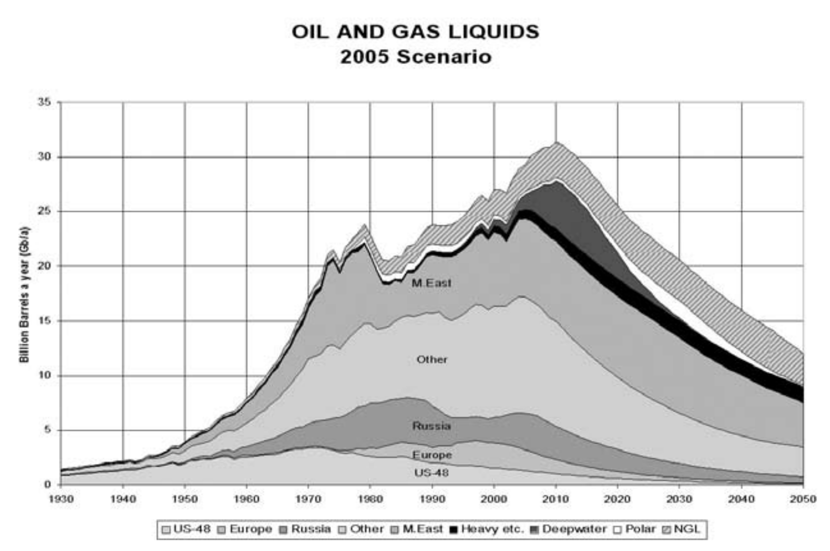

Figure 2.4 The oil depletion curve. *Oil availability over time is shown for a number of regions in the world. It is seen that e.g. the American oil is practically used up and the North Sea resources is declining. Oil is a finite resource. Peak oil refers to the time when global oil production is at its maximum. It is presently expected to occur 2008-2010. The production is then predicted to come to a very low level at about 2040. Natural gas production and consumption is seen to follow a similar pattern, with some ten years delay. (http://www.peakoil.ie/peakoil)*

the late Jurassic, some 150 million years ago. Another period was the Cretaceous, some 90 million years ago, which was responsible for the formation of oil in northern South America. The oil in North America dates from the Permian, some 230 million years ago. Oil and gas usually formed in shallow seas or lakes in areas around the tropics. Stagnant sink holes and lagoons were perfect places to preserve organic material.

Unlike the formation of minerals, the formation of fossil resources can be deducted from our knowledge of the plate tectonics, the climate changes and other processes that occurred the last half billion years of the earth's history. In global terms the bulk of oil and gas occurs in a geological "province" called the Tethys: a zone of rifting between the southern and the northern continents, of which the Middle East, the Mediterranean and Mexico are remnants.

Detailed geological mapping has revealed where suitable formations, under which oil could have been trapped, are located. Because of this understanding, one may conclude that the world has now been extensively explored, that all large oil resources have been found and that the scope for finding an entirely new field of any size is now greatly reduced, if not entirely removed [Campbell, 1998] (Figure 2.4).

From this and the present rate of extraction it is straightforward to predict the rate of depletion. The data at present (2005) (See Internet Resources, *American Society of Preventive Oncology*) predicts that resource extraction will culminate in 2008-2010 and oil resources will be mostly depleted by 2040. The comparisons between rate of extraction and rate of production (Figure 2.5) indicate that the price of oil will increase substantially in the near future.

The resource availability for coal is much higher than for conventional oil or gas. The proven resources should be sufficient for about 200 to 300 years, if the present extraction rate is sustained, and if no major discoveries are made.

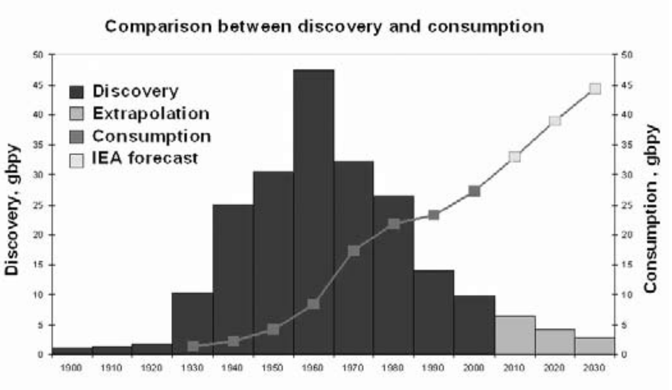

Figure 2.5 Rate of production vs the rate of discovery. *Global oil discoveries peaked in the 1960s and are rapidly declining as oil becomes harder to find. Today there is a growing gap between new oil discoveries and production. (http://www.peakoil.ie/peakoil).*

2.3 Resource Depletion

2.3.1 Problems Connected with Resource Depletion

In general there are three important problems when resource depletion is described:

The stock size (or, in the case of flow resources, the supply rate) is very much dependent on *the effort* mankind is prepared to make to get a resource. To some extent, most *resources can be substituted* by other resources. Even between the categories of resources, substitution is often possible (for example, replacing steel with wood). Because of this it is difficult to determine the essential property of a resource and, therefore, why depletion of such a resource would be a problem. The essential property determines the primary function the resource has to mankind. Usually this is an economic function.

Some resources are not really used in the sense that they disappear after use. In principle all minerals stay on earth, and can theoretically be recycled. This is not the case for fossil fuels. Although they do not disappear, their useful essential property is lost.

Bulk resources are abundantly available for the foreseeable future in most regions. In many countries the real problem is the land conversion problem. For instance, in the Netherlands the extraction of lime and gravel will stop completely within a few years, while the proven reserves for lime would at least cover the present consumption rate for 300 years.

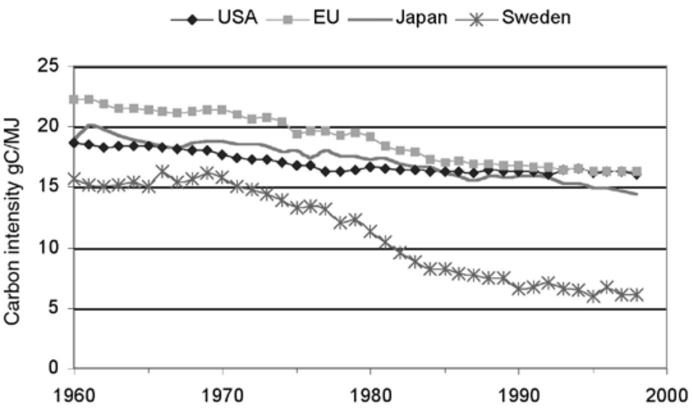

Figure 2.6 Carbon content of energy. *The graphs show carbon emissions divided by primary energy supply in the EU, Japan, Sweden and the United States over a 40-year period. The graphs show a slow decarbonisation of energy or decoupling of energy from carbon flows. The dramatic drop for Sweden during 1970-1990 is mostly due to the expansion of nuclear energy. [International Energy Agency, IEA, 2001 and Marland et al., 2001 cited in Azar et al., 2002].*

2.3.2 Damage to Resources Caused by Depletion – Minerals and Fossil Fuels

If the resource quality decreases, economic factors and environmental burdens associated with mining low grade ores will become the real problem. The latter includes the land use for the mining operation and the amount of energy to extract the resource from the low-grade ore. The availability of land and energy could thus form the real limitations, and land-use and energy use will probably be the most important factors. This is the basis for the proposal by Blonk [Blonk et al., 1997]. When we look at alternative energy resources, another additional option is to translate increased energy consumption into increased future land use, as most non-fossil energy sources use a relatively large area. Ros proposes some land-use values for the most important solar- and wind-based technologies [Ros, 1993].

Surplus energy is defined as the difference between the energy needed to extract a resource now and at some point in the future. The only purpose of the surplus energy concept is to have a relative measure of the damage the depletion of a mineral or fossil resources causes.

The relation between energy use and the lowering of ore grades for the most common minerals has been analysed by Chapman and Roberts [Chapman and Roberts, 1983]. Chapman states there are three effects:

- The amount of energy needed to change the chemical bonds in which the mineral is found is by definition constant. It is not possible to reduce this energy requirement by efficiency improvements or technological developments.
- The energy requirements needed to extract, grind and purify an ore goes up as the grade goes down.
- The energy requirements needed to extract, grind and purify an ore goes down with efficiency increases and technological developments.

Chapman shows convincingly that until now the third mechanism is stronger than the second. This means that although the grade of all ores decreases, historically the energy requirements also decrease.

Chapman shows that this trend will continue many decades from now. In the case of copper you can extract about 100 times more than mankind has done so far before the actual energy requirements get higher than the present values. For most other metals the situation is even better.

Future efficiency increases are not taken into account in existing life cycle assessments, LCA. This is consistent with the other damage models. For instance you do not take into account the possibility that the treatment of cancer will be improved, when you look at long term exposure. It is also common practice in LCA not to take possible remediation technologies into account (this is also widely discussed in Chapter 12).

With the descriptions of the typical characteristics of the fossil resources in the resource analysis, and with the data on the increased extraction energy for non-conventional resources, you can begin to construct the model for the surplus energy. However, in the case of fossil fuels you need to discuss three specific problems:

- The discontinuous or stepwise character of the quality decrease for fossil resources.
- The possibility of substitution between fossil resources.
- The possibility of outphasing fossils and substitute with renewables.

In the case of minerals, you could assume that the decrease of mineral resource concentrations is almost a straight and continuous line. In the case of oil and gas extraction, you are faced with the problem that the extraction will cause rather abrupt steps in the resource quality, when the marginal production of oil and gas switches from conventional to unconventional resources.

2.4 Perspectives on the Resource Flows Dilemma

2.4.1 Resource Substitution

In mineral resource analysis substitution between resources is not taken into account, as the possibilities for substitution are dependent on future changes in demand and technology development [This section is based on Hillary and Jolly, 2001]. In the case of fossil fuels the possibility for substitution is much more logical to assume, as all fossil fuels share the same essential property, that is, that they supply energy. It is even possible to produce an oil replacement from coal. This is in contrast with the case of minerals. You cannot say that mercury and iron have the same essential properties.

For full substitution between fossil fuels, you will have to assume a future fuel mix. It is fair to assume that about 50% of the fuel will be a liquid, as such fuels are easy to handle and transport. Chapman shows that coal liquefaction is very energy-intensive; about 50% of the energy produced is lost. He therefore argues that it is not likely that in a future energy mix coal will be converted on a large scale. As a result, coal will have a share of less than 50%. Therefore he proposes to assume an energy mix of 50% shale, and 50% coal. He also assumes that coal mining will be mainly practised in a mode that has the same approximate energy requirements as underground mining of anthracite or mining of lignite.

The fossil fuels supply us with energy, but there are many other sources of energy. Substitution of oil and other fossils for e.g. biomass is thus standard in many instances, as well as substitution of using of fossils with other energy producing technologies. These include nuclear power, hydropower and more recently wind power. These alternatives will be further discussed below.

About 90-95% of oil is used for energy purposes, and 5-10% in the manufacturing of various materials, mostly plastics. It will be more difficult to substitute for oil in petrochemical plants. This will not be as urgent as finding substitutions for use of fossils for energy purposes. More processes are however found that uses materials of biological origins, such as cellulose or starch, for such purposes. It is for example possible to use biomass to produce methanol or ethanol which in turn can be processed into various plastics.

2.4.2 Three Perspectives – Individualists, Egalitarians and Hierarchists

Much of the environmental perspective is built up from a kind of (environmental) pressure and exerted by the social environment via the market: consumers make demands about products and production processes. But, through their social contacts, managers and employees are also asked about safety at their place of work and the responsibility that the company takes for nature and the environment. The "environment", in the sense of well-being of nature, also has a direct influence on personnel. Perceptible damage to the immediate environment serves as an incentive for improvement. This, placed in relation with resource depletion, is a typical subject in which cultural perspectives can lead to different approaches. Here we will distinguish three different attitudes, called Individualists, Egalitarians and Hierarchists.

Individualists do not consider fossil fuel resources a problem, and they advocate a business as usual attitude. Furthermore, individualists would argue that, based on experience (especially after the so-called oil crisis), fossil fuel depletion is not really an issue. Furthermore, as the long-term perspective is not relevant to them, they would not give much weight to future problems that might occur.

Egalitarians have a different view of needs and resources. Egalitarians assume resources cannot be managed, while needs can. For them it is logical to assume substitution, as they are not really interested in the differences between resources; fossil fuels all belong to the same "unmanageable" group of resources. For them it is important to implement a need-reducing strategy for fossil fuels as a group, for instance, by stimulating alternative energy sources.

Hierarchists assume needs cannot be managed, but resources can. For them it is important to look carefully at the differences between the resources in order to develop management strategies.

Box 2.4 Energy Policy in Europe

Energy policy in Europe today has three main sets of drivers:

- Increased competition to bring down costs and make industry more competitive.
- Security of supply to keep the lights on at times of peak demand and to avoid overdependence on any one fuel.
- Protecting the environment from harmful emissions.

Renewable energy offers considerable prospects as it can reduce dependence on exhaustible fossil fuel reserves and offers emission-free energy. The shallow sections of the North Sea and Baltic Sea offer possibilities for offshore wind generation, and the coastline of our western shores are among the richest potential sources of wave energy. Waste to energy, biomass (burning cropped materials to recover energy) and solar energy either passively in building design or for direct generation of energy could have a role to play. So what barriers are preventing the rapid deployment of renewable energy in a liberalised market?

The principle issue is cost. While renewable energy prices have tumbled, in the vast majority of instances they still fail to compete with conventional power generation from coal, nuclear and natural gas. Some argue that they should be given a guaranteed price premium, as they are in certain parts of Europe. Others argue that if the cost of environmental damage were included in the cost of fossil-fired generation (the externality cost), then renewables would be cost competitive and hence seek such mechanisms as a carbon tax to balance up the economics in favour of renewables.

The sale of "green energy" is likely to be encouraged, using certification schemes such as that recently developed for industry by the Energy Savings Trust, but customers will have to be found and retained. It seems probable that all energy suppliers operating in the new competitive energy markets will have to secure a portion of their energy from renewable resources, but they will need to keep costs down. The planning system may well be streamlined, but public acceptance will still require hard work.

Source:
http://europa.eu.int/scadplus/leg/en/lvb/l27014c.htm

In early 2006 the energy policy of the European Union is in a phase of strong development and the present policy (from 2004) is likely to soon be revised.

Table 2.2 Archetypes of current fuels *[Eco-indicator 99, 1999].*

	Future fuels		
Current fuel	**Hierarchists**	**Egalitarians**	**Individualists**
Conventional natural gas	oil shale	coal-shale mix	conventional gas
Conventional oil	oil shale	coal-shale mix	conventional oil
Hard coal, open pit mining	brown coal	coal-shale mix	hard coal, open pit
Crude oil, secondary extraction	brown coal	coal-shale mix	oil, secondary
Hard coal, underground mining	brown coal	coal-shale mix	hard coal, underground
Brown coal, open pit mining	brown coal	coal-shale mix	brown coal, open pit
Crude oil, tertiary extraction	oil shale	coal-shale mix	oil, tertiary
Crude oil from shale	oil shale	oil shale	oil shale
Crude oil from tar sand	tar sand	tar sand	tar sand

Box 2.5 Individualists, Egalitarians, Hierarchists – Three Ways to Perceive the World

How to perceive and act on environmental risks depends on your world view. An often-used model is derived from a *cultural theory of risk* published by Michael Thompson in 1990. He categorised people in five main groupings: Individualists, Egalitarians, Hierarchists, Fatalists, and Hermits. Hermits and fatalists are at the fringe of society and certainly not numerous, but the other three groups are often seen as major perspectives on environment and world development. This categorisation has been tested in focus groups in risks analysis and seems to describe reality fairly well.

Alan AtKisson in his *Believing Cassandra* [1999] describes what he calls "the three kinds of active players in the game called the World" as follows:

Individualists are believers in the ingenuity of human beings and the resilience of Nature. Nature is there for us to use, there is plenty of it to go around, we can't do much to hurt it, and if we do, technology will fix the problem. Any risk to nature is worthwhile, because the rewards – freedom and prosperity for all – are too great to pass up. Human creativity, hard work and the free market will carry us over any hurdles and up to unimaginable heights.

Egalitarians hold quite the opposite view. Nature is already buckling under the pressure of humanity, and must be protected. No further risks should be taken or we will lose our planetary life-support system. We should guide people toward a more equitable, less environmentally damaging, lifestyle.

Hierarchists occupy a kind of middle ground, but with a twist. They believe in partnership and control. Stability is their core value. They will accept a certain amount of risk to Nature in pursuit of broader social goals. But they also think that human nature is basically problematic and that only by a solid system of clear rules, regulations and financial incentives can you prevent people from pushing Nature – or the World – too far.

Paul Harrison, a clear Egalitarian, in his *The Third Revolution: Environment, Population and a Sustainable World* [1992], writes "Human history is the history of increasing numbers, increasing consumption and increasingly invasive and disruptive technology." AtKisson suggests that we should compare this with an Individualist's view: "Human history is the story of triumph over the terrors of nature, increasing mastery over the earth and its resources, and increasingly brilliant technological achievement." and a Hierarchist's: "human history is the record of a steadily rising population, meeting its needs through careful stewardship of both people and resources, and pursuing least-cost technological solutions to the inevitable problems encountered along the way, with the hope of effective government and justly administered laws."

It is clear that today the world is run by Individualists pointing to Economic Growth as the remedy to any problem; it is part of most commercial cultures. The three perspectives are used both when it comes to how we see the use of natural resources (this chapter) and the seriousness of environmental impacts (used in the Eco-indicator 99 weighting, see Chapter 8).

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Table 2.2 shows the assumed fossil fuels that will replace the current fuels for the three archetypes. The surplus energy calculation is based on this table. The coal-shale mix is the assumed future energy mix for the egalitarian perspective.

Although egalitarians are very much in favour of eliminating the need for fossil resources, you cannot assume that this will happen in their perspective. The main reason is that other societal aspects, such as the distribution of wealth, are also important. As long as alternative energy sources are more costly, they would argue that fossil fuels could not be excluded.

Based on these characteristics, you can propose to assume substitution for egalitarians, while for hierarchists you do not assume substitution.

2.4.3 A Policy to Reduce Fossil Fuel Use

Fossil fuels are today dominating the world's energy flows. At the same time as the total depletion of fossil fuel use seems remote, the environmental consequences of its use is already serious. Accumulation of carbon dioxide in the atmosphere, due to combustion of coal, oil and gas, is today not only a theoretical cause of global warming. Since the 1990s a dramatic increase in global average temperature is ongoing. The observed temperature increase is in fair agreement with the calculated consequences of actual carbon dioxide accumulation in global climate models. The world leaders have reacted by efforts to reduce the emission of carbon dioxide. This is for all practical purposes identical to reduction of fossil fuel use. A major step was the elaboration of the Kyoto Protocol in 1997. This requires an average reduction of CO_2 emissions by 8% by 2008-2012 using 1990 as a base year. The Kyoto protocol was ratified in Febuary 2005, as some 120 states, including Russia, have signed it. However, some large fossil fuel dependent nations, especially USA, have not yet signed. For some time it has been implemented as if it were valid, notably by the European Union.

Policy tools to achieve reduction of carbon dioxide emissions include taxes on emitted CO_2, already quite high in some countries, as well as subsidies for changes to other sources of energy. Substantial reductions of fossil fuel use are seen e.g. in Denmark (coal substituted mainly by wind power) Sweden (introduction of nuclear, oil substitution by biomass etc.) and Germany (coal substituted in several ways, wind power and improved efficiency included). In addition since many years a large scale exchange of coal to gas is on-going, which will reduce carbon dioxide emissions per energy unit. Finally increased efficiency of energy use is a main strategy where still much is left to be done, a strategy which is becoming increasingly interesting to industry as the energy prices increase.

A Designers Role

Designers have a key role in addressing the material flows dilemma. In creating our future cars, houses, roads, household utensils etc. they decide about the resource flow in our societies to be. Designers should:

- Design products that need less material.
- Design products that are energy-efficient in a life cycle perspective.
- Design products that can be recycled.

The Kyoto protocol includes the introduction of trading of emission rights. This is now becoming an important economic incentive to reduce fossil fuel use, introduced in the European Union in 2004. Units, such as power plants in less developed countries, for which it is less costly to reduce emissions, will sell emission rights to units where fossil fuel substitution or efficiency increase is already far advanced. This will accelerate the march away from fossil fuel dependency.

Some technical solutions to the problems, such as sequestration of carbon dioxide in the underground e.g. in emptied oil wells, are at hand but these probably will play only a minor role in the short term. Thus we should expect that the efforts to implement strategies of substitution of fossil fuel with flowing energy resources will be high in the future.

2.4.4 Perfect Recycling – An Alternative to Resource Depletion

If recycling of a resource is perfect, the resource depletion problem is solved. This is an option that should be carefully examined for some metals. Now a perfect recycling, without *any* loss, is not possible in practice, but close to perfect cycles have been realised. Thus recycling of lead in batteries can be done up to 99.9% which already is enough for practical purposes. This is also essential for the purposes of avoiding emissions of lead into the environment due to its toxic properties.

With legal and economic instruments society can support a highly effective recycling. This is interesting for some resources not because they are easily depleted but because it is economically profitable. Thus aluminium and copper both are much less expensive as recycled metal than as virgin ore. The figures for copper are about 1:30. Also iron is cheaper as scrap iron with a factor of about 1:6 (See Internet Resources, *The Wuppertal Institute for Climate and Environment and Energy*). However these values differ in different aspects and depend on many factors. The recovery of these metals are now common practice in many countries, and scrap metal is an object of trade.

Case Study: Fuel for transport – A Dilemma for Oil Society

The transport dilemma

Oil is the base for industrial society, and the largest challenge to sustainability. One may have different opinions on how long the existing reserves of oil will last, but everyone agrees that at some point they will be depleted, and therefore oil is not sustainable. While oil consumption is slowly declining in the housing and industrial sectors, it is increasing in the transport sector. To find alternatives to gasoline for cars seems to be a special challenge. Below you will find a few cases where this has been achieved.

Alternative fuels

The idea of using fuels other than petrol for cars is over a hundred years old. In 1900 at the World Exhibition in Paris Dr. Rudolf Diesel demonstrated an engine powered by peanut oil. Also at the exhibition an electric car, constructed by Ferdinand Porsche and Jacob Lohner, was demonstrated. In 1925 Henry Ford expressed his opinion, that ethyl alcohol is the fuel of the future:

> *"The fuel of the future is going to come from fruit like that sumach out by the road, or from apples, weeds, sawdust – almost anything… There is fuel in every bit of vegetable matter that can be fermented."*

Finally, in the last decade of the twentieth century, this vision of Henry Ford was gaining momentum, as Toyota and Honda offered commercially produced hybrid cars on the market. Toyota still has a market lead with their Toyota Prius model, which is an electric-hybrid car, but today many other companies offer so-called environmentally friendly cars. They are all low-emission vehicles.

Hybrid cars

Several cars on the market are hybrids, using two kinds of fuels/motors. As mentioned the Prius uses both an electric and a combustion motor. The electricity needs to be "green" to make it sustainable, but then it is a good alternative. In a combustion motor only some 18% of the energy in the fuel becomes mechanical energy at the wheels. This figure is several times higher in an electric motor. It is also a zero emission motor.

In hybrids, the most common combination is petrol and ethanol. Ford Focus Flexifuel model is an example. Saab's new 9-5 models called BioPower also use ethanol and petrol. In fact, any conventional motor may be rebuilt/adjusted to use ethanol instead of gasoline. In the European Union today most petrol contains 5% ethanol. This corresponds to some 300,000 cars operating fully on ethanol.

Combustion motors can also run on methane (biogas). Several car models using biogas are available. Volvo, Opel, Volkswagen, Mercedes and Fiat all have models with hybrid engines that combine petrol and biogas/natural gas.

Figure 2.7 The Lohner-Porsche. *The electric engine was placed in the front hubs. (The Lohner-Porsche Electric-Car is part of the Exhibitions of the Technisches Museum Wien.)*

Figure 2.8 *Audi A2 1.2 TDI. Photo: Svenska Volkswagen AB.*

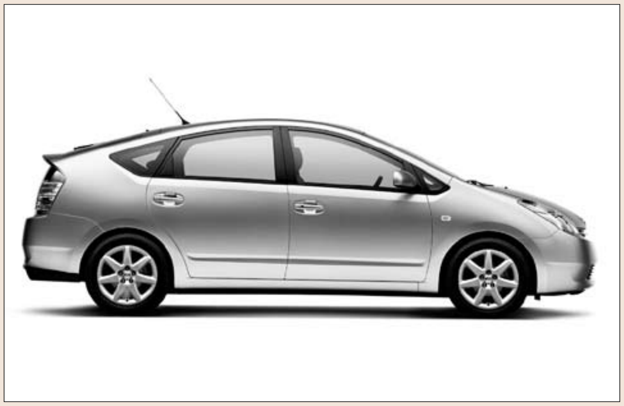

Figure 2.9 *Toyota Prius. Copyright © 1998-2003 Toyota Motor Marketing Europe ("TMME").*

Figure 2.10 *The hybrid engine in Toyota Prius.*

More efficient cars

Cars in general use much more energy than needed to run. Another option is thus to make cars that are more energy-efficient. A good example in this category is Smart Fortwo Coupé, a small car for two persons that runs on only 2.9 litres/100 km (petrol). Also very efficient is the much bigger model, Audi A2, built of aluminium and with space for four. Audi A2 has a diesel engine, which runs on 2.99 litres/100 km. The Audi has a hybrid engine, which can also use e.g. rapeseed oil (RME) as fuel.

Transport for the future

For the future, cars using hydrogen in a combustion motor or hydrogen-powered fuel cells, which in turn run an electric motor, are the most discussed options. An interesting car is BMW 750 hL, a hybrid with the capacity to use both petrol and hydrogen. The technique of hydrogen-powered fuel cells in busses is now being tested in nine European cities in the CUTE (Clean Urban Transport of Europe) EU-project (http://europa.eu.int/comm/energy_transport/en/cut_en.html). In Stockholm there are three hydrogen busses in operation.

Introduction on the market

A problem with hybrid cars, for the consumer market, has been the price, which still is slightly higher than for conventional cars. This is changing rapidly with higher oil prices. It is natural that public transport takes the lead for investing in new cars. For short-distance busses and delivery firms, electric, biogas or ethanol is already working in many cities. Their numbers will increase when old vehicles are phased out and replaced. Then we will also have a second-hand market.

Another obstacle is the low number of refilling stations with alternative fuels, which however will change with increased demand. In Sweden the number of refilling stations is increasing rapidly according to a governmental plan (http://www.miljofordon.com).

Magnus Lehman

Figure 2.11 *Bus with hydrogen-powered fuel cells in front of the fuelling station. Copyright © 2003 HOCHBAHN.*

The use of biomass as energy sources can be seen as another case of recycling. The carbon dioxide emitted as the wood is combusted will later on be reabsorbed during photosynthesis and returned to biomass. As it is harvested for energy purposes the cycle is complete.

2.4.5 Social Impact, Quality of Life

All businesses have a choice to make about their attitude to the environment: they can set the trend or they can wait and see. Both attitudes have their benefits and drawbacks. A trendsetter will go against current tendencies or define "a new flow", while the market, his competitors and legislation fail to go along with him. This requires investment and energy. On the other hand, the trendsetter is rewarded: his image is improved, he has a better market potential, a cleaner environmental record and the pleasant feeling of being prepared for what is to come. The trendsetter will see the environment change from being a threat to becoming an opportunity, and even the investment made can yield benefits instead of costs.

A follower adopts a 'me-too-attitude' or reacts only when a certain trend is obvious. This makes it unnecessary to think in terms of scenarios and experimentation. The follower does not regard environmental challanges as an opportunity. After the financial argument ("it costs too much"), uncertainty about environmental issues and forthcoming legislation is one of the most frequently heard arguments for being, and remaining, a follower. This, however, is not ecodesign-specific; uncertainty is a threshold for innovation in general.

Study Questions

1. Which are the seven principal categories of resources?
2. Describe shortly how the resource flow is working and why it often is a problem
3. Is space a raw material?
4. Which categories of fossil fuels do we have; what are the environmental consequences of their use?
5. Are renewable raw materials exhaustible?
6. In which cases do we face a problem of resource depletion? How can it be solved?
7. How can designers help to reduce the problems connected with resource flows?

Abbreviations

LCA	Life Cycle Assessment *or* Life Cycle Analysis.
MFA	Material Flow Analysis.
PCB	PolyChlorinated Biphenyl.

Internet Resources

European Environment Agency
http://www.eea.eu.int/main_html

International Energy Agency, OECD
http://www.iea.org/

Intergovernmental Panel on Climate Change
http://www.ipcc.ch/

European Commission,
Directorate-General for Energy and Transport
http://europa.eu.int/comm/dgs/energy_transport/index_en.html

Overview of European Union energy activities
http://europa.eu.int/pol/ener/overview_en.htm

The Global Footprint Network
http://www.footprintnetwork.org

The Wuppertal Institute for
Climate and Environment and Energy
http://www.wupperinst.org/

Association for the Study of Peak Oil and Gas
http://www.peakoil.net/

The Factor 10 Institute
http://www.factor10-institute.org/seitenges/Factor10.htm

American Society of Preventive Oncology
http://www.aspo.org