Resource Efficiency Atlas

An international perspective on technologies and products with resource efficiency potential

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Authors:

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1 Developing resource efficient technologies and products – a global challenge

1.1 Resource efficiency as a central task for the 21st century

Sustainable management of natural resources and efficient use of raw materials have increasingly gained importance with respect to ecological, social, and economic aspects. Simultaneously, knowledge and know-how about resource efficiency and implementation options are becoming more significant.

This has many reasons: due to rising prices and price fluctuations on the worldwide energy and raw material markets (see *figure 1*), resource management is increasingly becoming an issue for businesses. Competitive disadvantages, which arise from inefficient use of resources, increasingly endanger jobs and the development of companies (Bundesministerium für Umwelt 2007). Natural resource shortages and related international raw material conflicts as well as highly and strongly fluctuating raw material prices can lead to massive economic and social problems.

Figure 1: Rise in the prices of important raw materials as shown by the Reuters CRB Commodity Index (Source: Moore Research Centre Inc. 2011)

Therefore, improved resource efficiency is becoming an issue in international and national politics as well as in business. This is visible on the political agenda, for instance, by the strategy "Europe 2020" where resource efficiency is one of the seven flagship initiatives (European Commission 2011), or in the German national resource strategy "ProGress" (Reiche 2011). In addition, the German Enquete commission on growth, wealth, and quality of life focuses on the decoupling of wealth and resource consumption as central theme (Deutscher Bundestag 2011). Resource efficiency gains increasing acceptance within the context of the "Green economy" debate (OECD 2011; UNEP 2011). Additionally, more and more companies start to look for resource efficient technologies (OECD 2009).

Improving resource efficiency is also necessary for not exceeding ecological boundaries on earth. The pressures on the environment caused by natural resource extraction and consumption, and by the emissions and waste generation, result in direct ecological problems. The global consumption of materials, metals, and minerals as well as fossil raw materials and biomass, has strongly increased over the past 30 years (Sustainable Europe Research Institute 2011). The use of resources is accelerated by the industrialisation in emerging countries. The global economy is expected to grow on average by three percent each year until 2030 (Bundesministerium für Umwelt 2007).

Furthermore, a growing world population expedites the already continuously rising global demand. Until 2050 over nine billion people will live on earth and an increasing number will live in cities and/or industrial societies (Bundesministerium für Umwelt 2007). *Figure 2* shows examples of the estimated worldwide demand for resources based

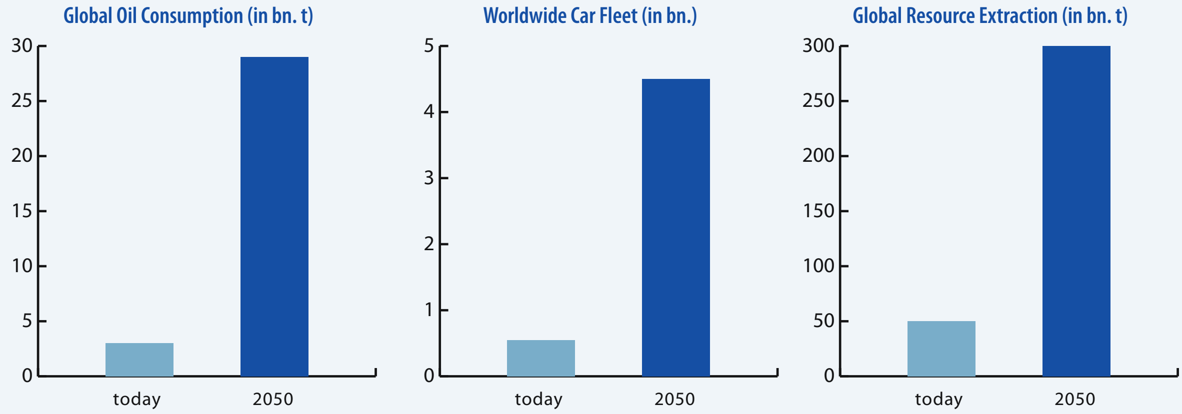


Figure 2: Worldwide demand for raw materials in 2050 without increasing efficiency levels (Source: Hennicke 2006)

on oil consumption, number of cars, and global resource extraction in 2050.

The relevance of different business sectors in terms of resource consumption varies from country to country. The most resource intensive sectors in Germany, for instance, are construction, food and beverage, metal and semi-finished metal goods, as well as the energy and motor vehicle sectors (Acosta-Fernández 2007). In Finland, however, mining and construction are the most intensive sectors, followed by agricultural, forestry and wood-processing industry sectors. The car industry only plays a minor role here (Mäenpää 2005). This demonstrates that for each country different technologies, products and, thus, different strategies are relevant in order to improve resource efficiency.

An analysis of resource consumption by areas of demand (see *figure 3*) reveals that in industrialised societies the majority of resources are used for housing and nutrition. This refers to resources directly contained by consumer goods as well as to lifecycle-wide (indirect) resource consumption such as energy used for manufacturing or distribution. Furthermore, mobility plays a central role here when analysed separately (e.g. driving to the supermarket within the field of nutrition) and not integrated within each demand area (Matthews et al. 2000; Bringezu / Schütz 2001; Kotakorpi / Lähteenoja / Lettenmeier 2008).

In general, higher resource efficiency not only within the above mentioned fields offers various benefits for society and economy (e.g. Ritthoff et al. 2007; Bringezu 2004; Van der Voet et al. 2005; Schmidt-Bleek 2007; Liedtke / Busch 2005). Examples are:

- Cost reduction (production and product costs as well as the reduction of costs during the use-phase),
- Securing raw material supply,
- Decreasing environmental impacts during the entire lifecycle.

Furthermore, resource efficiency facilitates product and production innovation and opens up new markets for products with reduced resource input. Here, national markets as well as international export markets can be addressed. A study by Roland Berger Consultants points out that environmental technologies show high market potential and a dynamic growth around the globe (Bundesministerium für Umwelt 2007). The six leading markets identified in this study (environmentally friendly energy production and storage, energy efficiency, material efficiency, recycling, sustainable mobility, and sustainable water management) already represented a total volume of about one trillion euros in 2005. Considering the average growth rate of each of these markets, the market for raw material and material efficiency is expected to have the highest annual

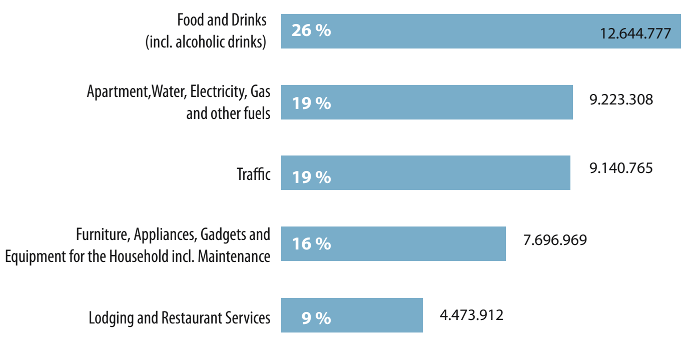


Figure 3: Resource consumption incl. ecological backpack of especially resource intensive areas of demand in Germany for the year 2000, in percent and 1,000 tons (Source: Acosta-Fernández, 2011)

growth rate of eight percent (Bundesministerium für Umwelt 2007).

There are relatively simple optimization methods for businesses promising cost saving potentials of more than ten percent (Baron et al. 2005; Bundesministerium für Umwelt 2007). After all, material costs on average correspond to approximately 47.5 percent of the gross production costs in the German manufacturing sector. Thus, they represent the largest part of total costs before personnel costs with around 17.8 percent and energy costs with approximately 2.1 percent (Destatis 2010, 377). Consequently, material consumption reduction promises major cost saving potentials (Baron et al. 2005). However, one should not only pay attention to single processes. In an integrated optimisation all upstream and downstream processes from raw material mining up to product disposal should be considered. This is a major challenge because complex and globalised lifecycle value chains make it difficult to transparently track and influence all upstream products.

Key decisions influencing the future resource efficiency of products are not only made during the production process, but especially in the early stages of the product innovation process (generation of ideas, design, R&D) (Bullinger 2006). This represents a vast array of relatively simple options for a sustainable design of processes, products and services (Geibler / Rohn 2009).

Within the framework of the national project "Material Efficiency and Resource Conservation" (MaRess) in Germany, the resource efficiency potentials of approximately 1,000 applications were estimated in a qualitative study supported by experts. Subsequently, the resource efficiency potentials of 22 applications were calculated and, hence, great potentials determined (Rohn et al. 2010). The areas showing great potential for efficiency improvements are summarised in *table 1*.

The key areas of action with potential to increase resource efficiency	
Technologies	Cross-sectional technologies and „enabling-technologies": door openers for resource efficient applications Renewable energy enables enormous resource savings The growing market of information and communication technologies requires diligent resource management
Products	Food – requires an analysis of production and consumption Transportation – infrastructure has more efficiency potential than engine-driven systems
Strategies	Product development needs to be aligned with resource efficiency goals Business models have to follow resource efficiency goals: product-service-systems (PSS) require revision

Table 1: The key areas of action with potential to increase resource efficiency (Rohn et al. 2010)

Different obstacles might prevent the examination of resource efficiency potentials (Baron et al. 2005):

- There is insufficient knowledge about new materials and processes providing higher resource efficiency.
- Risks are perceived associated with switching from existing production processes to more material efficient production processes.
- Resource efficiency gains can often be realised only by looking at the entire value chain. However, this demands a new kind of intense cooperation of multiple actors involved.
- There are wrong or missing financial incentives (e.g. by focussing on partial costs) and only short-term operation options.

The publication at hand aims at contributing to overcoming these constraints by concentrating on the problem of lack of knowledge about resource efficiency as a major challenge for achieving resource efficiency.

1.2 The project Resource Efficiency Atlas

Resource efficiency is a topic that is being discussed more and more intensively in Germany in recent years. A range of federal and state funding activities as well as societal initiatives have emerged, motivated by rising energy- and resource prices, scarcity of resources and the increasing importance of sustainable economic activity within the context of global warming. The awareness of new technological solutions contributing to increased resource efficiency levels is widely supported by past and current studies (e.g. in the "MaRess" project, Rohn et al. 2010). However, a strategic perspective on resource efficiency within technological developments can rarely be observed in Germany. In contrast there is a strong international trend towards introducing resource efficiency as a strategic topic for technological development: For instance, in the Technology Platforms of the European Union, the Cleaner Production Centres and in countries such as Japan and the USA – very often under the heading "Green Tech" or "Clean Technologies".

In this context, the primary aim of the project Resource Efficiency Atlas was to identify and evaluate products and technologies with high resource efficiency potential (leading products and technologies) on a global level. Specific implementation examples for general principles have been investigated and prepared. The analysis was focused on a European context. Additionally, countries with assumed technological advantages in selected areas such as Japan and the USA have been covered. The developments of low-tech solutions as well as solutions, which are processed in developing countries, were not explicitly included in the research. However, this does not preclude that some of the identified solutions are relevant for developing countries.

Another task of the project was to assess the potential contribution of identified products and technologies to innovation policy action fields for sustainable development. In addition to that, courses of action for a better implementation of the identified technologies have been developed within the German national context. Afterwards, the generated results have been discussed and validated with experts and stakeholders in a workshop.

The project started with an analysis (desk research) of existing publications, studies, technology platforms, strategies as well as further materials focusing on resource efficiency and innovative technologies. Thereby, aside from searching for relevant technologies and products, relevant international renowned experts were identified. During the selection process of the experts, emphasis was placed on a wide range of all areas such as application, research and development, and politics as well as selected industry sectors and topics. In interviews, 17 experts (see appendix) were questioned about issues related to, for example, opportunities and risks of the implementation of resource efficiency. Furthermore, it was necessary to identify resource efficiency enhancing products and technologies within selected industry sectors and topics as well as their potentials.

The main target group of the survey were the Cleaner Production Centres operating in 43 countries worldwide as well as comparable institutions abroad. The integrated and comparative evaluation of the results provided strategic approaches for the implementation of identified resource efficient technologies and resource efficient products in Germany as a contribution for sustainable development. A workshop with stakeholders and resource efficiency experts from science, politics, and associations was organized in order to discuss the results of the first phase of the project and their options of utilization. The results of the workshop were incorporated into the final version of the examples and the Resource Efficiency Atlas.

A general aim of all activities within the project was a broad dissemination of results; this should be continued beyond the project's scope. For this purpose, a project website, which is available in both German and English (www.ressourceneffizienzatlas.de) was created, where further best practice examples are described apart from the existing print version. Moreover, the distribution of results took place in workshops, presentations, special events, publication of results in specialized, corresponding committees and networks (e.g. Eco-innovation Observatory, Factor X network, Resource efficient network).

1.3 The structure of the Resource Efficiency Atlas

An essential outcome of the Resource Efficiency Atlas project is the document at hand consisting of three main chapters:

In the first part of *chapter 2*, conclusions from the interviews with international experts on resource efficient technologies and products are presented. The process of searching for innovative and resource efficient products and technologies is presented with an overview of the results in *chapter 2.2*. A detailed presentation can be found in the online database accompanying this printed version of the Atlas (www.ressourceneffizienzatlas.de).

Some of these products and technologies, 21 in total, are described in greater detail in *chapter 3*. An overview of these examples of resource efficient products and technologies is given at the pages 24 and 25.

In *chapter 4*, conclusions of a SWOT-Analysis are presented giving information about the strengths and weaknesses as well as opportunities and risks of developing resource efficient technologies. Moreover, courses of action are suggested on how developing and using resource efficient technologies and products could be promoted in Germany.

2 Resource efficiency potentials in focus of research

As described in chapter 1.2 the Resource Efficiency Atlas aims at identifying and evaluating potentials arising from resource-efficient products and technologies with emphasis put on the integration of international perspectives. Chapter 2 begins with the presentation of international experts' opinions on resource efficiency aspects.

The second part of this chapter includes the procedure for collecting international good practice examples of resource efficient key products, technologies and strategies. It describes both findings and difficulties in terms of identifying and evaluating these examples. In addition, an overview of the results of the collected examples is given.

2.1 International experts' perspective on resource efficiency

As part of the project Resource Efficiency Atlas a number of interviews were held with international experts. The purpose of these interviews was to obtain an overview of the general understanding of resource efficiency, main potentials, possible prospective developments and obstacles, and success factors in the implementation of resource efficiency in an international context. In total 17 interviews were conducted. A compilation of names and contact details of the interviewed experts are listed in the appendix. The results of the survey, based on the four interview sections "understanding and importance of resource efficiency", "potential estimation of resource efficiency", "possible future developments" and "cross-cutting themes" as well as "implementation of resource efficiency", are presented in the following:

Understanding and importance of resource efficiency (interview part 1)

Within the context of major global challenges such as demographic trends, climate change, and resource scarcity, the interviews showed that resource efficiency is mainly considered as one of the key global strategies for economic activity. There is consensus on a tightened shortage of primary resources considering rapidly increasing demand for resources. There is a need for resource efficiency – a concept to achieve the same performance with geologically limited resources to serve the same number of people. The objective is to maximize the use of existing resources.

According to the interviewed experts, already for decades, there are a number of scientific publications and capabilities available in various disciplines concerning this topic. The publications illustrate possible instruments, methods, and solutions that can support the increase of resource efficiency at different levels. Even in the public debate, the issue is on the daily agenda. For this reason, most of the experts agree that responsible resource management is fundamental. However, there are differences in opinions concerning questions of implementation and several focal points. Here, the regional and discipline-related interests are natural determinants.

Economic gains or *benefits* are the key driving factors for resource efficiency. In many countries, there is concern about reducing dependencies on imported raw materials – hence, they secure the control of resources and their availability. Recent geo-political activities of several countries, such as China, which occupy strategic raw material deposits in the long term, generate large uncertainties. However, the pursued measures differ highly from each other depending on the type of resources. While the energy-related issues such as renewable energy or energy efficiency obtain wide recognition, material efficiency on the other hand has little importance in some areas. Some experts state that material efficiency is an important field of research, because it contains potentials beyond all value-chain phases from the development, production, removal up to recycling. Here, it is imperative to develop alternatives with long-term and lifecycle comprehensive perspectives. In the meantime, respectable efforts are needed to make additional use of alternative (secondary) sources for selected commodities, such as phosphorus and copper or strategically important and rare metals/earths. In some countries, especially in those with low fossil fuel reserves, the security of energy supply is directly connected with growth and wealth, which makes energy efficiency a top priority.

Increased efficiency associated with *economic advantages* is seen as economic motivation for resource efficiency. Thus, resource efficiency gains practical relevance due to high material and energy consumption costs. An attempt is made to reduce the direct cost and to increase efficiency. Costs are a central control parameter for many companies, because only a few pursue a long-term non-price orientation. Considering the debate about companies developing towards greater resource efficiency, for example by using alternative technologies, companies especially require an effort-reduced and at the same time reliable decision support, in form of an assessment of available technologies. Most companies perceive sustainable economic activity to create "win-win-situations". However, the global economy does still not include external costs resulting from environmental influences in prices. This non-reliable cost internalization remains a major problem for economies attempting to achieve resource efficiency.

From the *societal point of view*, the experts focus on human needs and natural basic conditions. Thus, the following questions are important here:

- How can technology improve people's lives?
- Is there a consistent connection between benefits and needs?
- Has an intelligent production process taken place considering long-term effects and performance parameters?

The need for a sustainable utilization of existing resources without unnecessary pressures on the ecosystems and the human environment is becoming more important. Within this context, particularly at the international level, transboundary pollution to other countries along global value chains should be avoided. The overall reduction of negative effects, particularly the risk of so-called "rebound-effects" [1] which constitute an unintended and unforeseen negative consequence (high resource consumption, emissions) of a new, efficient solution by itself, has to be taken into account. The uncertainty of this risk increases if a new solution requires a strong intervention in the existing system. Thus, for example, according to one expert, there is a high potential in resource savings and less risks for rebound-effects in a technology called "digital power". This technology is used for optimized control of several different devices for the existing power grid and thus, savings can be achieved simply when integrated into the existing infrastructure. Conversely, it is necessary to search for the implementation of positive rebound-effects in order to lock in the potential effective savings.

In this combination, according to the experts, the *research* is perceived as the "saviour" or at least a "motor" to generate new solutions for resource efficiency. A variety of current global research and development activities creating new products, services, technologies or concepts are considered as indirect or direct requirements that can be derived from efficient resource handling. Indirect in this context means, for example, possible savings can be

1 A rebound effect occurs when savings through higher technology efficiency are overcompensated by the increased use/consumption of that same technology. (Jenkins et al. 2011; Schettkat 2009)

obtained by a newly developed technology, although this was not initially intended. Such potentials will be detected, implemented and actively communicated more frequently, for example, if more funding is available. This especially applies to sectors such as aviation and space technology, where such issues have been overlooked so far. In the meantime, it is to note that a variety of research activities are already contributing to resource efficiency; it is incorporated as a cross-cutting issue. These research activities should be strengthened further.

All in all, the experts phrase a similar understanding and define similar motivational factors for resource efficiency as it can be observed in Germany. These are, for example, positive economic effects, reduction of dependencies on limited resources, and, reduction of negative environmental consequences. Only the priorities are not congruent. According to many experts, these different perspectives and interests concerning this subject need to be highlighted and taken into account during the development of measures.

Potential estimations for key areas (interview part 2)

The experts confirm the high importance of technologies to reduce the consumption of resources worldwide. Disagreement is only present concerning range and stimuli of change of a solely or mainly technology-oriented focus. Consensus is reached among all experts on the outstanding resource efficiency potentials of the technology fields introduced in chapter 3. However, technologies can only develop their full potential if the underlying framework provides suitable conditions.

Most experts consider *two different approaches* for saving resources. First of all, it is possible to develop relevant technologies. Secondly, technical applications for a particular area can be developed. For example, information and communication technology (ICT) helps new generations of computers to consume even less energy and require fewer resources in the field of "Green IT". On the other hand, ICT supports increased energy efficiency by using an intelligent control of power supply (smart grid) from different sources. In this context, the experts mention particularly relevant priority fields for which special solutions should be developed. These will be described in the following.

One priority field is *energy supply and use*. Globally, alternative energy technologies (such as solar, wind, and bio-fuels), depending on the regional conditions, are being used. For this, an intelligent energy management (energy production and transportation) is required. These include the realization of high performance and high-efficient power systems or leaps of efficiency in the area of electricity. It is necessary to accomplish increased efficiency both at converting primary sources into electricity and transporting generated electricity to the final consumer. According to some experts, it is most important to generate low-carbon energy, to achieve a low-carbon future. Some experts say that in sectors, such as transportation, heating, lighting and industry, much energy is wasted. In the future, some technological developments will have a bigger impact on the efficient use of energy. The Green IT, for example, increasingly focuses on energy issues. In general, energy-saving production systems are increasingly common in the industrial sector. Powered by the economy and increased social awareness, the importance of green technologies for buildings also increases, because energy savings are highly valued. In some countries, according to the experts, various projects for infrastructure and mobility (e.g. electric mobility) are entering the market. Generally, the experts recognize some positive effects on the labour markets, because of newly created tasks.

Biotechnology and utilization of renewable resources are considered as another priority. The particular evaluation of appropriate technological solutions in individual areas varies. In the USA there is a general acceptance of biotechnology in the food industry, whereas this is a highly controversial issue in Europe. That is why the associated resource efficiency potentials are easier to be implemented in the USA. The change from an industry based on crude oil derivates to biochemical-produced derivates is foreseeable for most of the international experts. Gradual developments such as the "bio-processing" will gain acceptance in industrial production, as it is now in some parts of the pharmaceutical industry. In agriculture, the question of how to preserve the long-term productivity of the soil is becoming more and more important. Moreover, it is necessary to use renewable raw materials (wood, agricultural products) in a more efficient way, for example in form of a cascade utilisation. Due to limited agricultural area, improved system productivity is needed in order to ensure worldwide food supply. It is necessary to strengthen the competitiveness of bio-based products.

The third current priority area is seen in *recycling*. Here, possible recycling systems, recycling of rare and special resources, "trash mining" or "landfill mining", and better circulation models are topics, which are approached in several particularly resource-poor countries. According to the experts, recycling is an aspect that is also relevant for the construction sector. Throughout the recycling process, it is necessary to examine which key parameters on the production side are particularly significant for the utilization of resources. This already takes place, for example, on the material level with steel, wood and concrete. Furthermore, it is necessary to optimize the respective correlations between resource consumption and environmental effects.

In addition, there are various other topics, such as new, resource-efficient materials; most of them are currently researched or in use already.

Possible future developments and cross-cutting issues (interview part 3)

The previously mentioned priority areas and related issues are likely to remain significant in the future. In some cases, new areas will evolve or create entirely new tasks. Corresponding developments are related to changing conditions. Thus, mega-trends such as population growth and urbanization as well as an increasing flexibility in the way of life will have a strong influence on needs, which in turn must be satisfied by technology. In the near future – in ten years or more – the following issues will gain importance according to the experts.

- *Converging technologies*
  The interdisciplinary cooperation in the field of nanotechnology, biotechnology, and information technology as well as neurosciences is called converging technologies (CT). Progress in the combination of these areas will create ethical and social concerns, but will also enable environmental opportunities.

- *Food/Nutrition*
  Current food production patterns cannot provide sufficient supply for a globally growing population. Synthetic biology, bio-processing and transgenic research offers solutions for the future food and energy demand and, therefore, will play a role. Thus, for example, new crops and chemicals for plant treatment need to be developed. Moreover, according to individual experts, it seems necessary to incorporate genetically modified food. However, this leads to the social problem of public acceptance, because some societies, for example the Japanese, are critically opposed to genetically modified products. The use of arable land for growing corn used for biofuels substituting fossil energy feedstock remains to be further discussed.

- *Resource efficiency technologies to mitigate climate change*
  Global attention to climate change has increased considerably in recent years. However, from the experts'

point of view, current data and awareness of the interactions between climate change and resource use are still unsatisfactory. Apart from the energy issue, solutions for changing water supply should be developed based on specific factors such as, for example, extreme meteorological events, demographics or trends in agricultural land use. Sustainable agriculture is becoming more and more important, not only in terms of climate change, but also particularly due to questions concerning the competition of land use between energy and food industries. New pathogens supported by climate change (e.g. insect-transmitted infections) are an additional challenge. For mitigating of climate change, low carbon solutions are preferred.

- *Water efficiency*
  According to one of the experts, water will have the same meaning in the future as energy has today. There is already a growing fear of water scarcity because it is assumed that droughts will increase in numbers and severity in some regions due to climate change. A modernized infrastructure resistant to extreme weather conditions can foster a more efficient use of water resources. At this time, improved irrigation systems as well as a more efficient configuration of wastewater treatment can be helpful.

- *Decentralization*
  The desire for independence and new technological options lead to decentralization on various levels. For example, energy independent buildings are aspired to obtain a "wireless" house without any supply lines. The required demand of energy is covered by on-site solar panels. In the field of "production of goods" a change from "clean production" to a decentralized production becomes apparent.

- *Social networks*
  This aspect concerns the reorganization of the modern lifestyle. Social networks can be helpful, for example, to identify nearby solutions and to get additional information. Even a simple access to "green" solutions and "do-it-yourself" instructions will gain importance. In general, the social awareness of "green" technologies will continue to increase.

Implementation of resource efficiency (interview part 4)

The interviewed experts agree on the fact that resource efficiency is an important issue, though obstacles and success factors for implementation need to be considered. Thus, at the beginning of implementing measures, decisions have to be made for which a solid information base is needed. This information should be carefully analysed by focussing on issues such as, for example, cost, availability of personnel and financial resources (e.g. are the home owners financially capable of and willing to make their home more energy efficient?). Some decision-making processes should be made automatically instead of leaving it to the home owners, as people often do not act in line with optimal efficiency. For example, the choke used in automobiles was handled manually in the past and more inefficiently than it is controlled nowadays (automatic). The experts emphasize that the implementation of resource efficiency depends on economic, structural and geopolitical conditions. *Figure 4* gives an overview of the determining factors for the implementation of resource efficiency from the experts view. Multiple responses were allowed in the survey.

For the implementation of resource efficiency, the following factors were identified as being of great importance in many interviews: legislation, public funding for research and development, consideration of resource-efficient quality factors in business processes, and availability of personnel. Besides, considering the value chain and possessing specific knowledge to assess the entire value chain as well as using new potential technologies were often stated as influencing factors for implementing resource efficiency. Other little less important influencing factors are the public opinion and social demands. Medium importance was assigned by the experts to the adjustment to external factors (e.g. climate change). According to several experts, venture

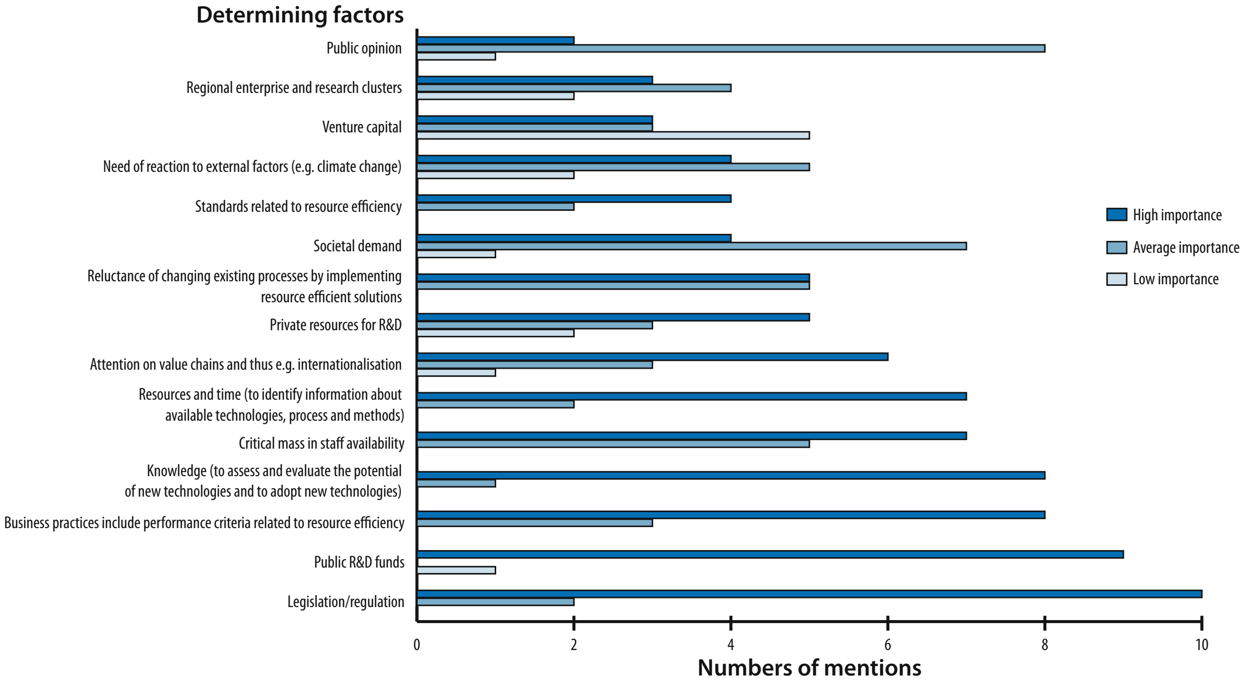


Figure 4: Determining factors for the implementation of resource efficiency (Number of times mentioned in the 17 interviews)

capital has a minor importance in the implementation of resource efficiency.

In the following, statements from the interviews to four actor-related factors of implementing resource efficiency (research, industry, politics and society) are summed up.

In general, *research plays a central role* in the implementation of resource efficiency. Expected challenges emerge from its inter- and multidisciplinary nature, which is, however, important and increasingly necessary for this field of research. Therefore, representatives from business and society have to be involved in scientific research. The approach of the interface management could make an important contribution. It connects expert knowledge to solve issues, chances and problems of the real world. According to the interviewed experts, the international cooperation for all technology developments is increasingly important. Therefore, it should be possible to ensure a transfer of technology for resource efficiency. Some future topics, such as the recycling of construction material, will increasingly become a social challenge instead of being an engineering or scientific challenge; thus, it will become a multi-disciplinary challenge, because the implementation of existing potentials can only be reached by systemic changes and behavioural changes, based on simple and open access to "green solutions" as well as their stronger and wider distribution. However, there is a lack of relevant experts established in this field. It is necessary to create resource efficiency networks for bundling and developing necessary expertise.

According to the experts' opinions, there are still problems related to the topic of resource efficiency in the German research landscape. One of them is, for example, a mainly third parties funding of quality research and, therefore, an increased influence of the industry on these research projects. In this way, it is very difficult to conduct required multi-disciplinary research. Funding institutions often fall back to traditional patterns, where complex issues such as resource efficiency are optimized only in one direction rather than optimizing the entire system.

Despite these difficulties, the topic "resources" is increasingly dealt with at important international universities. This is an indication for the growing importance of resources in the area of research. At the same time it suggests, that the issue has not been established yet but will arrive in the economy in about 10 to 15 years.

In general, *industry is seen as "realizer"* in the implementation of resource efficiency. International cooperation is a main success factor even for the industry in order to successfully implement resource efficiency. An example is the use of available recycling know-how of respective Japanese companies. Industries must pursue a global approach. In value-added networks the treatment of resource efficiency should succeed together with the global players and thereby create a clear connection between resource efficiency and competitiveness.

Still, barriers exist to invest in resource efficiency innovations in many companies (e.g. in the construction sector). The modification of existing processes is problematic, even if the payback period can be relatively short. Only where the implementation of resource efficiency requires a small effort (such as substitutes of investments in energy), innovations are currently implemented.

The topic of resource efficiency can gain importance in terms of economic benefits, when it is measured by economic metrics. That way, appropriate data should be put in relation to costs or shareholder value. Generally, companies should explore resource efficiency options, because many of them expect benefits from them.

In order to accomplish this, the economic thinking should change according to the experts: environmentally friendly product design and a product-related environmental management can be considered as a model and implemented accordingly. Therefore, it is necessary to allocate the required assessment systems with established communication skills. A more intensive communication also serves to spread the available knowledge in large companies.

Raising demand for efficient solutions is needed for an extensive implementation. Here new business, production and consumption models could play a supporting role (e.g. mass customization). There are already many resource-efficient technologies ready to be used; however, they are not used due to the lack of demand. In the field of eco-innovations, the question arises of how much market the industry can generate by itself or how much it depends on the framework conditions.

An important role for the implementation of resource efficiency is attributed to *politics providing suitable frameworks*. Thus, a successful implementation of efficient technologies depends on complying with existing requirements set by the different authorities. This possibility of control and influence needs to be used to strengthen the implementation of resource efficiency. Politics is required to review the existing regional and national requirements and their implementation. Many of the statutory basic conditions appear not to be adapted for the current challenge. A revision of existing environmental laws and contracts should take place with a global perspective.

Meaningful integration of various themes (e.g. water, air, soil or chemicals) should take place, whereby a harmonised use of the term "resources" supports the promotion of resource efficiency. Globally, it is important to consider that a few countries such as China and the U.S. will claim most of the global fossil resources in the future with the result that new strategies are necessary. In the fields of climate and energy there are already many legal regulations such as emission trading; but in the field of resource efficiency, such regulation is mostly missing. Thus, the Kyoto Protocol might be used as blueprint for changes at process level being implemented in a relatively short period of time. Similar arrangements should take place in the field of resource efficiency soon.

It is a political task to provide appropriate incentives and instruments. For example, the legislation has an important role in increasing the efficiency of regulated monopolies (e.g. electricity grids). At the same time, the diversity of regulation complicates radical changes. The development of legislation determines the rules companies must meet in the future. These "external" factors arising from regulations are the central impetus for research, especially for monopolies. Furthermore, there are fiscal instruments, e.g. tax breaks for investments in the environment, encouraging the development of resource-efficient technologies. Consequently, the role of state and the state funding should not be underestimated for the implementation of resource efficiency.

Politics should be able to succeed in achieving comprehensive awareness-building through positive incentives. This should include media coverage, whereby precise strategies, incentives and signals can be set. Here, a lack of political will and practical implementation can be observed so far. The interviewed experts criticize that it is partially not easy to receive respective funding for applied research projects on resource efficiency.

A large-scale "efficiency increase" in developing countries with large resource efficiency potentials should be initiated. Here, the long-term benefits of resource efficiency should be considered and must not be neglected at the expense of other short-term priorities and lack of incentives. Frequently, these countries with a low-income population require a different political focus. Synergies between resource efficiency and poverty reduction are harder to acquire and communicate.

The role of *society as an important push-factor* has been indicated previously under the already described perspective of the multidisciplinary nature of research. According to many interviewed experts, it is to create a change in many areas of society from a purely technology-oriented research paradigm to a perspective, which includes "soft" requirements, for instance, from the area of social sciences. Here, the question arises how people adopt new technologies. The change in human behaviour is frequently seen as a factor that is hard to be influenced. Thus, more solutions should be developed in the future. In this regard, it is important to identify driving factors for human behaviour. According to the interviewed experts it is necessary to create an understanding of the "real value" of resources in society. Since the price for many products steadily decreases, people forget their "value".

This applies especially to countries with only low levels of environmental awareness. Accordingly, it is unclear whether societal demands can be major driving forces for resource efficiency. The topic of resource efficiency is indeed advanced into the consciousness of a broad social stratum, but the willingness to change the own lifestyle is often missing.

Opinion leaders and intermediaries play a central role in the public opinion building process. So it is crucial to determine how the management can be convinced to adress the topic of resource efficiency.

2.2 The identification of resource efficiency examples for practical application

In order to identify examples for practical application with high potential for resource efficiency, potentially interesting examples for technologies and products were screened *(see figure 5)*. For the selection process a method mix of two core areas was chosen: desk research and expert involvement. The desk research included Internet research, analysis and evaluation of literature as well as statements from stakeholders. As already described in chapter 1.2, the focus was set on Europe, with additional examples from North America and Japan. The innovation- and technology analysis (ITA) was used as a conceptual method (BMBF 2001), which helped identifying key questions regarding innovation, action, and future orientation.

The preliminary research results provided the focal points for the expert interviews and were used for selecting relevant experts from the application, research and development fields according to the relevant topics. They were questioned about resource efficiency in specific fields and their exemplary application. In addition to the expert interviews, questionnaires to identify resource efficiency methods were distributed to research organisations, companies, and intermediaries in Europe and other selected countries (especially North America and Japan) worldwide.

Next to gathering general information about potential examples, the questionnaire aimed at gathering qualitative and quantitative information on the resource efficiency potential, economically relevant information (i.e. market potential), and information on implementing resource efficiency through an assessment of risks. The questionnaire was sent to approx. 700 addresses. In response only 25 examples could be obtained, from which only 16 were relevant for the Resource Efficiency Atlas. Simultaneously, in order to obtain examples for the atlas, flyers were actively distributed during scientific conferences and other professional events in Germany as well as in Europe or generally via the website www.wupperinst.org/rea.

To further increase the amount of examples, a "Call for Posters" was organised during an international conference in September 2009 aimed at exchanging resource efficiency examples. As result four additional examples could be collected, from which only two were of sufficient relevance for the Resource Efficiency Atlas. In order to guarantee the multitude and versatility of examples in the atlas the project partners researched and prepared additional examples themselves. Here the coverage of different technological fields, different technologies, results of the expert interviews, a review of the European technology platforms and literature were considered.

Method for gathering examples for resource efficiency

Production and consumption are the key drivers of global resource requirements. Therefore, the focus of the Resource Efficiency Atlas project is not only on research of technologies, but also on products and broadly applicable strategies. Based on the previously systemized search fields and research results the following additional subcategories were identified *(see figure 6)*.

Selection and description of the examples

The results of the screening process (approx. 350 examples) were evaluated. Relevant examples (21 cases) were selected for this publication as well as for the Internet (approx. 90-100 cases). All examples were graded based on a scale from one to six, where one represented best suitability for the atlas. This meant, the following criteria were considered: high potential for resource efficiency, good informational background, economical relevance, environmental impact, feasibility and transferability. In order to obtain an unanimous rating as basis for selection, all project members conducted the grading, upon which the results were discussed.

During the assessment of the resource efficiency potential numerous challenges occurred; i.e. little quantifiable data on sustainability effects are available. Whereas, for example, technical data in the early development stages are often available from provider, only assumptions can be made about the use-phase or possible rebound effects. Therefore, even if sustainability effects cannot be measured, foreseeable risks and opportunities should at least be mentioned in the Resource Efficiency Atlas.

Aiming at collecting approx. 90 to 100 examples, from almost 350 collected examples, only those with grades one and two were selected for the Resource Efficiency Atlas. These were then thoroughly researched and commented on by the manufacturer or developer. Thus, the majority of examples are based merely on own research, excluding a few submitted examples.

Finally, the selected examples for resource efficiency were described in a consistent manner. Hence, for each identified technology, product, and strategy the resource fields of potentially improved efficiency in material, energy, water, and surface fields were selected. According to these fields a qualitative analysis about resource efficiency was performed and as far as data could be researched a rough estimate in quantitative terms followed as well. Consequently, a description about the chances and risks as well as potential appraisal was made *(see chapter 3 for the examples)*.

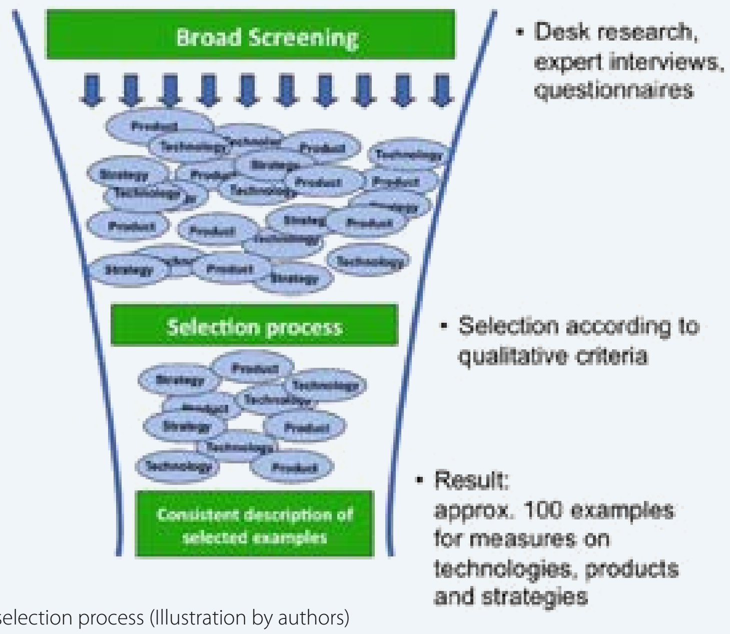


Figure 5: Methodology of selection process (Illustration by authors)

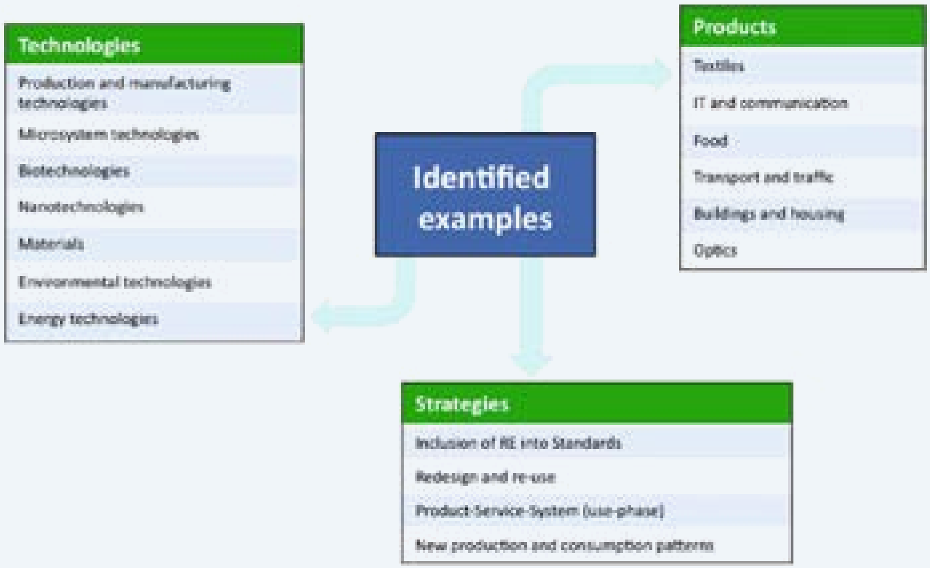


Figure 6: Overview of sectors for resource efficient measures derived from the screening results (Illustration by authors)

Results of the screening

It is evident that the majority of the 92 selected examples for the Resource Efficiency Atlas come from Europe and Asia, followed by North America *(see figure 7)*. In particular, the majority of examples come from Germany, Japan, and Austria, followed by USA and the UK *(see figure 8)*.

Amongst the examples linking to strategies the majority of examples are for redesign and re-use strategies, followed by the new production and consumption pattern strategy *(see figure 9)*.

Within the technology field, many examples could be found for materials, followed by energy technologies and production and manufacturing technologies. Just a few examples have been collected for the environmental technologies and biotechnologies. Nano technologies are represented with three examples and microsystems technologies with one *(see figure 10)*.

Lastly, the majority of product examples are for buildings and housing, followed by a few product examples for transport, food and textile products *(see figure 11)*.

While gathering relevant examples, a number of insights were gained. They can be summarised as follows:

- There is a multitude of examples available varying from high to low tech, from an idea to an already established/developed product/method, from partial solution to a complete system. The examples cover many application fields including examples with high resource requirements (transportation or building and housing). There is an above average amount of energy efficiency examples.

- Although the spectrum of examples is very wide, there is little variance in regards to the origin of the examples. This could indicate potential leading countries or regions in the field of resource efficiency. However, based on the amount of chosen examples and the regional focus of the research, no valid general statements about regional innovation forces can be made.

- Only very few examples are described comprehensively, especially outside of Europe. An exception to this is Japan, however, here the greater focus is on energy efficiency. The European technology platforms provide only limited information on specific example descriptions and resource efficiency potential.

- The evaluation is often not quantified or only based on manufacturer's data. The potential of a specific application is only described at a very generic level, if at all. Very differing methods are used to determine and describe the potentials for resource efficiency.

- Barriers and risks such as rebound-effects are usually left out. This is true not only for the manufacturer information, but also for already existing resource efficiency example websites.

- The 92 examples for the Resource Efficiency Atlas have their main focus in the field of technologies on production and manufacturing technologies, energy technologies, and materials; in the field of products on buildings and housing and in the field of strategies on redesign and re-use as well as new production and consumption patterns.

- Information on certain cases, for example from the Asian region, were only available in their native language. This limits their international diffusion. They could be translated for the Resource Efficiency Atlas only in exceptional cases.

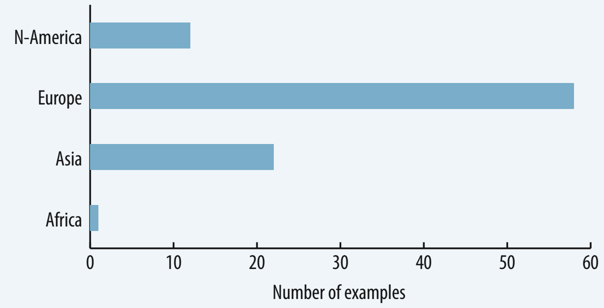


Figure 7: Distribution of the 92 resource efficiency examples according to continents (Illustration by authors)

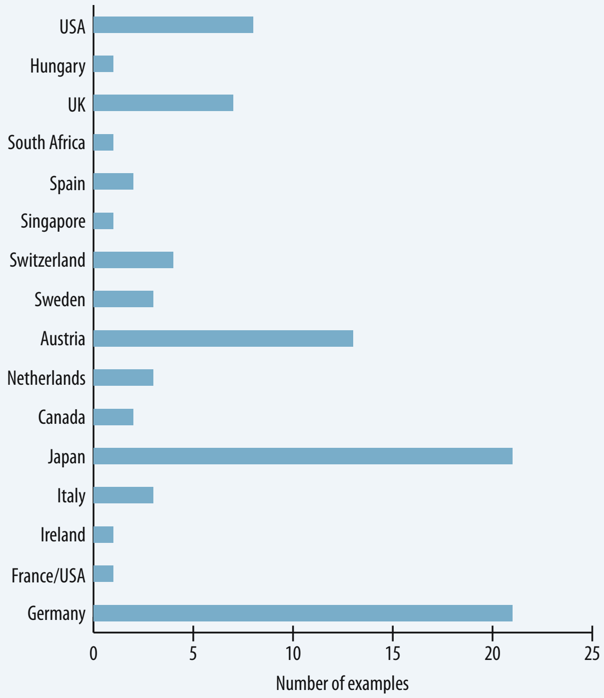


Figure 8: Distribution of the 92 resource efficiency examples according to countries of origin (Illustration by authors)

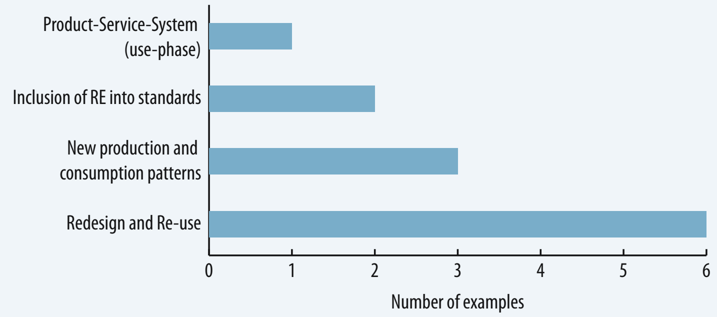


Figure 9: Distribution of the 12 resource efficiency examples within the strategy field (Illustration by authors)

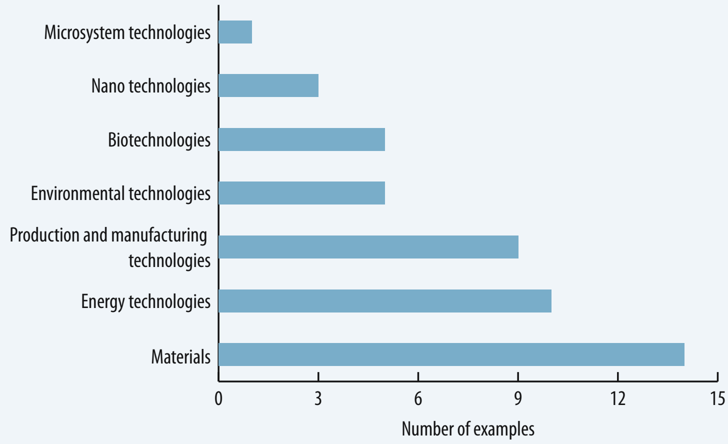


Figure 10: Distribution of the 47 resource efficiency examples within the technology field (Illustration by authors)

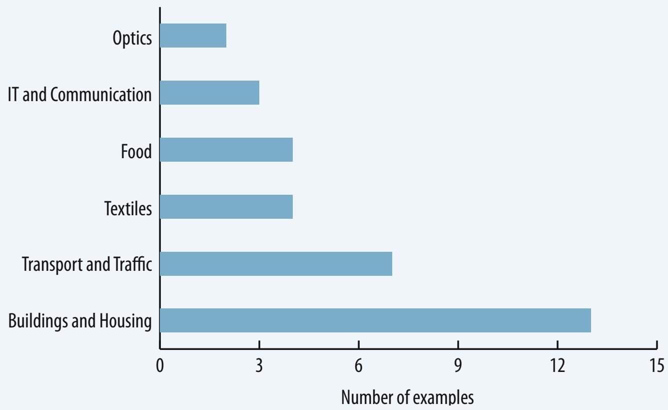


Figure 11: Distribution of the 33 resource efficiency examples within the product field (Illustration by authors)

3 Resource efficiency in research and practice: 21 examples

One of the main goals of the Resource Efficiency Atlas project is to identify and consistently describe resource efficiency examples. The following chapter portrays a selection of 21 examples from the 92 identified examples in order to illustrate the characteristics of the identified examples and their variability concerning different technological fields, products groups, strategies, and regions[1]. This page provides an overview of the selected 21 examples. All 92 examples are described at the project Internet platform www.ressourceneffizienzatlas.de.

1 The information has been gathered during the course of the project. Changes in the meantime or mistakes might occur despite careful research.

1 Magenn Air Rotor System
M.A.R.S. is a mobile wind-power plant producing energy in large heights (approx. 300 m) where wind velocities can reach from approx. 6 to 100 km/h.
→*see more on page 26*

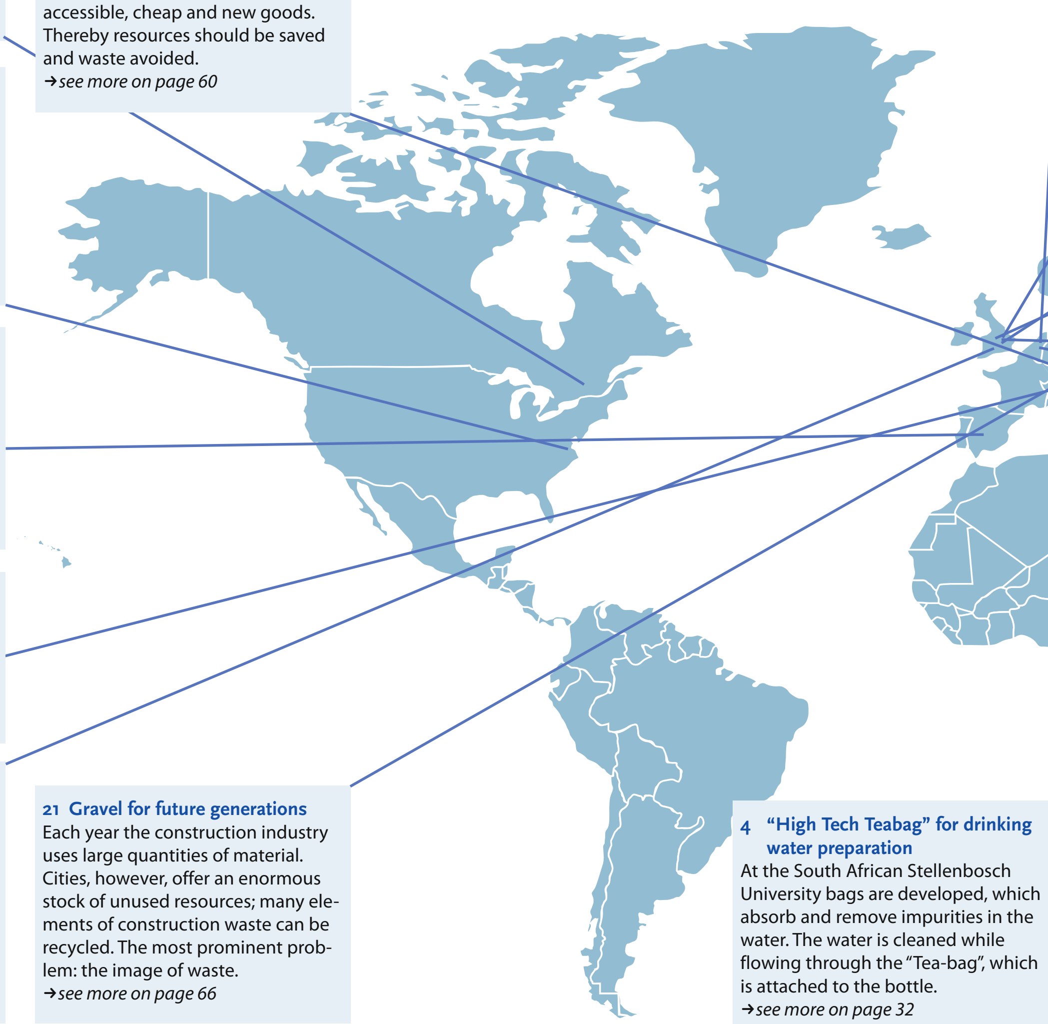
9 Vertical Farming
Vertical Farming allows the production of vegetable and animal products in the city. Instead of agricultural production on the field or in conventional greenhouses and farms, it takes place in multi-story buildings in the city.
→*see more on page 42*

15 Dyeing Bath Re-use via Laser Spectroscopy
Because of high water consumption and water pollution, dyeing of textiles is environmentally harmful. A new method uses laser technology in order to enable dyeing bath reuse.
→*see more on page 54*

19 Chemical leasing
Pay for services, not products. This concept aims at an efficient use of chemicals – a business model, from which everyone involved can profit.
→*see more on page 62*

20 NISP-Networking for Sustainability
With the National Industrial Symbioses Programme (NISP) Great Britain shows how industries can profit from one another's know-how through local partnerships – with the aim of reducing the environmental impact and strengthening the business.
→*see more on page 64*

18 Repa & Service Mobil
Repair services can be made more popular and attractive with mobile repairing points and service points. The aim is to make all goods more competitive in comparison with easy accessible, cheap and new goods. Thereby resources should be saved and waste avoided.
→*see more on page 60*



21 Gravel for future generations
Each year the construction industry uses large quantities of material. Cities, however, offer an enormous stock of unused resources; many elements of construction waste can be recycled. The most prominent problem: the image of waste.
→*see more on page 66*

4 "High Tech Teabag" for drinking water preparation
At the South African Stellenbosch University bags are developed, which absorb and remove impurities in the water. The water is cleaned while flowing through the "Tea-bag", which is attached to the bottle.
→*see more on page 32*

2 Groasis Waterboxx
Groasis Waterboxx supports the growth of young plants under arid conditions (e.g. in deserts or on gravel soils) without using electricity or large amounts of groundwater.
→ *see more on page 28*

3 Seewater Greenhouse
The functionality of conventional greenhouses is reversed in the Seawater Greenhouse. Here, sea water serves as a cooling system of the greenhouse allowing for the cultivation of vegetables and fruits even in dry regions, which normally are unsuitable for agricultural use. The necessary water is obtained via an integrated sea water desalination plant.
→ *see more on page 30*

5 THECLA: Thermoelectricity in Clathrate
In order to convert waste heat into usable electricity, the thermoelectric efficiency of materials with promising thermoelectric characteristics is optimized within an Austrian research project.
→ *see more on page 34*

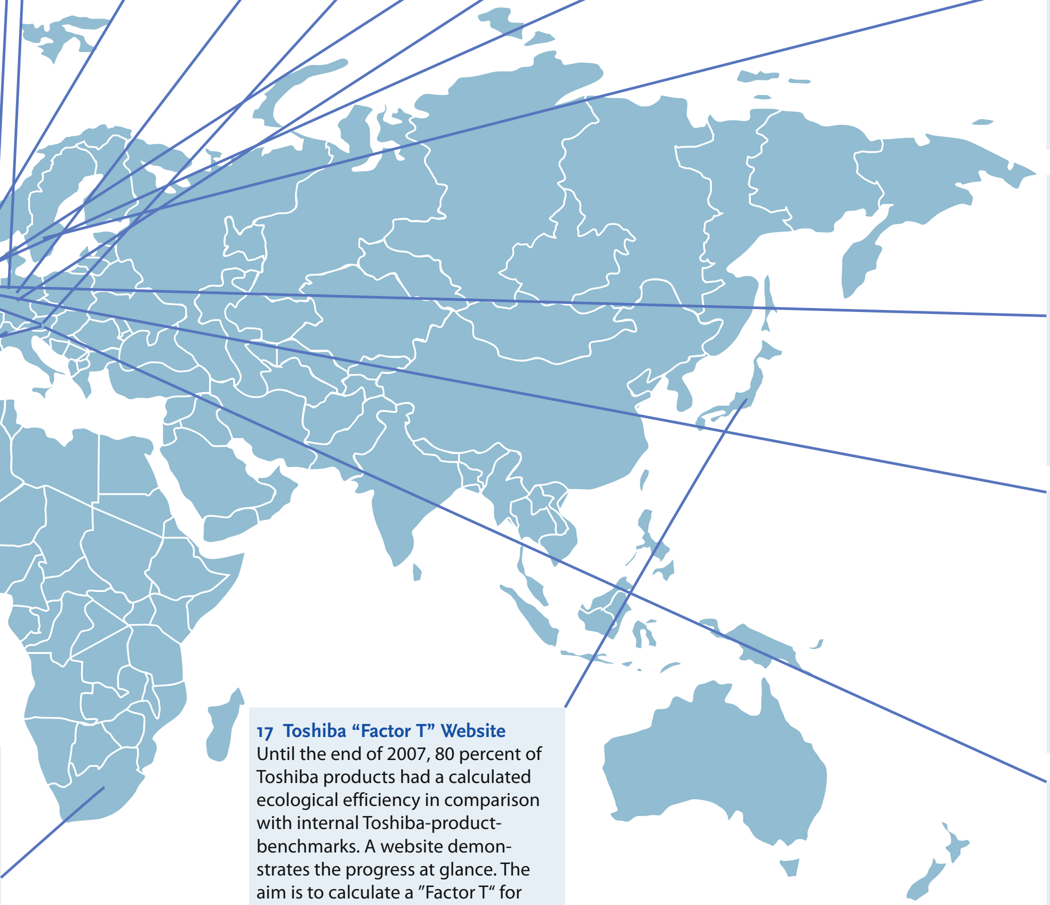
10 Xeros – Washing without Water
British researchers are currently developing a washing machine, which needs only one glass of water. Reusable plastic balls are used to suck stains off the clothes and get them fresh again. Additionally, this procedure saves energy, as there is no drying of the clothes needed.
→ *see more on page 44*

6 Higher Energy Efficiency by using high-tech steel
By using a newly developed strip casting technology, steel with excellent strength and deformation properties can be manufactured with improved energy efficiency. New alloys based on steel arouse particular interest of the automotive industry in regards to body construction.
→ *see more on page 36*

7 Green Cement
Scientists of the Karlsruhe Institute of Technology have developed a "green cement", a new type of hydraulic binder, during which's production up to 50 percent of the conventional CO_2 emissions can be saved.
→ *see more on page 38*

11 SkySails – the Wind Propulsion System
SkySails is a towing kite propulsion system for cargo ships. Depending on the wind conditions, approximately 10 – 35 percent annual fuel savings can be achieved, which implies lower exhaust emissions.
→ *see more on page 46*

8 Aquamarine Power
Scottish developers present a wave power station at the coast feeding an onshore turbine via offshore pumping stations. An enormous flap uses the power of the ocean for transformation in electric current.
→ *see more on page 40*



12 Peepoo
The Peepoo is a self-sanitising, biodegradable, single-use toilet in the shape of a bag, which serves as a fertilizer two to four weeks after use. It is produced to provide maximum hygiene at minimal cost in order to supply densely populated urban slums, refugee or emergency camps with a safe sanitation solution.
→ *see more on page 48*

13 Universal Charging Solution (UCS) for mobile phones
In February 2009 the initiative to develop a uniform charging device for mobile phones was announced, inviting all mobile phone manufacturers to join in. The charger should fulfil the USB-IF standards (USB Implementer's Forum) and the first models were produced already in 2010.
→ *see more on page 50*

14 Environmentally friendly potato processing method
A fermentation process enables a closed loop blanching in the potato industry. With a sugar-removing-technology it is possible to recycle most of the process water, reduce energy and raw material usage during potato processing.
→ *see more on page 52*

16 S-House – building with Factor 10
Innovative building and technical concepts do not only consider the energy consumption but also the lifecycle-wide resource requirements. Instead of building with resource-intensive materials, here, straw is used for building.
→ *see more on page 56*

17 Toshiba "Factor T" Website
Until the end of 2007, 80 percent of Toshiba products had a calculated ecological efficiency in comparison with internal Toshiba-product-benchmarks. A website demonstrates the progress at glance. The aim is to calculate a "Factor T" for each Toshiba product until 2010.
→ *see more on page 58*

M.A.R.S. is the first wind power station for high altitudes worldwide

Magenn Air Rotor System (M.A.R.S.)

M.A.R.S. is a mobile, largely location-independent wind power station, which generates energy at altitudes of approximately 300 meters and at wind speeds of 6 to approximately 100 km/h.

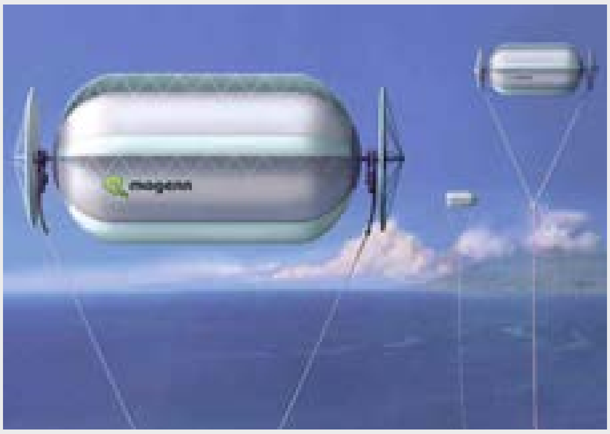


Illustration of M.A.R.S wind turbines (Source: © Chris Radisch)

In order to reach high altitudes, M.A.R.S. consists of a lightweight wind turbine filled with helium. The turbine rotates in the wind about a horizontal axis and generates electricity, which is transferred to earth through a tether. This energy can either be used immediately or stored in a battery for later use. The installation as well as the reallocation of the station does not require any large construction equipment.

M.A.R.S. is placed in greater hights and, therefore, can be used in many different areas, unlike conventional wind power stations. It also costs less and performs better. Moreover, it produces lower noise emissions and, due to its three-dimensional shape, it is better visible and, thus, easier to bypass for bats and birds. The first wind power stations of a 100 kW size should roll out on the market in 2011.

Resource Efficiency

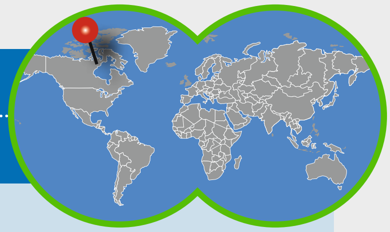
Because of the mobile nature of the power station and the ease of installation, efficiencies can be achieved by installing it in the near vicinity of the user. This would reduce the loss of electricity caused by long transfer routes to a minimum. M.A.R.S. can also be used complementary to a diesel generator. Then, according to the producers, after exchange rate conversion, the cost of producing electricity is below 0.15 euro/kWh and, thus, significantly below the current cost of 0.37 euro/kWh to 0.74 euro/kWh for electricity produced by diesel generators. M.A.R.S. requires only little surface field, because of its construction characteristics. The great energy yields resulting from the high altitude as well as from the comparatively resource-low construction lead to expected low resource requirements per produced kilowatt-hour. However, a detailed lifecycle analysis and resource efficiency analysis still have to be conducted.

Effects

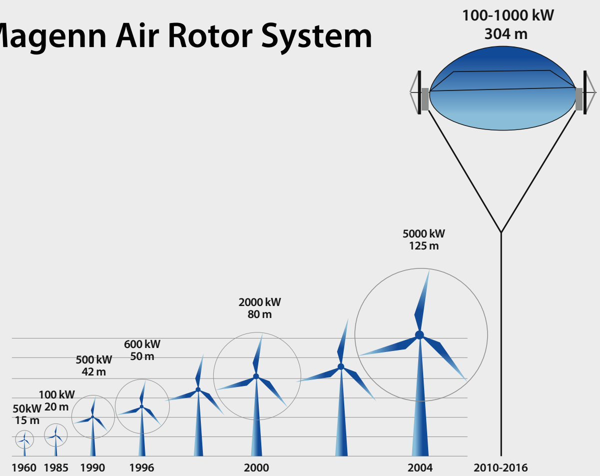
Material	Energy
Water	Surface fields

Region and Country

North America
Canada



Magenn Air Rotor System



M.A.R.S. System and conventional wind turbines
(Source: ubb based on Magenn)

Barriers and Risks

Compared to conventional wind turbines, M.A.R.S. can generate electricity more continuously and reliably, because it operates in higher altitudes with higher wind speeds. However, the periodicity problem of air streams at this height (i.e. jet-streams) caused by, for example, seasons still exists. Therefore, in order to guarantee a continuous supply of electricity, a battery or connection to other M.A.R.S. stations is required.

There is also a risk for the air traffic at those altitudes and, thus, the M.A.R.S. station itself. Therefore, M.A.R.S. stations cannot be used in the direct vicinity of airports. The stations are equipped with a NOTAM (Notice to Airmen) system, which inform pilots about any changes in the airspace. Furthermore, the turbines have installed lights blinking every second. In the case of an emergency, such as the partition from the tether, the turbine will discharge the helium automatically. These measures were approved in Canada, but for the use in other countries an assessment of the legal basis is required.

Customers have to obtain a permit for installation and use. They have to buy the helium and battery and also need to organise the connection on their own. M.A.R.S. offers only a one year warranty and the maintenance fees add 3 to 7 percent of the station costs annually. In addition, the helium evaporates at a rate of 6 percent per annum, requiring a fill-up every 4 to 6 months, which also leads to extra costs.

Another issue is the energy storage: if the generated energy cannot be used up directly, then the use of M.A.R.S. depends strongly on further developments in powerful and efficient electricity storage systems.

Potentials

M.A.R.S. poses a good alternative for electricity production in developing countries or rural, less densely populated areas. It could also be installed on, for example, oil platforms, mines, islands or be used in agriculture.

The great potential of the wind power stations operating in high altitudes is demonstrated by a recent study "Global Assessment of High-Altitude Wind Power" by Archer and Caldeira (2009) concluding that jet-streams have the potential of producing hundred times more energy than the actual global demand.

Further information

- Archer, Caldeira (2009): Global Assessment of High-Altitude Wind Power.

Magenn Power, Inc.
105 Schneider Road (Wind Mill Center)
Kanata, Ontario, Canada
K2K 1Y3
www.magenn.com

Intelligent water incubator for plant cultivation

Groasis Waterboxx

Groasis Waterboxx from AquaPro supports the growth of young plants under dry conditions (e.g. in deserts or on gravel soils) without using electricity and with reduced water usage.

Tree cultivation in difficult locations with Groasis Waterboxx (Source: © AquaPro)

The Groasis Waterboxx is a water collecting plant incubator made of plastic with the size of a motorcycle tire. Here, two small plants or seeds can be planted. Only one watering is required at the beginning of the planting process. Afterwards rainwater and condensed water is collected in the box and released to plants. As a result, the following benefits are achieved: water evaporation is reduced, the temperature and humidity levels of the roots are at an improved level, no artificial irrigation or soil preparation is necessary. Moreover, according to the producers, the water in the box remains clean, i.e. algae-free. Another effect achieved is the improved growth rate of biomass around the Waterboxx, in moderate climates, which has been observed to increase by 15 to 30 percent compared to conventional planting methods, despite the achieved lower competing weed growth next to the plants.

As soon as the roots have reached sufficient depth and humidity (in about one year), the plants start to grow more rapidly and the box can be removed. If both plants have developed well, the weakest is cut off. The remaining tree is now strong enough to grow on its own and the free Groasis Waterboxx can be reused for planting another plant. According to the producers, four years of testing have proven that the success rate reaches almost 90 percent.

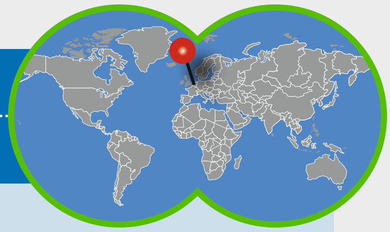
The Groasis Waterboxx was named as one of the top ten global inventions in 2010 by the popular science magazine.

Effects

Material	Energy
Water	Surface fields

Region and Country

Europe
Netherlands



Resource Efficiency

The Groasis Waterboxx enables the growth of plants with highly reduced water use. The plants require only one watering of approximately 18 litres, which lasts for one to two years. Thus, compared to standard planting methods, whereby a plant consumes about three litres of water per day, significant water savings can be achieved. Additionally, since there is no need for artificial irrigation systems, electricity (e.g. for a pump) is saved.

Since this method offers many economical benefits in comparison with traditional planting methods; operating costs are low. It could help in the development of specific regions generating far reaching positive effects. The Groasis Waterboxx has many applications such as growing fruit trees in Sahara desert in Morocco or planting trees in Barcelona at avenues in order to absorb the respirable dust.

Barriers and Risks

The fact that the Groasis Waterboxx can only be reused 5 – 10 times could generate criticism. In order to determine the actual resource and water savings from using the Groasis Waterboxx as opposed to traditional planting methods, detailed analysis of the ecological footprint of both methods should be performed. Furthermore, very young plants are preferred for the Groasis Waterboxx, which roots still need to develop. Thus, the limiting factor is the need for expert assessment about the plant characteristics in order to determine if the plant would be able to grow successfully on its own even after the Groasis Waterboxx has been removed.

Potentials

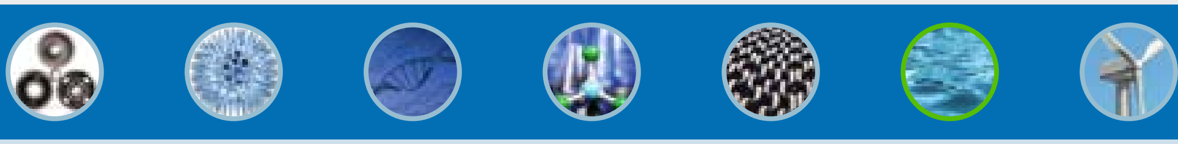
Groasis Waterboxx contributes to solving problems regarding receding groundwater levels, deforestation, erosion, desertification, food shortages and upkeeping water purity.

Further information

- www.sonnenseite.com (search for: ”Groasis”)
- www.presseportal.de (search for: ”Àquapro Holland”)
- www.canna.ch (search for: ”Bewässerung”)
- www.popsci.com (search for: ”Groasis”)

AquaPro BV
Franseweg 9
4651PV Steenbergen, The Netherlands
www.groasis.com

Technologies



Production and manufacturing technologies | Microsystem technologies | Biotechnologies | Nano-technologies | Materials | **Environmental technologies** | Energy technologies

The natural water circulation as model for the future greenhouse

Seawater Greenhouse

The functionality of conventional greenhouses is reversed in the Seawater Greenhouse. Here, seawater serves as cooling system of the greenhouse allowing for the cultivation of vegetables and fruits even in dry regions, which normally are unsuitable for crop cultivation. The necessary water is obtained via an integrated seawater desalination plant.

The water demand of the Seawater Greenhouse can be covered with the help of a solar powered seawater desalination plant. Hence, it is particularly suitable for dry, costal regions. In the Seawater Greenhouse, a simulation of the natural water circulation takes place. Apart from serving as climate control within the greenhouse, this principle allows for the transformation of seawater into fresh water, which is used for irrigation of the plants. In addition, plantations outside the greenhouse with fruits like oranges or lemons can be watered. Furthermore, minerals from the seawater are used for the fertilization of the crops as well as for the production of salt crystals.

The concept of the Seawater Greenhouse has been developed by Charlie Paton in England and further researched by the British enterprise Seawater Greenhouse Ltd. since 1991. By the end of the 90ies it was ready to be launched. In 1992, a first pilot plant was set up on the Canary Island Tenerife. Positive results confirmed the capacities for development and, thus, suggested application in other regions. Other research facilities ensued. The first Seawater Greenhouse in the world used for commercial purposes was opened in South Australia in 2009.

Resource Efficiency

The solar powered desalination of seawater represents an eco-friendly and energy-saving alternative to conventional seawater desalination plants. The obtained fresh water is pure and distilled and requires no further chemical treatment. Groundwater withdrawal is minimised due to production of the necessary fresh water. The use of pesticides can be reduced or even completely avoided by using the "germ-free" evaporated seawater. For these processes only solar- and wind energy is used. The salt, which is won during the desalination process, can be sold as table salt – as long as it is economically viable. Other minerals obtained in this process are used for fertilization.

Barriers and Risks

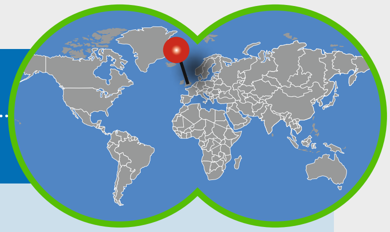
The investment volume of solar powered seawater desalination plants is high. Therefore, there is a serious risk of creating dependencies on the desalination industry, especially in poor countries. Furthermore, taking other environmental protection measures, for example improving the water management system, might not be given priority due to the use of seawater desalination.

Effects

Material	Energy
Water	Surface fields

Region and Country

Europe
UK



Possible assembly of the Seawater Greenhouse (Source: © Seawater Greenhouse Ltd.)

Potential environmental risks of seawater desalination have not been thoroughly assessed yet. Returning the filtered salt as brine into the sea can have negative effects on the already disturbed coastal regions. This is one of the major concerns of the environmental organisation WWF. They warn about the destruction of coastal regions. Supporters of the desalination technology argue, that the conditionally increased salt concentration of 6.5 – 7 percent caused by the refeed is not measurable already within a few meters from the point of discharge into the sea.

Potentials

In 2008, the manufacturer Seawater Greenhouse developed together with a team of architects the concept of the Sahara Forest Project. This project is a further development of the Seawater Greenhouse concept and intends to use large-scaled greenhouses together with solar plants for the food production in deserts. Solar tower power stations not only supply the energy needed for the pumps installed in the greenhouses but also support the evaporation process of the sea water due to their heat waste. The plants are expected to produce a surplus of energy and drinking water.

Further information

- Brendel (2003): Solare Meerwasserentsalzungsanlagen mit mehrstufiger Verdunstung.

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Clean drinking water by using nano-fibres

"High-tech-tea bags" for drinking water purification

At the South African University of Stellenbosch, bags are being designed, which absorb and remove impurities from the water. These bags are similar to conventional tea bags and are to be placed with a top piece on the bottleneck. Thus, the water is cleaned automatically while flowing out of the bottle during drinking.

High-tech-tea bag in a bottle-attachment
(Source: Stellenbosch University)

The innovative bags are comparable to conventional tea bags in their shape and size. The material is very similar as well, but there are very thin fibres inside the bag, whose size is at nano-scale and which are able to filter the impurities. Furthermore, the bags contain activated carbon, which kills bacteria.

The bags are being fixed in a top piece, which has to be placed on top of the bottleneck. The bottle top may look very different depending on the shape of the bottle. Project information from the University of Stellenbosch illustrates, that a single bag can purify one litre of highly polluted water, so that it is safe to drink without any health risks. After usage, the bag can be disposed off easily. The nano-fibres are supposed to decompose after a few days and not to have any negative impact on the environment.

A major advantage of this technology is the simple implementation, because the top piece including the bag is easy to use. Therefore, the purification can take place without any energy wherever it is needed. The risk, that the purified water will be contaminated again while transporting, can be eliminated. In addition, the costs with less than half a U.S. cent per bag are being kept low.

The cleaning bags are still in the development phase. For the implementation of a mass production, some analyses need to be made. However, according to the involved researchers several tests show promising results.

Resource Efficiency

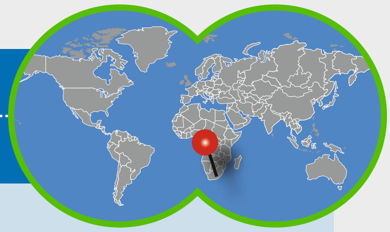
It is possible to foresee significant savings compared to a conventional central water purification, because this usually requires several complex stages. In the central water treatment, water is at first being cleaned mechanically to remove coarser, undissolved and sediment sewage components. Afterwards, a biological treatment in order to reduce dissolved organic compounds takes place. Finally, in

Effects

Material	Energy
Water	Surface fields

Region and Country

Africa
South Africa



the third cleaning stage mostly chemical removal of special inorganic and non-degradable organic substances occurs. All these cleaning processes require energy and or chemical additives such as chlorine, which can be saved by using these cleaning bags. If it is possible to replace central water purification by these innovative bags, huge material efforts due to the construction of a municipal water supply infrastructure could be saved.

The local water purification in rural areas is often done by boiling water. More than half the world´s population uses fuels such as wood or kerosene for their fireplaces, which are inefficient in nature. By using the "high-tech-bags" it is possible to avoid the use of mentioned raw materials, emissions resulting from the combustion, as well as the expenses for transportation of freshwater and wastewater.

Potentials

The potential of these cleaning bags lies in their ease of use, especially in regions that are not easily accessible and do not have proper water treatment facilities. About three billion people suffer from an inadequate supply of clean drinking water, which in developing countries constitutes to the main cause of disease and deaths. Therefore, the bags could have positive effects on the health of many people. Other fields of application are both in leisure activities such as hiking or camping and emergency situations, where quick help is required, for example, after earthquakes or for flood victims.

Barriers and Risks

Although the price of the bags appears to be very low for consumers in industrialized countries, for the developing countries it might be too high. Thus, a widespread, prevailed usage may be prevented due to price of the bags. Moreover it is unclear, whether all possible contaminants of water, such as highly toxic chemicals, are being filtered. In the end, the bags help the underprivileged, who have to drink contaminated water every day and have no other option. However, the bigger problem in many developing countries is that there is no water available in the first place, which cannot be solved by the cleaning bag.

Further information

- www.thehopeproject.co.za
- www.southafrica.info (search for: Teabag)
- www.eartheasy.com (search for: Teabag)

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7602 Stellenbosch, South Africa
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Upcycling of energy by thermoelectric materials

THECLA: Thermoelectricity in clathrates

In order to convert waste heat into usable electrical energy, the thermoelectric capability of materials with budding thermoelectric properties are being optimized in an Austrian research project.

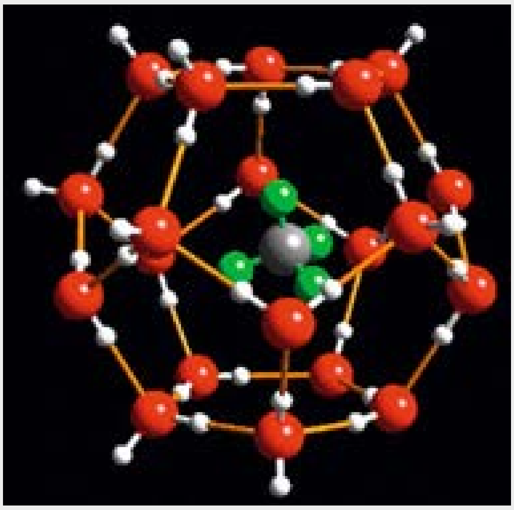


Illustration of the atomic structure of a clathrate
(Source: University Göttingen)

Heat recovery is one of the key strategies to increase energy efficiency of a system for many different applications such as the recovery of heat from air (for instance passive houses) and wastewater (e.g. industrial processes).

Thermal electricity is one possibility for heat recovery. This refers to the mutual influence of temperature and electricity and its respective conversation. Thermoelectric materials can transform the occurring thermal diffusion currents into electrical energy (Seebeck effect) between two spaces or objects at a sufficient temperature difference (thermal gradient). The reverse principle is existent in the so-called Peltier effect. In this process an outward current flow causes a change of flow of the heat. Thus, thermoelectric materials can be used for active cooling or heating.

Although both phenomena have been known for a long time, they are being considered recently for a growing number of applications. One reason for this is that the thermoelectric energy conversion does not need any moving mechanical parts compared to most of the other energy conversion principles. That implies a shock- and vibration-free operation as well as the quietness of the application. Furthermore, small effort for integration of thermal electricity into existing solutions is needed. Applications for thermoelectric materials are seen especially in waste heat recovery and combined heat and power production.

First consideration of the Austrian research project THECLA is the material family of clathrates. This is a compound with two substances: a gas molecule is embedded in a host molecule from the existing grid. Due to the cage-like crystal structure, the clathrates closely correspond to the so-called "phonon-glass electron-crystal concept" (PGEC), whereby the heat is conducted in an inefficient manner, while electric charge is moving virtually undisturbed. Aim of the THECLA-project is the optimization of the thermoelectric capability of clathrates by the selective support or substitution with other elements. In addition,

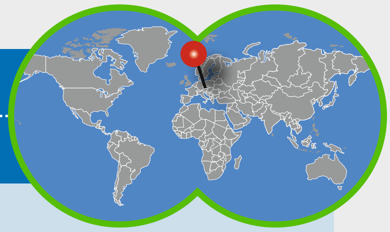
Effects

Material	Energy
Water	Surface fields

Region and Country

Europe

Austria



various methods of micro- and nano-structuring were studied within the project to increase the thermoelectric capability and with that the heat recovery was improved.

Resource Efficiency

Exact information about the increase of resource efficiency cannot be given. Conventional generators of this type have an efficiency of 3 to 8 percent. So far, this project has not made a clear statement about how this efficiency can be increased. Despite the comparatively low efficiency, thermoelectric generators contribute to energy savings of a system, because they usually take effect in applications where up to now the heat has remained unused.

Barriers and Risks

In a number of cases the degree of efficiency is still too low for practical application to be economically profitable. Furthermore, it must be assured that the higher energy efficiency will not be foiled by augmented usage, for instance, of scarce commodities like certain required metals, because then the material efficiency will be degraded.

Potentials

New applications for thermoelectric materials are likely to appear in the automotive industry and in power plants. Thus, the major car manufacturers such as BMW, Mercedes and Toyota are working on plans to use the engine heat to produce electricity via thermoelectric generators. Another potential can be seen in the Peltier cooling effect, meaning cooling by applying electricity to thermoelectric materials.

Further information

- www.fabrikderzukunft.at (search for: ”Thecla”)
- www.cpfs.mpg.de (search for: ”Thermoelektrika”)
- peggy.uni-mki.gwdg.de (search for: ”Gas Hydrates”)

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Energy efficiency with high-tech steels

New kind of strip casting technology enables the manufacturing of high-manganese steels

By using a newly developed strip casting technology, steel with excellent strength and deformation properties can be manufactured with improved energy efficiency. New alloys based on steel arouse particular interest of the automotive industry in regards to body construction.

Coiling of the casted steel strip
(Source: Salzgitter Mannesmann Forschung GmbH)

Strip casting is a worldwide unique conception of casting, which allows the casting of new, high-manganese steels. The advantages of this technology, compared to conventional technology, are the achieved energy and carbon dioxide savings. Generally, during the manufacturing of steel, the molten steel is being casted continuously and subsequently, in a hot state, being rolled into the desired form. In the conventional continuous casting process, steel is poured into a strand with a thickness of 200 to 250 mm. A reheating of the cooled and the strands, which are separated into slabs, usually takes place between casting and rolling.

Due to the tape casting technology, it is possible to pour the steel in thicknesses from 8 to 15 mm by using a radically altered concept of casting. Thereby, the steel is being cast vertically in a chill-mold (reusable mold for the casting of metals) on a horizontal running steel strip. Due to the low casting thickness, it is possible to save up to 75 percent energy during casting, heating and rolling.

The strip casting is suitable for the production of modern high performance materials, because of the horizontal casting direction and the consistently horizontal process management without bending operations at high temperatures as well as the avoidance of relative motions between the strand and the chill-mold.

The innovative steel casting process, which is being realized the first time on an industrial scale at the Salzgitter Stahl GmbH, enables improvements in the utilization phase apart from providing advantages in the manufacturing processes. If the steel is used in lightweight applications such as automotive bodywork, in case of a crash the occupants will benefit from the 3 or 4 times higher plastic capacity compared with conventional steel. Due to the lower weight of the vehicle, it is possible to reduce carbon dioxide emissions while increasing safety.

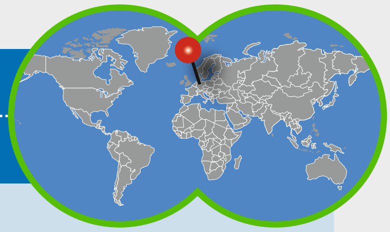
Effects

Material	Energy
Water	Surface fields

Region and Country

Europe

Germany



Resource Efficiency

BCT (Belt Casting Technology) system requires six times less material than building at conventional continuous casting plant. This in turn saves energy in the manufacturing process for the plant components. Compared to the typical manufacturing process of flat steel (continuous casting, hot rolling), 2.1 gigajoule per ton of hot rolled steel can be saved by using the combination of strip casting and so-called steckel-mills. By using the strip casting and in-line rolling up to 2.7 gigajoule per ton of steel can be saved. In addition, due to the strip casting process, cooling water does not come in direct contact with the product, which translates into a closed water circuit, hence, no water contamination occurs.

Barriers and Risks

The first commercial strip casting plant is operating at the Salzgitter Flachstahl GmbH in Peine. Although some experience with such technology has been collected on a laboratory scale in Clausthal, there are still some risks regarding commercial implementation, because of the necessary upscaling and longer hours of operation.

In order to utilize the full potential, e.g. in the lightweight automotive market, the costs for the new steel may not outweigh its advantages. Up to now, no cost estimates have been published for a future series production.

Potentials

Commercial production is planned for the late 2012. According to the manufacturers' data, 25,000 tons of high-manganese high-performance steel can be produced by then. If these 25,000 tons will be used in the automotive manufacturing, 160,000 cars could be built based on the steel. Due to the improved strength of the steel, less steel is needed for each car, resulting in reduced weight and, thus, a reduction of fuel consumption of cars, up to 0.2 liters per 100 km is possible. According to this scenario up to about 8 million litres of fuel could be saved per year. Savings of abiotic resources concerning material (about 190,000 tons) and fuel aspects (about 9,000 tons) are being estimated.

Furthermore, this technology provides the potential to substitute conventional steel products of the worldwide market.

Further information

- www.nachhaltige-innovationen.de (search for: "282")
- Meyer (2004): Energieeffizienz mit Hightech-Stählen. BINE Informationsdienst Projektinfo.

Salzgitter Flachstahl GmbH
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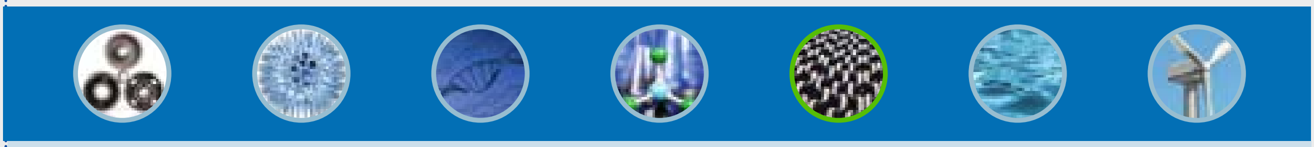
www.salzgitter-flachstahl.de

Technologies



Production and manufacturing technologies | Microsystem technologies | Biotechnologies | Nano-technologies | Materials | Environmental technologies | Energy technologies

New cement 'Celitement' leaves smaller ecological footprints

Green Cement

Scientists of the Institute for Technical Chemistry of the Karlsruhe Institute of Technology (KIT) have developed a "green cement", a new type of hydraulic binder. During its production up to 50 percent of the conventional CO_2 emissions can be saved. With Celitement approx. half a billion tons of CO_2 could be saved per year.

Cement cube (Source: Celitement GmbH)

Hydraulic binding agents such as cement form the basis for building materials as concrete and mortar. The cement keeps the other concrete components together and is, thus, indispensable for the entire industry of construction and building materials. With a worldwide cement production of more than 2.8 billion tons in 2008, the cement industry is one of the most important industries around the globe. At the same time it induces 5 percent of global CO_2 emissions. The conventional production of one ton of cement emits one ton of CO_2. The cement production emits more than two billion tons of the greenhouse gas carbon dioxide per year - three to four times as much as the entire air traffic.

A new group of hydraulic binding agents, with the trade name Celitement, promises a considerable improvement of the energy and environmental balances in the cement production. Celitement is a cementitious binding agent, comparable to Portland cement, based on hydraulically active calcium hydrosilicates, previously unknown to producers. When this binding agent for the production of cement is used, less lime is needed and the burning temperature can be reduced to 300°C during the manufacturing process. Usually the production of cement is carried out at temperatures of approx. 1,450°C, as for example is the case with Portland cement clinkers.

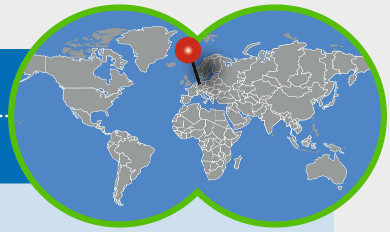
Effects

Material	Energy
Water	Surface fields

Region and Country

Europe

Germany



Resource Efficiency

In the entire production process of Celitement up to 50 percent of the required energy can be saved compared to the production of conventional Portland cement. Furthermore, CO_2 emissions can be reduced by up to 50 percent. Thus, the energy and environmental balance of the cement production could be improved considerably.

Barriers and Risks

The practical implementation of this new building material in the industry might still take some years. Even though Celitement seems highly promising, intensive research work and testing trials must be conducted. A failure of the material during construction could have serious consequences for humans and the environment. Therefore, a detailed examination of the physical and chemical characteristics of the material is necessary before launching such a new product. Only these extensive testing trials will show whether Celitement can compete with conventional cement in the long run.

Potentials

According to the Celitement GmbH, Celitement has numerous advantages. Apart from the improved ecological balance, Celitement features optimal material properties and is compatible with conventional types of cement. Another advantage is the well-known process engineering, since the process of production of Celitement is already known and widely tested in the manufacturing of cement or aerated concrete.

In order to develop the new cement up to a stage of marketability, scientists of the KIT together with the industrial partner Schwenk set up the Celitement GmbH. A pilot plant on the KIT campus enables the conduction of first tests, which are necessary for the long-term industrial implementation. Starting in spring 2011, the pilot plant is to supply 100 kilograms of Celitement daily. Already in 2014, the new cement is to enter the market.

Further information

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Using offshore waves for clean power generation

Aquamarine power

Scottish developers present a wave power station at the coast feeding an onshore turbine via offshore pumping stations. An enormous flap uses the power of the ocean for transformation in electric current. Storm tides should not have any effects on the swinging wave power station Oyster.

System components of Oyster Wave Energy Converter (Source: Aquamarine Power)

The oscillating wave surge converter called "Oyster" uses the potential energy of waves for energy production. The power station is shaped like an enormous flap, which is attached to the seabed around 10 to 15 metres under the water surface. Vertically aligned, the flap scarcely sticks out of the water surface. The waves are pushing the flap forward to the ground before it swings back to the rear. The movement of the flap drives two hydraulic pistons pushing water onshore with high pressure via a subsea pipeline; the water is then pumped into a conventional hydroelectric turbine. Thus, the actual power generation takes place onshore using conventional technology; the main innovation here is the transformation of kinetic energy into potential energy using a flap in the sea.

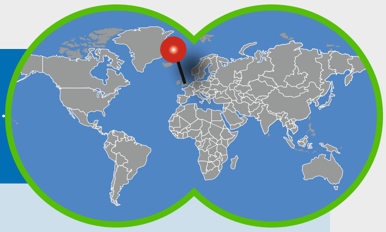
The first prototype of Oyster started running in November 2009. Connected to the generator ashore, it supplies an electrical output of 315 kW. At present, the second prototype is being developed: Here, three Oyster pumping stations are connected in order to power a generator with an output of 2.5 MW. Construction of the plant is to begin in Scotland in 2011. The plant is designed for mass production. In the long run, it is planned to develop power stations with a total output of 20 to 100 MW, depending on the specific coast line.

Effects

Material	**Energy**
Water	Surface fields

Region and Country

Europe
UK



Resource Efficiency

The wave power station uses renewable energy of waves and emits no CO_2 during the utilization phase. The plant is designed in such a way that the energy of waves even higher than the Oyster stations itself can be used. The first prototype generates 6,000 operating hours per year. Additionally, the power station technology can be used for seawater desalination if the Oyster stations power a plant for reverse osmosis.

Barriers and Risks

With the hydroelectric turbine, the wave power stations are designed based on conventional, sufficiently established, technology. A problem – as known of offshore wind energy plants – could be the corrosion caused by the salt water. So far many pilot plants for the use of wave energy have been destroyed by storm tides. However, the Oyster power stations should be more robust due to its simple construction: On the one hand, turbine and generator are located ashore, on the other hand, the pumping stations with the swinging flaps offer small contact surfaces; they can be washed over completely. The effects on flora and fauna of the coasts have not been examined yet. Conflicts with the tourism industry could occur.

Potentials

Coastal regions, which are particularly suitable for the use of wave energy, are located between 30° and 70° East on the northern and southern hemisphere. Thus, particularly suitable coastal regions in Europe are located in England, Portugal, Spain and Norway. Also the coastal regions of North and South America along the Pacific and Atlantic Ocean offer good conditions for wave power stations. According to the study "Future Marine Energy Challenge" of the society "Carbon Trust" from 2006, sea energy could cover up to 20 percent of power requirements in Great Britain. The World Energy Council estimates a possible electrical output of 2,000 TWh, if the potential of wave power stations such as Oyster is used worldwide. That corresponds to more than the threefold quantity of annual gross requirements of electric current in Germany in 2010.

Further information

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Urban agriculture - where potatoes grow into the sky

Vertical Farming

Vertical Farming allows the production of vegetable and animal products in cities. Instead of agricultural production on the field or in conventional greenhouses and farms, it takes place in multi-story buildings in the city – by means of high-efficient technologies, agriculture gets a vertical dimension.

Farmscraper with limited land use requirements
(Source: verticalfarm.com, Blake Kurasek)

In order to adopt a more resource efficient way of agricultural food production, the concept of vertical farming was developed. It allows mass production of vegetable and animal products in cities. In so-called "Farmscrapers", multi-story buildings, the production of vegetables, fruits, mushrooms and algae, even meat and fish, takes place throughout the year, based on the model of the closed loop economy. Such system depends heavily on adequate modern technologies that are already used nowadays. The required technical equipment exists – nutrient and irrigation monitoring systems or instruments measuring ripeness as well as potential diseases of the respective fruit/plant – and only needs to be adapted for the application in Farmscrapers.

The idea of vertical farming was developed in 1999 by Dr. Dickson Despommier and his students at Columbia University in New York. It was developed in an academic project studying roof gardens as a potential source for supplying 50,000 inhabitants of Manhattan with food. These roof gardens proved, however, insufficient and the idea came up to cultivate agricultural crops in a vertical arrangement. To this day, scientists are working on this concept to develop it further.

Resource Efficiency

Vertical farming could contribute to covering the rising demand for food. According to Despommier, up to 50,000 people could be supplied with food from crop yields in a 30-storyed building. The farmscrapers could be built directly in the city centre. This allows for a production close to the urban consumer, long transport and complex cooling systems are not necessary any more. The idea of vertical farming not only aims at increasing resource efficiency in production and processing of food products; additionally, land used for agriculture based on current farming systems would not be needed.

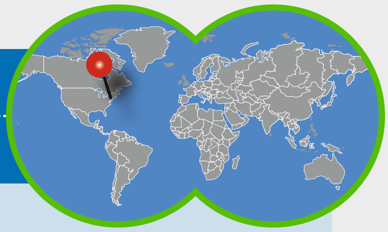
Effects

Material	Energy
Water	Surface fields

Region and Country

North America

USA



Urban food production with farmscraper
(Source: verticalfarm.com, Blake Kurasek)

Barriers and Risks

Detailed analyses of the feasibility and resource efficiency of vertical agriculture are still pending. Thus, an economic and ecological assessment comparing vertical farming systems to conventional agricultural systems is not possible at present. Substantial additional expenditures such as artificial lighting and other operational work, for example, are expected. This could minimize expected advantages. Another constraint is the acceptance by the population. The Dutch project "Deltapark", which was scheduled to be finalised in 2010, failed due to the refusal of the public.

Furthermore, other, much simpler, measures for a sustainable agriculture in rural areas might be postponed if focussing on this new farming concept. A sustainable agriculture as well as responsible consumption patterns are crucial for ensuring a sufficient food supply for all humans in the future.

Potentials

According to UN estimations, worldwide population will reach up to 9.2 billion humans in 2050. By then presumably up to 80 percent of the world population will live in cities and these metropolitan areas need sufficient food supply.

The project "Greenport" was set up in Shanghai, as successor of the Deltapark in the Netherlands. The core of this project is an "Agropark", an area of approximately 24 square kilometers with greenhouses, stables and affiliated processing industry that was established on an island close to the 14-millions-megacity of Shanghai for the Expo 2010. Here, the products are produced as environmental friendly as possible; aiming to increase Shanghai's independency on imported goods. Despommier's enterprise Vertical Farm Technologies is planning further (similar) projects.

Further information

Environmental Health Science of Columbia University
60 Haven Ave. Room 100
New York, NY 10032, USA
www.verticalfarm.com

The washing machine of the future washes with plastic balls instead of water

Xeros – Washing without water

British researchers are currently developing a washing machine, which needs only one glass of water. Re-usable plastic balls are used to suck stains off the clothes and get them fresh again. Additionally, this procedure saves energy as there is no drying of the clothes needed.

Nylon granulate (Source: © Xeros Ltd.)

The British enterprise Xeros is developing a washing machine, which needs only very little water for the cleaning process. According to the developers, only one cup of water is needed for each wash cycle. In contrast to conventional washing machines, which on average use more than 40 litres of water. Furthermore, a high amount of energy is needed for heating this water to 40, 60 or 90 degrees as well as drying the clothes in the tumble dryer. The Xeros washing machine aims at reducing the water and energy use substantially. Instead of large amounts of water, re-useable plastic balls are used for textile cleaning. The clothes are spun with thousands of small, 3 mm long nylon balls, a cup of water and detergent.

The nylon ball surface, thanks to a natural characteristic of the material, sucks the dirt particles in. Nylon reacts to the humidity of its environment with reversible water absorption. Thereby, the water is stored in the amorphous areas of the polyamide. If the moisture content reaches 100 percent, the dirt particles are absorbed by the nylon balls. After the washing cycle the balls can drain off like the water of a normal washing machine. This special technology makes a tumble dryer redundant. After up to 100 loads of laundry the nylon balls must be exchanged and recycled.

The idea of cleaning technology based on plastics was developed by Stephen Burkinshaw, a professor for textile chemistry at the University of Leeds. In 2007, he established Xeros Ltd. The company is testing the cleaning process developed by the Design faculty. Xeros is also the brand name of the patented cleaning system. So far, it is in the development phase.

Resource Efficiency

According to the developers, it is possible to save up to 90 percent of water with the washing machine of Xeros compared to conventional washing machines. According to the developers the machine uses only two percent of the conventional washing machine water and energy requirement, because heating of large amounts of water and drying of

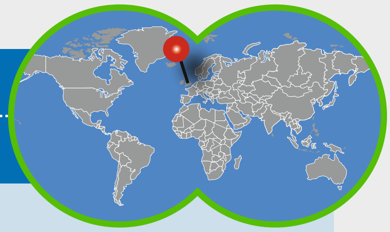
Effects

Material	Energy
Water	Surface fields

Region and Country

Europe

UK



the clothes are now redundant. At the same time, the CO_2-footprint can be reduced up to 40 percent in comparison to the conventional cleaning and drying process. This declaration includes the preparation of the Xeros specific plastic balls. These are regularly cleaned and recycled instead of being thrown away. However, if no tumble dryer is used and the laundry is air-dried, the energy saving of the Xeros washing machine is much lower.

Barriers and Risks

High acquisition costs could put sellers off, considering that the maintenance costs for private households are not that significant. Since no exact data are available for the quantity of required plastic granules, the environmental impact of production and cleaning of the granulate in comparison to conventional washing can hardly be measured. Therefore, the expected advantages could be reduced by efficiencies in water and energy use.

Potentials

According to preliminary estimates of the manufacturer, up to 30 percent of direct operating costs can be saved in comparison to a conventional washing machine used in private households. However, only launching this product and testing it in real life situations can produce reliable data on savings in operating costs. In addition to that, the Xeros machine could reduce the overall water and energy consumption (of private households). According to recent data of the German Federal Statistical Office, approximately 17 litres of drinking water per German capita are used for daily washing activities; three times as much as used for food preparation and beverages. Apart from private households, this technology could represent an alternative to chemical cleaning agents for commercial cleaning companies.

Further information

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The automated towing kite system for ships

SkySails – the Wind Propulsion System

SkySails is a patented towing kite propulsion system for cargo ships. It is based on a large towing kite with which, depending on the wind conditions, approximately 10 – 35 percent annual fuel savings and reductions in emissions can be achieved.

Due to the increasing crude oil prices and stricter emissions regulations for ships (sulphur emissions regulation, carbon dioxide regulations in the development phase), shipping is experiencing steadily rising operational costs. Henceforth, the SkySails system is a lucrative option for the shipping industry.

The SkySails system was introduced to the public in Hamburg in 2001. The system consists of three parts: towing kite with a towing rope, a launch and recovery system and the control system. According to the producers, the system is able to realise an effective load of 8 – 16 tons. Depending on the ship's characteristics such as the effectiveness of the marine screw propeller and the resistance, eight tons of effective load correspond to the engine performance of 600 up to 1,000 kW.

The system does not require extra personnel and can be run in parallel to support the main engine. SkySails does not require a large storage space (a 160 square meter folded SkySail takes up only the size of a telephone booth), and it is lightweight, because it is made out of textile. Compared to conventional sails, SkySails can generate 5 – 25 times more driving force and thus, provides effective support for the engine-driven ship propulsion.

The financial amortisation period is only between three to five years, since the investment costs are low. SkySails calculates the cost to benefit ratio ("Skyprofit") for each shipping company and each ship individually.

The SkySails system has received many awards such as the Sustainable Shipping Award (2009) and the Clean Innovation Award (2009).

Resource Efficiency

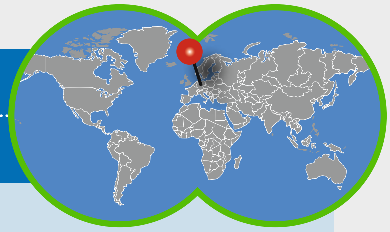
Since SkySails can be installed on almost any kind of ship, the overall potential of fuel savings and emission reductions is high. Ship transport emits about 813 million tons of CO_2 per year with an increasing tendency and accounts for almost 3 percent of the global CO_2 emissions (approximately 30 billion tons in 2005). The worldwide usage of SkySails could cut the global annual CO_2 emissions by 150 million tons, corresponding to approximately 15 percent of Germany's total CO_2 emissions. Numerous studies have confirmed savings between 10 to 35 percent per ship. In optimal conditions a reduction of 50 percent could be reached. However, the exact fuel savings have to be determined on an individual basis, depending on parameters such as ship size, swell and wind speed.

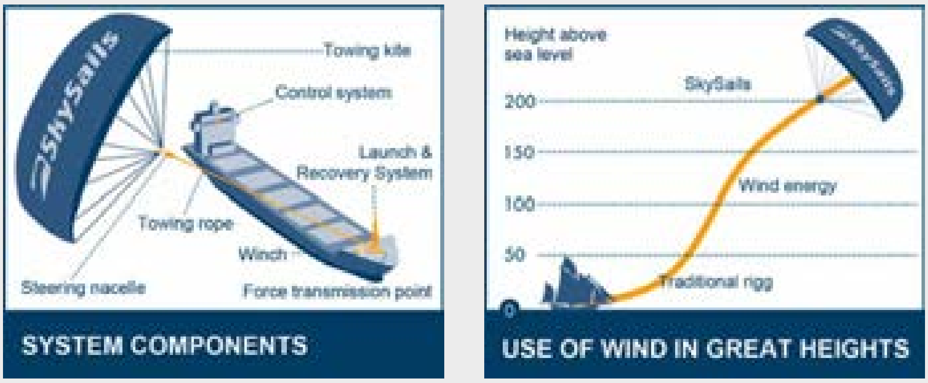
Effects

Material	Energy
Water	Surface fields

Region and Country

Europe
Germany





Skysails system components and the use of wind in great heights (Source: © Skysails, own translation)

Barriers and Risks

Since the SkySails system depends on the wind conditions, the achieved fuel savings can vary. Furthermore, safety issues are a potential risk. SkySails has developed many safety features such as the option of an emergency release for the towing kite. SkySails operates beneath 800 meters outside of the controlled airspace. Moreover, SkySails cannot be started by wind speeds lower than three Beaufort. A landing at these wind conditions is, however, possible.

Another constraint is the fact that, due to the SkySails size and weight, it has so far only been installed on cargo vessels, fish trawlers and super yachts. However, initial plans have already been made for SkySails installation on sporting yachts.

Potentials

The future technological potential depends on the further increase of the tractive forces in order to obtain higher levels of fuel and emissions savings. Currently SkySails is working on the development of tractive forces of 32 tons and plans to increase this up to 130 tons. The fact that not only cargo ships can make use of this system demonstrates the versatility of SkySails, which could encourage its entrance in further markets.

Another potential is based on the fact that reducing fuel consumption also reduces sulphur emissions. The alternative – an installation of a catalyst – would according to the producers, not only increase the fuel consumption by 3 percent, but also require additional resources for filters and discharging of the filtered substances.

Further information

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A self-sanitising biodegradable disposable toilet

Peepoo Bag

The Peepoo is a self-sanitising, biodegradable, single-use toilet in the shape of a bag, which, in two to four weeks after use, can be utilized as a fertiliser. It is produced to provide maximum hygiene at minimal cost in order to supply densely populated urban slums, refugee camps or emergency camps with a safe sanitation solution (e.g. formed due to natural disasters).

Peepoo in Kiberia (Nairobi, Kenya) (Source: Peepoople, Camilla Wirseen)

According to UNICEF Germany, 2.6 billion people worldwide live without access to basic sanitation. As a result, ordinary plastic bags, also commonly called "flying toilets", are often used as substitutes for toilets and thrown away without any consideration. Since such bags are very thin and rip easily, the pathogens in the contents can reach the groundwater and, thus, contaminate the drinking water. Contaminated drinking water is responsible for – next to many other problems – a quarter of the worldwide children´s deaths. By using the Peepoo toilet, contamination of groundwater and drinking water can be avoided. Therefore, Peepoo contributes to the improvement of drinking and groundwater quality as well as to the achievement of the UN Millennium Development Goals.

The Peepoo has the shape of a slim elongated bag that is made from biodegradable plastics and filled with urea. Urea is a non-toxic and harmless carbamide. It is a natural nitrogen based fertiliser used to sanitize the faeces and to start the enzymatic process during which the faeces develop ammonia and carbonate. Within two to four weeks the dangerous bacteria and organisms become inactive. After the complete degradation of the Peepoo, only water, carbon dioxide and biomass remain. Untreated faeces, however, hold the potential pathogenic germs active for two to three years. As a result, a nutrient-rich pathogen-free by-product is produced, which can be safely used to fertilise soil.

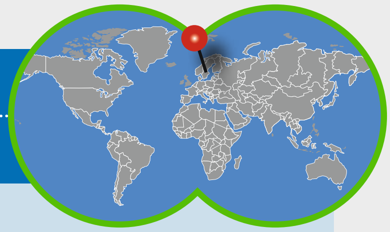
Peepoo should only be used once and can be stored after use for up to 24 hours without developing any odour. The bag weighs less than ten grams, has a size of 14 by 38 centimetres, and is made in two layers with a wider inner funnel. The consumer cost is between two and three cents per piece, corresponding to about 10 euros per person and

Effects

Material	Energy
Water	Surface fields

Region and Country

Europe
Sweden



year. The start of a large-scale production of Peepoo toilets is scheduled for 2012. Then 500,000 Peepoos could be produced per day.

Resource Efficiency

Peepoo does not require water and, thus, contributes to water conservation. Furthermore, a high value nitrogen fertilizer is produced. The organic matter in the fertiliser improves the soil's characteristics through, for example, better structure and higher water holding capacity.

Barriers and Risks

A potential risk could be the continued use of standard plastic bags by the consumers, because the short-term function of Peepoo might appear to be almost the same. However, according to the producers, field tests in Kiberia, the urban slum of Nairobi, Kenya, show that by providing consumers with the necessary information and logistics for using the Peepoo, this risk can be diminished. Still, an ability to purchase the disposable toilet from an economical point of view has to be ensured.

Moreover, there could be an acceptance problem by the users of the nitrogen-based fertiliser, since it originated from human excrements. In order to combat this, a transparent communication about the benefits and risks of Peepoo has to take place.

Furthermore, there is the potential risk that due to the cure of short-term sanitation problems, less interest in investment could be shown in the mid- and long-term wastewater and sanitation infrastructure.

Potentials

A sanitation system entirely based on Peepoos could be developed, whereby the Peepoos would either be collected at a collection point (eventually involving a refund system) or be disposed of as a fertiliser in urban gardens. The potential has already been proven within a pilot project in Kiberia. Here, a refund collection system works. The Peepoos are sold and distributed by local micro-entrepreneur women. As a result, new business opportunities arise not only through Peepoo distribution and collection, but also by the possibility to produce fertiliser. Fertilization could lead to higher harvest yields, leading to positive trickle down effects on the local economy.

Peepoos could also contribute to reducing health care costs. For example, in Nepal, where only a fifth of the population has access to toilets, about 150 million dollar savings could be achieved yearly.

Finally, Peepoos have a great potential for being used in emergencies or refugee camps.

Further information

- www.fairplanet.net (search for: Peepoo)

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Industry wide standard USB charger for mobile phones available worldwide as of 2012

Universal Charging Solution (UCS) for mobile phones

A universal charger for all. This is the goal of an initiative from GSMA (Global System for Mobile communications Association), a global network for mobile devices and accessories. The charger should fulfil the USB-IF standards (USB Implementer's Forum) and the first models were produced already in 2010.

The initiative aims at reducing mobile phone charger energy consumption from stand-by and waste stemming from the growing number of chargers. The standardisation of chargers would also lead to a significantly higher user-friendliness for customers.

UCS concept should at a minimum meet all current energy efficiency laws and parameters. Thus, the old, less efficient devices could be exchanged and the amount of chargers per household could be reduced altogether. According to the Environmental Ministry in Germany, each household in Germany owns 2.5 mobile telephones (with an equal amount of chargers) and, thus, with about 40 million households the volume of about 100 million chargers is reached.

The charger cable should have a USB standard-A and a USB micro-B outlet and it should be removable from a common power supply in order to provide higher flexibility for the end-user. Up until now, for example Motorola, Sony Ericsson and Nokia, have already developed a UCS.

Resource Efficiency

It is estimated that the new devices would reduce the stand-by energy consumption by up to 50 percent. Additionally, the production of 51,000 tons of chargers (duplicates) per year would be eliminated, which would decrease greenhouse gas emissions by 1.44 million tons per year. The chargers would not have to be sold with the mobile phones; instead they could be reused, regardless of the mobile phone model. Finally, the packaging of the mobile phones could be reduced. This would decrease the amount of waste generated and lead to savings in energy required and greenhouse gas emissions emitted during the transportation.

Barriers and Risks

During the transitional phase, this initiative could lead to an increased volume of old charger waste. These should be disposed of in an environmentally friendly manner in order to reuse the valuable, partially rare, non-renewable resources. Thus, new i.e. better recycling concepts would have to be developed. In addition, customers should be actively informed about recycling opportunities.

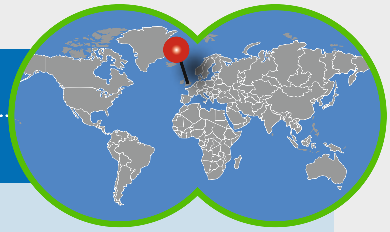
The full potential of energy and resource efficiency could only be reached if all mobile phone producers join the UCS initiative. Currently 27 producers are signatories, which include the biggest mobile phone companies (e.g. Nokia, Sony Ericsson, Motorola, Samsung, HTC, LG). However, Apple, already the fifth largest mobile phone producer worldwide with a sales increase of 87.2 percent since 2009, has not signed this initiative so far.

Effects

Material	Energy
Water	Surface fields

Region and Country

Europe
UK



The universal charging solution (UCS)
(Source: © GSM Association 1999 – 2009)

Effective incentives should be developed to stimulate the demand for mobile phones without chargers, e.g. through price incentives. If the mobile phones will not be sold together with the UCS, it must be ensured that in all locations selling mobile phones customers could also purchase a UCS if desired.

The mobile phone manufacturers will have higher initial costs, because of, for example, the joint development of the UCS and informing customers, employees and retailers. Furthermore, permanent changes will have to take place along the production chain such as, for example, in purchasing, production and the new packaging design.

Potentials

Already in January 2009 Nokia conducted a test in Italy, France, Great Britain and Spain with Nokia N79, whereby customers could purchase this mobile phone without a charger. Many customers chose this option and additional customer questionnaires proved the acceptance for such a product. UCS chargers should be available worldwide as of 2012.

This idea could be transferred onto other fields i.e. markets such as, for example, digital camera or notebook chargers. This would increase potentials for resource savings and environmental benefits.

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- GSM Association (2010): Universal Charging Solution. Whitepaper Consumer Awareness Initiatives 1.0.
- Nokia (2010): Nokia sustainability report 2009.
- www.recyclemycellphone.org
- www.umweltbundesamt-daten-zur-umwelt.de (search for: "Ausstattung privater Haushalte mit langlebigen Gebrauchsgütern")
- www.gartner.com/it/page.jsp?id=1543014
- www.usb.org/about

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A new method of blanching potatoes saves energy and wastewater

Eco-friendly potato processing

A key process in potato processing is blanching. Blanching can be run in a closed system where the loss of freshwater, wastewater, energy and vital ingredients can be reduced.

Fermenter (Source: Aviko Holding)

During the blanching process food is dipped into boiling water for a short period of time, mostly 10 to 30 seconds. This process is particularly applicable for vegetables and mushrooms. Potatoes are blanched, for example, before freezing different kinds of potato-products. It helps to prevent undesirable changes like enzymatic browning or the degradation of valuable ingredients and, thereby, a large amount of scrap by deactivating the enzymes. Furthermore, the natural level of sugar in potatoes can be reduced. However, essential ingredients such as minerals or amino acids are being leached out of the potatoes. Studies have shown that the loss of these essential ingredients during the blanching process can be prevented if the defined concentration of minerals and amino acids in the hot process water is set correctly.

In order to remove sugar from the hot process water after the blanching process, the Dutch company Aviko uses a fermenter. Thus, the hot water has a lower concentration of sugar and it can be used for a further blanching process. Due to the repeated different sugar concentration levels within the potato and the process water, leaching of sugar from the potato occurs while concentration of essential ingredients is reliable. This process is also called "Closed-Loop Blanching" (CLB).

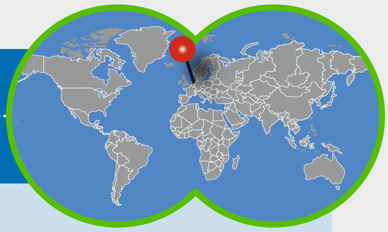
With CLB technology it is possible to recycle most of the process water and reduce energy consumption during potato processing. This is because the recycled water requires significantly less heat to achieve the required process temperature. Aviko has patented this technology.

Effects

Material	Energy
Water	Surface fields

Region and Country

Europe
Netherlands



Resource Efficiency

According to the manufacturer Aviko, the process allows savings of 240 litres of freshwater per ton of processed potatoes, which reduces the overall wastewater. In addition, 94 mega joules of energy per ton of potatoes can be saved. This equates to an CO_2 omission of about 6 kilograms and an omission of nitrogen oxides of about 3.6 kilograms per ton of processed potato. Furthermore, with this procedure, a lower raw material usage of potatoes (3.6 percent) is possible and a smaller amount of waste material will be produced. Therefore, this process is more profitable than the standard processes.

Barriers and Risks

Up to now the process has only been tested at laboratory level. No technical problems are expected for the implementation in mass production. There could be risks concerning legal restrictions in the food industry. For example, the recycled water must meet the legal requirements and ensure an equivalent process and quality assurance compared to conventional blanching.

Potentials

This procedure can be transferred to other companies in the food production industry, which are using the blanching process. Thereby, the CLB-technology has a big potential, since according to the FAO (Food and Agriculture Organization of the United Nation) the worldwide production of potatoes in 2008 amounts to about 311 million tons.

The other potentials are the possibility of introducing additional nutrients or to remove undesirable elements. After several test runs in a pilot plant in the Netherlands between 2005 and 2007, the technology shall be first tested under operating conditions at the end of 2010. Other comprehensive tests will demonstrate the potential of this technology.

Further information

- Somsen et al. (2007): Selective withdrawal of reducing sugars during blanching, United States Patent Application Publication.
- www.cosun.nl

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Dyeing bath reuse for textiles by applying laser technology

Dye recycling by the use of laser spectroscopy

In the field of textile manufacturing the dyeing process is seen as a polluting process due to the high water requirements and contamination of water. This new procedure uses laser technology to enable reuse of the residual dyeing bath.

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The dyeing process is one of the biggest technical challenges in the textile industry. Due to predefined specifications, identical colours in the same quality have to be provided. To achieve this, the individual dyes and chemicals are being newly mixed for every dyeing procedure. Up to now the residues were not recyclable. This was due to the lack of reliable methods for the qualitative determination of the remaining quantities of dye in the residues. In this way, large quantities of contaminated water with chemicals and dyes have been discharged. This resulted in very cost-intensive cleaning processes.

By using a laser spectroscopy, the residues contained in the used dye bath can be determined qualitatively and quantitatively. The determined data of chemical media are processed by a software system, which calculates the required ratio of dyes, chemicals and water. Based on the results for the used dye bath, the desired original ratio can be set up. Thus, residues can be recycled without any negative effect on the colour reproduction and product quality.

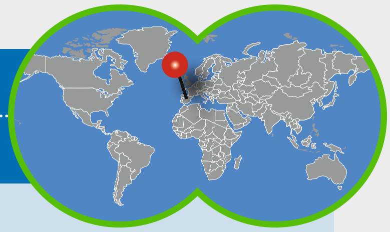
The process was developed within an EU-LIFE project at the University of Catalonia in Spain and tested with promising results in different dye systems and materials such as cotton fibres with direct dyes and polyester with shared dyes. At the end of the project, the technology was exported and is currently used in textile factories in Brazil and Peru.

Effects

Material	Energy
Water	Surface fields

Region and Country

Europe
Spain



Resource Efficiency

Compared to the conventional method, this newly applied technology enables up to 72 percent of water and more than 90 percent of dye savings. A dye bath can be reused up to 24 times without any loss in colour quality. Therefore, it is possible to dye up to 2500 kilogram of textile material compared to the usual 100 kilogram in one dye bath. This leads to an avoidance of 18 cubic meters of chemical polluted wastewater, seven kilograms of non-bio-degradable sludge and about 18 kilograms of tensides per dye bath. Since the dye bath does not have to be heated again during the new process, energy requirements can be reduced by 20 to 25 percent.

Barriers and Risks

The investment costs for a laser spectroscope are high; they can reach 80,000 to 100,000 euros. It is assumed that the costs will decrease in the near future to 15,000 euros and the payback period could be two to three years. Despite the economic mid-term profitability, the wider implementation remains questionable, because most textile companies are located in developing countries, where in addition to the high costs, further technical and organizational difficulties are expected.

Potentials

The laser spectroscopy is already widely used in the analytic field. Generally, the technology can be used in any water and wastewater related process. A large potential is seen in the food industry, especially, for dairy products as well as wood, paint, lacquer and chemical industry. In the future it is expected to carry out spectroscopic investigations in other fields of application where wastewater and sewage arises.

Further information

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Products

Textiles | IT and Communication | Food | Transport and Traffic | Buildings and Housing | Optics

Straw instead of concrete – resource-efficient buildings

S-House – Building with factor 10

Innovative building concepts should consider the energy demand as well as the lifecycle-wide resource requirements. Instead building with resource intensive materials, here, straw is used as building material.

Demonstration building S-House (Source: GrAT)

The construction sector is an economic sector with high energy and resource requirements. Along the construction lifecycle the phases "raw material production", "building material production" and "use phase" have turned out to be especially resource-intensive. Of central importance to the construction of new buildings and renovation is the planning phase, where strategic material selection can steer the material intensity of all remaining lifecycle phases. While energy-efficient construction is being already exercised in practice, aspects of resource protection often still remain unnoticed.

The Austrian group "Angepasste Technologie" (GrAT) managed to reduce the lifecycle-wide resource requirements in comparison to customary buildings by a factor of 10 through the construction of a demonstration S-HOUSE building. Within the framework of the program line "house of the future", an integrated concept was developed, which connects all relevant aspects of sustainable construction. In addition, the straw bale construction, the elementary concept for the S-HOUSE, is also economically interesting. The demonstration building shows the compatibility of traditional building materials with innovative constructions to normal passive house costs. During the deconstruction phase the building materials can be easily separated and, therefore, reused. The building design of the S-HOUSE and used components correspond to current needs of users without consigning disposal problems to future generations or forcing a subsequent use.

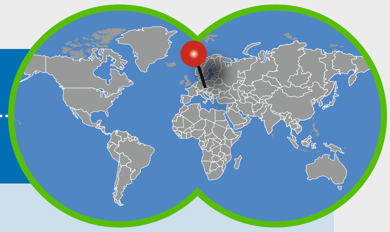
Effects

Material	Energy
Water	Surface fields

Region and Country

Europe

Austria



Resource Efficiency

The resource requirements decrease considerably when using renewable primary products and minimal fossil and mineral materials. The production of the straw wall causes a clearly lower ecological footprint than a comparable conventional wall construction, which has an up a ten times larger ecological footprint. Also the low energy demand of the S-HOUSE is noteworthy. An annual energy consumption of 6 kWh/m² is reached by an optimal insulation and the use of passive house technologies. This is significantly lower than the demanding standard for passive houses (15 kWh/m²).

Barriers and Risks

Components and measures for resource-efficient economic activities in the building industry are already used on a large scale. Nevertheless, by a combination of different attempts further research and development is required to realise efficient system solutions with low expenditures. For this purpose available databases of primary products have to be adapted to the requirements of the building industry. According to the differing demands in regards to building types coordinated work flow and communication processes have to take place between involved actors like architects, craftsmen and engineers. So far instead of finished modules individual solutions are used, which lead to higher costs. Furthermore, high initial investments can arise and building restrictions can complicate the implementation. The insulating effect and the reaction of straw to fire were tested in comprehensive preliminary studies. However, prejudices concerning deficient structural-physical attributes are prevalent.

Potentials

Higher requirements for old and new buildings on federal and EU level such as, for example, energy saving regulations and comprehensive supporting possibilities, will lead to an increase in renovation and new building construction. Reduction of energy demand to a tenth compared with today's best available technology and use of renewable primary products may lead to a widespread dispersal of this building technology based on renewable products, while energy and primary product costs are increasing.

Further information

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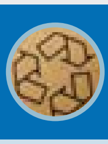
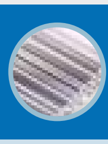
Strategies



Redesign and Re-use

Product-Service-System (use-phase)



New production and consumption patterns

Inclusion of RE into Standards

″Factor T“ shows the achieved eco-efficiency of selected Toshiba products

Toshiba ″Factor T“ Website

A website demonstrates the Toshiba's developmental progress at a glance. The goal is to have calculated the so-called "Factor-T" for each Toshiba product by the end of 2010. By the end of 2007 already 80 percent of Toshiba products had an improved, calculated eco-efficiency value with respect to an internal benchmark product.

In ″Factor T“ the ″Factor“ stands for the relationship between the newly achieved eco-efficiency of a product and the eco-efficiency of an internal benchmark product defined by Toshiba. The ″T“ stands for Toshiba. This value can also be described as the increased quality benefit of the product multiplied by the reduced environmental impact of this product. The so-called Quality Function Deployment (QFD) technique is used to calculate the improved quality of the product, whereby the functionality and performance of a product can be concluded from customer questionnaires. LIME (Lifecycle Impact assessment Method based on Endpoint modelling) method is used to calculate the reduced environmental impact of the product. It is the most frequently used method to calculate environmental impacts in Japan. As a result, the indicator ″Factor T“ is derived.

″Factor T“ should motivate Toshiba's employees to develop more environmentally friendly products i.e. to improve the existing products. Simultaneously, the transparency for Toshiba's products should be improved. Toshiba products fall into one of three categories: a product with significant improvement in environmental performance (17 products are listed as of March 2011), a product with significant improvement in environmental performance as well as in value added (19 products) and a product with significant value added (15 products). For clarity purposes these categories are also labelled with various colours.

Resource Efficiency

On the ″Factor T“ website it is possible to find products with a factor of up to 14.2. An example for such an eco-efficiency improvement is an LED lamp, which has a significantly longer life span (20,000 hours) and lower energy requirements compared to a regular lamp. This lamp can be switched on and off very quickly. It is listed under the significant environmental performance improvement category.

Another example is an LCD-TV with a factor of 6.60, whereby, due to optimized video signals and better backlight control, a 76 percent reduction in electricity consumption per year could be achieved. Moreover, the use of lightweight metal enables a weight reduction of about 70 percent.

Barriers and Risks

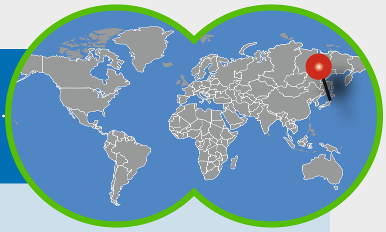
There is the risk that these values, calculated by the industry itself, could be manipulated, because no defined external industry standard exists. Thus, for instance, a new product could have a higher eco-efficiency than the benchmark-product, but still a worse one than the direct predecessor of the new product. Moreover, no comparisons are made with similar products from other companies, which would significantly increase the transparency and could be used as decision-making aid for the customers.

Effects

Material	Energy
Water	Surface fields

Region and Country

Asia
Japan



An LED-lamp from Toshiba with a „Factor-T" of 14.2 (Source: © 1995-2011 TOSHIBA CORPORATION, ALL Rights Reserved)

Since, the basis for the calculation and the values are not transparently communicated, the resource savings can only be quantified to a certain degree. The previously mentioned weight reduction does not lead, for example, automatically to an increase in the resource efficiency. Last but not least, the use of resources with higher environmental footprints can even lead to unintentional rebound-effects.

Potentials

Toshiba strongly supports the idea that such a calculation should become an industrial standard. Thus, the Japanese Eco-Efficiency Forum was launched. As a result, in 2004 a general guideline about the calculation of "Factor X" was published. Today, next to Toshiba, seven companies follow this guideline on a voluntary basis: Hitachi Ltd., Fujitsu Limited, Panasonic Corporation, Sanyo Electric Co., Ltd., Sharp Corporation, NEC Corporation and Mitsubishi Electric Corporation. The long-term goal is to offer more industry wide transparency to customers and relevant stakeholders about the environmental performance and standards of various products available on the market. Consequently, an independent product registry could be developed. Such a product registry would, for example, enable a comparison of environmental impact generated by the purchase of a new product and the repair of an old product and, thus, lead to more environmentally conscious consumption decisions.

Further information

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- Japan Eco-efficiency Forum (2009): Guidelines for Standardization of Electronics Product Eco-Efficiency Indicators.
- www.toshiba.co.jp/env/en/products/ecp/factor.htm

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www.toshiba.co.jp/env/en

The mobile maintenance and repair station for consumer goods

Repa & Service Mobile Station

A dense grid of repair and service points at highly frequented locations can make repair services more attractive. The aim is to improve the competitiveness of repaired goods compared to buying new goods. As a result, higher resource efficiency and reduction of waste could be achieved.

Repairs in Repa&Service Mobil
(Source: ARGE Reparatur- u. Servicezentren GmbH / arge.at)

With increasing global competition, online retail and shorter development phases of products, access to newer, cheaper consumer goods has become easier and more attractive. These developments lead to a non-sustainable consumer behaviour. Repair and maintenance services could increase the life span of goods and, thus, prevent the consumption of new goods, reduce waste and contribute to resource protection. Such services are often, however, harder to access than new goods. In addition, the society lacks awareness about sustainable consumption habits.

Repa & Service Mobil should make repair and maintenance of consumer goods more accessible to the public. The results of the forerunner project ”RepaMobil“ in 2006 proved the need and interest by consumers for such measures. This included a study of opportunities and risks of repair service points at four large business locations. The feasibility study shows that fixed and mobile location repair service points outperformed the virtual ones.

Therefore, during a 19 months pilot test phase in Vienna, a transferable concept for implementing mobile repair service station points should be developed based on the inputs from relevant stakeholder groups (repair service businesses, consumers, large business locations etc.). In addition, during the pilot project, the effects on sustainability such as resource protection, jobs and profitability should be evaluated as well.

Resource Efficiency

German households alone produce 754,000 tons of electronic waste per year with an increasing tendency. The largest part of it ends up in waste incinerating plants, landfills or abroad. According to the ”Export von Elektroaltgeräten“ study of the Federal Environmental Ministry in Germany (UBA 2010), 155,000 tons of electronic waste is exported illegally per annum. Especially abroad the toxic material contained by the products is often not disposed of in an environmentally friendly and unharmful way. The exact potential regarding material, energy and water savings of this project is unknown yet and should be analysed and quantified at the end of this pilot project.

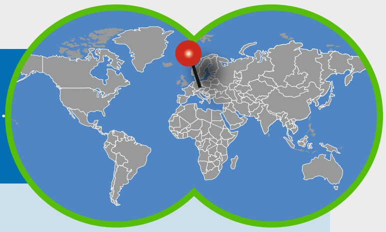
Effects

Material	Energy
Water	Surface fields

Region and Country

Europe

Austria



Barriers and Risks

Customer information regarding such services and the cooperation with the appropriate locations such as big shopping malls, where a Repa & Service Mobil could be installed, is of great importance. In order to ensure this, workshops with relevant stakeholders and public relations work have been planned through, for example, a newsletter, website, informational event and media work.

However, the risk remains, that the repaired old goods would hinder the spreading of more efficient goods. This risk is especially given for products with high resource requirements during the use-phase such as, for example, refrigerators. Therefore, next to ensuring the repair friendliness of goods and a positive cost-benefit ratio, resource efficiency should also be ensured along the lifecycle of the products, if their lifetime is extended. In light of this, a sustainability label for repair friendly and durable products was introduced in Austria in 2007. It should not only serve as guidance for purchasing decisions, but also ensure the profitability of repair services for customers. In 2008 the sustainability label received the Austrian environmental excellence price ”Daphne“.

Potentials

Repair services could extend the use-phase of consumer goods and, thus, improve the utilization of entailed resources in the products. The amount of resources for new products could be reduced. In addition, new business fields as well as jobs at a regional level could be generated. The Austrian sustainability label for repair friendly and durable products could be used as a blueprint on the European or even global level.

Further information

- www.fabrikderzukunft.at (search for: ”Repa”)
- Neitsch et. al. (2010): Umsetzungskonzept zur Implementierung des Gebotes der „Wiederverwendung“ gemäß ARL2008 in Österreich.
- Umweltbundesamt (2010): Export von Elektrogeräten. Fakten und Maßnahmen.
- www.repanet.at
- www.rusz.at

Arge Abfallvermeidung Ressourcenschonung und nachhaltige Entwicklung GmbH
Dreihackengasse 1
8020 Graz, Austria
www.arge.at

New business model to reduce use of chemicals

Chemical Leasing

Pay for services, not products. This concept aims at an efficient use of chemicals - a business model, from which all involved parties can profit.

Application of the concept "Chemical Leasing" could lead to decreased demand for chemicals through more efficient use. The customer pays for the service, for example, for each square meter of cleaned surface, and not for the quantity of used chemicals. Aside from the chemicals, the manufacturer sells the know-how for an efficient application of the respective chemicals. Depending on the leasing model the manufacturer can assume responsibility for chemical safety (industrial safety, environmental protection). In contrast to the classical business model the turnover is not connected directly to the quantity of sold chemicals – in fact, the company is interested in a more efficient use of a respective chemical. This leads to reduced production costs and, thus, to a reduction in total costs. This again is beneficial for the customer.

Pilot projects, which started in 2005, are testing the new concept in different fields of application; for example, in the metal working sector, where chemicals are used for cleaning, pickling, pouring, and cooling. Furthermore, it is tested in other sectors such as the chemical synthesis (application: catalysis), food industry (application: extraction, water purification) as well as the trade sector (application: cooling of goods/refrigeration). The projects were initiated by the United Nations Industrial Development Organization (UNIDO) in co-operation with the Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management (BMLFUW). Apart from these projects in Austria, other projects are carried out in developing countries such as Mexico, Egypt, and Colombia.

Resource Efficiency

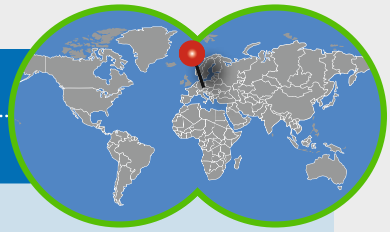
An analysis of the Austrian BMLFUW in 2002 showed that 53,000 tons of chemicals, including related emissions and waste, could be saved in Austria each year if this model was implemented in all suitable sectors. This corresponds to approximately one third of all chemicals used in Austria each year. According to the market analysis "Chemical Product services into the European Union" (CPS), conducted by different universities together with the Öko-Institute on behalf of the Institute for Prospective Technological Studies, a reduction of 5 to 30 percent of chemicals used each year can be reached, if CPS is implemented; depending on the type and application of the chemical.

Barriers and Risks

For implementation of the business model all involved players (suppliers and customers) must assent to the new concept. This, however, might represent a first obstacle. Additionally, the accounting of the service causes problems since the sales unit e.g. surface or number of cleaned items, needs to be defined depending on the application. A risk

Effects	
Material	Energy
Water	Surface fields

Region and Country
Europe
Austria



Conveyor belt for powder coating (Source: Copyright by UNIDO)

for the manufacturer might be the transfer of know-how; if the customer acquires know-how from the company in order to work with cheaper manufacturers. One of the general criticisms of the concept is the possible application of chemicals, which are harmful to health and environment. In order to avoid this, the International Working Group on Chemical Leasing is currently developing possibilities for the certification of the applied procedures, for example according to ISO 14000, in order to develop a set of qualitative criteria.

Potentials

According to the CPS study of the Institute for Prospective Technological Studies, the possible sales value for CPS amounts to a total of 77 billion euros, which equates to 14 percent of the annual turnover of the European chemical industry. According to representatives of the chemical industry, the study shows that the spread of CPS is primarily influenced by the market and in some cases by environmental legislation. Therefore, one of the measures mentioned for the promotion of CPS is the extension of laws increasing the industry's responsibility for the security of its products (e.g. REACH). A business case for this business model is the German Safechem Europe GmbH, a subsidiary of The Dow Chemical Company (Dow), which was established in 1992. Safechem offers industrial cleaning services with solvents in a closed loop. The business model also promises high resource efficiency potentials within other sectors such as IT (e.g. for cloud computing).

Further information

- www.chemicalleasing.com

UNIDO Headquarters
Vienna International Centre
P.O. Box 300
1400 Vienna, Austria
www.unido.org

Strategies

Redesign and Re-use	Product-Service-System (use-phase)	New production and consumption patterns	Inclusion of RE into Standards

A successful concept for increasing resource efficiency through partnerships in business

NISP – Networking for Sustainability

With the national Industrial Symbioses Programme (NISP) Great Britain shows how industries can profit from one another's know-how through local partnerships – with the goal of reducing the environmental impact and strengthening the business competitiveness.

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The British enterprise International Synergies Ltd (ISL), in cooperation with the University of Surrey, developed the concept of "NISP". The company was founded in order to develop and implement environmental solutions for the industry. So far, NISP seems to be implementing this idea with great success. NISP supports companies from different industries in increasing their resource efficiency and simultaneously reducing their greenhouse gas emissions at no extra costs. There is no membership fee.

The programme supports participating companies by developing strategies for a sustainable business policy and, furthermore, helps with finding suitable business partners.

Here, the closed loop/cycle economy is used as common approach, whereby improvements are often linked to reasonable application of waste products. But also other solutions are explored, such as new ideas for reducing the use of raw materials. 12 regional offices ensure that networks can be locally developed and local partnerships established. In the region "West Midlands" for example, a co-operation was initiated between a shoe manufacturer and an internationally operating organization, which passes on textile wastes to children and teenagers for artistic purposes – for example for art classes in school. In this way, 225 tons of waste have been avoided already.

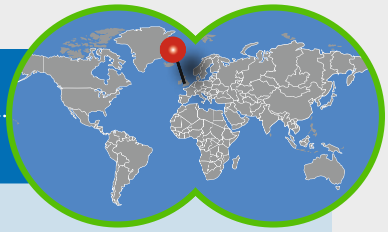
Successful projects of each region are put onto the NISP website as good practice examples, including figures of economic and ecological savings. Today, approximately 10,000 companies from different industries are participating in the programme, most of them small and medium-sized companies but also some giants of the industry like "Shell UK" or "Lafarge Cement".

Effects

Material	Energy
Water	Surface fields

Region and Country

Europe
UK



Resource Efficiency

Since starting the programme in 2005, the greenhouse gas emissions of the companies involved in NISP were reduced by 5.2 million tons. At the same time, approximately 3.8 million tons of waste of these companies were led back into the material cycle instead of dumping them. In addition, the amount of wastewater was reduced by approximately 9.4 million tons.

Barriers and Risks

Considering the fact that NISP is a strategic approach, it has limited direct risks. However, when evaluating ecological saving effects on company level, rebound effects might occur, for example, resulting from longer transportation distances. Therefore, a standardised, integrated evaluation process should take place. Since not only environmental but also economic aspects are considered here, companies might focus on economic aspects instead of choosing the best solution for the environment. Furthermore, the risk to disclose sensitive business data could be opposed to a successful partnership.

Potentials

The NISP programme registers an enormous increase, 10,000 members were attracted within approximately five years. The benefits are obvious. The participating companies realised an additional turnover of 151 million Pounds so far. Additionally, around 131 million Pounds were saved in costs through efficient raw material use and synergies. The efficiency increase did not happen at the expense of jobs – quite the contrary: a total of 800 new jobs were created and over 1,200 jobs secured on a long-term basis.

Further information

- www.international-synergies.com

44 Imperial Court
Kings Norton Business Centre
Pershore Road South
Birmingham, B30 3ES, UK
www.nisp.org.uk

A Swiss initiative shows how building materials can be handled in a closed loop

Gravel for future generations

The construction industry uses large quantities of materials. Cities offer an enormous stock of unused resources and many elements of construction waste, which can be recycled. The most prominent problem: the image of waste.

Public Building of recycling-concrete
(Source: AWEL Amt für Abfall, Wasser, Energie und Luft)

About 50 million tons of mineral building materials are used in Switzerland each year. Thus, the construction industry is one of the industries with the highest material requirements. At the same time, large quantities of construction waste materials are accumulated each year due to redevelopment and demolition of existing buildings. These materials, however, can be recycled and used in cement production, for example. A study by the "Office for Waste, Water, Energy and Air" (AWEL) of the canton Zurich from 2003 concludes that there is no quality loss if these materials are recycled. At present, concrete from recycled material still has different characteristics than the primary alternative. However, if these characteristics are taken into account in the early stages of building planning process, recycled concretes can be used even for structurally challenging places. This certainly requires a new way of thinking in the construction industry. Therefore, the AWEL initiated the Swiss information alliance "gravel for future generations". This initiative aims to convey knowledge of using construction waste and to facilitate information exchange between science and practice.

Resource Efficiency

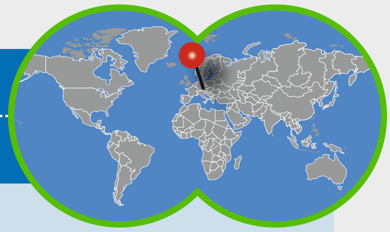
First of all, reusing construction waste reduces primary gravel resources and the demand of land for gravel exploitation. Moreover, the disposal of demolition material becomes redundant if recycled material is used. The use of construction waste compared to primary raw materials has only a minor influence on the production process of concrete and the cement needed for it. In order to determine the environmental impact of the combustion of fossil raw materials during the process, the content and type of cement as well as the transportation distance are crucial. This is a result of a lifecycle assessment done by the Swiss

Effects

Material	Energy
Water	Surface fields

Region and Country

Europe
Switzerland



Construction waste as raw material
(Picture: Juliette Chrétien, Zürich)

Holcim AG in cooperation with the Institute for Building and Environment (IBU) and the University for Technology Rapperswill.

Barriers and Risks

Old gravel pits are frequently used for disposal of excavated material from construction sites. An increased use of secondary construction materials and the associated decrease of gravel exploitation could lead to longer transportation distances of excavated material to the nearest gravel pit. This would worsen the environmental balance significantly. Long distances should also be avoided when transporting construction waste materials to appropriate processing sites. According to the lifecycle assessment done by the Holcim AG, secondary construction materials should, thus, only be used if the transportation distance amounts to more than 30 km over that of primary gravel.

Potentials

Already 80 percent of construction waste is currently recycled in Switzerland. However, these materials are usually used for inferior building materials in the civil engineering underground; the remaining 20 percent are disposed of as waste. At present, due to energetic redevelopment measures, the need of building materials shifts more and more from civil engineering to building construction: A resource model of the city of Zurich showed that the input of building materials for urban building construction adds up to 780,000 tons, whereas the input for civil engineering amounts for 104,000 tons. Thus, an increased demand for high-quality recycling materials for application in the building construction can be expected in the future.

Further information

- www.kiesfuergenerationen.ch
- TEC21 (2010): Recycling-Beton.

AWEL Kanton Zürich
Abteilung Abfallwirtschaft und Betriebe
Weinbergstrasse 34
8090 Zürich, Switzerland
www.awel.zh.ch

4 Strategic starting-points for more resource efficiency

The project results indicate that there are a large number of innovative technologies and products for resource efficiency available. Since their implementation and relevant knowledge is not widely spread, support is necessary. This general conclusion can be drawn based on the expert interviews and the identified examples. In this chapter, the strengths and weaknesses of technical solutions for resource efficiency are identified based on the result of the interim results of the Resource Efficiency Atlas project (*chapter 4.1*), followed by a description of starting points for increased resource efficiency (*chapter 4.2*).

4.1 Strengths and weaknesses of technology and product development

The following questions are central in light of the technical solution development for increasing resource efficiency:

- What is the motivation for resource efficient technology and product development to date?
- What are the counteracting forces?
- What are possible risks?

In order to answer these questions a SWOT-analysis (strengths, weaknesses, opportunities, and threats) of "technical solutions for increasing resource efficiency" was conducted from a technology and product development perspective. The project experiences are summarised by means of the SWOT-analysis against the background of accelerated resource efficient technology and product development. A particularly important issue is related to advantages and disadvantages coming along with a focus on resource efficiency during technical solution development. For this purpose, strengths and weaknesses of technology and product development (internal perspective, *table 2*) as well as opportunities and threats – with regard to framework conditions for development (external perspective, *table 3*) – are considered. This assessment is based on a cross-analysis of results derived from expert interviews and example collection. Furthermore, observations from the research process are included to ensure a comprehensive analysis.

The *internal perspective* on technology and product development indicates that some companies profit already today by focusing on resource efficiency during technology development. These companies gain from lower price risks and improved supply conditions. In addition, companies can profit from a positive image of resource efficiency allowing them to open up new markets. With respect to the production process, resource efficiency can lead to cost savings if, for example, material savings and waste prevention are implied. However, this is not always the case: For instance, material substitution might lead to a lower amount of material input due to higher stiffness. Still, total costs of production might increase because of higher material costs.

A key obstacle towards resource efficient technology development is the necessary investment cost primarily paid for by the manufacturer. In many cases the production process becomes more expensive as well: One example is the production of hybrid cars, which are more expensive than comparable vehicles. They also require higher resource use during the production process. The price premium is passed on to customers as they benefit from lower fuel consumption. Due to the high investment costs for this kind of innovations the demand is limited.

Another obstacle might be the relevance of other sustainability themes. Resource efficiency is only one issue within the holistic perspective of sustainability. Important expertise is often missing such as assessment with expanded indicator systems in the development stage to

Strengths *Which strengths are apparent in the development of resource efficient technologies and products?*	**Weaknesses** *Which weaknesses are apparent in the development of resource efficient technologies and products?*
Future-oriented development • Considering the increasing scarcity of resources and avoiding potential supply shortages • Development of innovative products and stabilisation of the German economy **Opening up new markets** • Opportunities for new marketing strategies • Market differentiation in a green segment **Economic incentives** • Process optimization and cost avoidance for waste treatment • Saving material and energy costs • Benefits from existing promotion measures **Improved communication** • Internal communication and workforce motivation • Possibilities for improving public image	**Missing cooperation and initiatives for resource efficiency** • Ecological initiatives focus on energy issues and climate change • Insufficient networking for resource efficiency **Missing funding sources** • High investment costs for technology and product development are often an obstacle • Avoidance of external costs in the production process is often economically not feasible for businesses **Missing competencies** • Limited use of resource efficiency assessments and practical implementation • Shortage of skilled workforce • Implementation of sustainability assessments particularly with respect to human toxicity, long term availability and social aspects (e.g. rare earths) • Necessary restructuring of processes within businesses and along the supply chain

Table 2: Strengths and weaknesses of technical solution development for increasing resource efficiency (internal perspective)

account for specific environmental impacts (e.g. soil acidification, human toxicity, and social criteria). Any consideration should address the demand for critical raw materials such as rare earths, as, for example, a resource optimized production process might increase the use of rare earths. In the light of anticipated shortages on the world market the use of rare earths is risky and can counteract technology diffusion.

A prerequisite for the development of resource efficient solutions is the availability of appropriate competences in research institutions and companies. This is a challenge, as innovative technologies require novel know-how and, thus, new professional qualifications. Therefore, training and further qualifications might be necessary.

From an *external perspective*, the development of resource efficient technologies opens up fundamental opportunities to minimize the environmental impacts within and beyond national boundaries. The corresponding effect is much stronger if the developed technology is widely diffused and / or used in resource intensive sectors *(see chapter 1.1)*.

Furthermore, increasing resource efficiency can reduce the dependency on imported raw materials. This is particularly important because Germany as a resource poor country has to import many of its raw materials.

It needs to be stressed that the development of resource efficient solutions has positive effects on the German economy, too. As described in *chapter 1.1* a reduction of material requirements can lead to significant cost savings. Within the MaRess-project it has been calculated that the gross domestic product (GDP) could increase by 14 percent through a higher resource efficiency on company level driven by specific information campaigns and consulting activities in 2030 (Distelkamp et al. 2010). A linear reduction of material and energy costs by 20 percent

Opportunities *Which opportunities arise from development of resource efficient technologies and products?*	**Threats** *Which risks arise from the development of resource efficient technologies and products?*
Improved environmental impact • Resource savings tend to reduce multiple environmental impacts (e.g. reduction of land use intensity, material and water savings, reduced greenhouse gas emissions). • Exploiting potentials for cost savings across different sectors. • Efficiency potentials exist in branches of production with high resource use (e.g. construction industry, energy supply). **Competiveness of Germany** • The development of resource efficient products strengthens Germany's dominant position in the field of environmental technologies • The export of resource efficient technologies can act as a growth engine and creation of attractive and long-term employment. • Lowering the dependency on resource rich countries. **Responsibility for future generations** • Preservation of resources for future generations (inter-generational justice). **Political strengthening of resource efficiency** • Reorganisation of financial subsidies at state, federal and EU level. • Support of political programmes such as EU2020-Strategy Flagship Initiative Resource efficiency.	**Resource efficiency as a niche market** • Saving effects of natural resources linked to commercial success / product diffusion. • The higher prices caused by increasing development costs can negatively effect the purchasing decision of cost aware users. • Danger of shifting resource requirements to other lifecycle stages. • Rebound effects are partly difficult to deal with during product development. **Multitude of assessment approaches** • No established assessment standard for resource efficiency is existent. This restricts the comparability of different businesses, products and technologies. **Behavioural patterns and mind set** • Inflexible mind set structures counteract required changes towards resource efficiency. • Lack of consumer and supplier demand.

Table 3: Chances and risks of technical solution development for increasing resource efficiency (external perspective)

could create 700,000 new jobs in ten years according to a scenario study conducted by the Aachener Stiftung Kathy Beys (2006). As a result, gross domestic product could increase by 10 percent and state budget could be unburdened by approximately 20 billion euros.

Viewed from a global perspective, reducing resource requirements might be positive for meeting the needs of future generations. Accordingly, there is a high political relevance of developing resource efficient solutions. This has been emphasised by the European Commission as resource efficiency is one of the seven flagships in the "Europe 2020" strategy *(see chapter 1.1)*.

The reduction of resource requirements through technologies is a complex theme. This is illustrated by some external threats: One major problem is due to the fact that a reduction of resource requirements at business level cannot necessarily be equated with total resource savings by businesses. The rebound-effects were often identified as a potential obstacle during the assessment of examples. Furthermore, the examples indicate that rebound-effects are a complex problem to deal with. Potential factors that might lead to rebound-effects should, therefore, be identified and addressed at an early development stage. Moreover, technology development should be optimized accordingly. In many cases relying on isolated technology development optimization will not be sufficient to prevent rebounds. Political measures are needed to counteract these effects though changed consumption behaviour.

From an environmental perspective another threat is that the spread of some resource efficient technologies and products might be restricted due to their very specific field of application. Technologies saving resources during the use phase are unlikely to realize their full potential if sold only in niche markets. This factor should be taken into account when promoting resource efficient technologies and products.

The same holds for technical solutions with high investment costs. The risk derives from the solution remaining in a niche market even if the use is economically feasible in the long run. Therefore, appropriate forms of promotion and funding need to be implemented by policies to counteract these risks.

In general, the results of the SWOT-analysis show that resource efficient technologies and products can only reach their full potential when framework conditions promote their use and their application aims at environmental improvements. In order to meet these conditions corresponding changes of political framework conditions are needed. This includes promotion and funding opportunities allowing manufacturers and users to make the required investments. Labels indicating resource efficient products, or other ways of information, can create incentives for consumers. For this purpose, the current public debate focusing on climate and energy issues should be expanded to material and resource efficiency. This is also postulated by the majority of interviewed experts.

4.2 Strategic starting points and courses of action

In light of the need to implement resource efficiency due to environmental reasons the question needs to be raised: Why is there only a limited amount of resource efficient technical solutions applied today? This question was intensively discussed in the expert workshop. The main problem is attributed to market failure: Today most raw material prices do not reflect ecological and social costs (external costs) resulting from raw material extraction and flows (e.g. water and air contamination, health risks, soil erosion). Therefore, the use of resources along the entire value chain is rarely leading to economic advantages for companies and consumers. As most of the interviewed experts confirm, more information on the benefits of resource efficient technological solutions is needed - even if financial incentives are missing.

Capturing existing potentials

Under current economic framework conditions numerous technical solutions are already economically feasible and do not depend on supportive policy measures. Some of the examples in chapter 3 and the expanded collection at the project's website can be good starting points.

One of them is the sail system "Skysails", a relatively simple solution for reducing fuel consumption in cargo vessels *(p. 46)*. The depth of intervention in the existing technology is low and the system works in practice. It reduces the fuel consumption of ships and needs only few adaptations.

There is an especially high potential for solutions, which can be easily transferred to other sectors like the business model "Chemical Leasing" *(p. 62)*. This example shows that technical solutions can be combined with appropriate business models. This is another approach with high efficiency potential applicable to many other areas. The example is far reaching as it addresses both the production and consumption side. The risk of rebound effects is therefore low.

The dissemination of existing solutions should be promoted. In order to achieve a better spread, the knowledge about present win-win solutions needs to be communicated. Many existing technical solutions are currently not applied due to inflexible patterns of thought and action. Hence, better information on solutions' advantages is a very promising approach. Moreover, it seems to be important to convey relevant knowledge for the proper use of these technologies and products.

The UK's "National Industrial Symbiosis Programme" is a good example of a successful communication strategy *(p. 64)*. It is based on the circular economy concept and a network of businesses. With the assistance of this programme a large number of companies could optimize their production processes leading to environmental and economic benefits. Another successful example is the initiative called "gravel for generations" aiming at a resource efficient construction sector *(p. 66)*. The initiative provides information about the possibilities of economic recycling and reprocessing of building demolition. The efficiency potential is backed up by scientific studies and projects.

Promoting market entrance

The interviewed experts argue that all identified technology fields bear remarkable resource efficiency potentials. However, they are still only 'tools' depending on surrounding conditions (see *chapter 2.2*). Promising, resource efficient technology and products, which require high investments, have to be promoted through pilot projects within the market launch phase. Attractive funding conditions and programmes should be used to support companies not yet adjusted to innovation programmes.

In research and development, sustainability and resource efficiency need to be integrated. Existing funding opportunities need to be promoted. As stated in *chapter 1.2* many support programmes are already existent in Germany (e.g. www.fona.de). Even with regard to resource efficiency many federal promotion activities are in place, such as promotion programmes for environmental technologies of the German Ministries BMU, BMWI and BMBF, the programmes VerMat and NeMat as well as the German Material Efficiency Prize of the BMWI, the development of institutional structures at the federal state level such as the Efficiency Agency of NRW and industry initiatives.

Development of international education and cooperation networks

To accelerate the development and diffusion of resource efficient technologies and products the further expansion of education and cooperation networks (such as the network resource efficiency of the BMU, network of cleaner production center of UNIDO) is desirable. Furthermore, the network of universities integrating the paradigm of resource efficiency in teaching and research should be internationally expanded. A very limited amount of university departments offer programmes (e.g. lectures, exercises, project work) related to resource efficiency. The topic of resource efficiency in research and teaching should be promoted in cooperation with the leading technical universities in Germany (TU9) and other design and technical universities of applied science as well as international universities. A significant expansion of teaching programmes is recommended which needs to be integrated into the existing curricula. Activities towards the establishment of a "virtual resource university" (with focus on implementation processes) could boost the widespread integration of resource efficiency in university research and teaching (Kristof / Liedtke 2010). The virtual resource university can be realised as online platform to connect national and international university chairs dealing with resource efficiency.

Further research

The Resource Efficiency Atlas project results highlight the need for further research in the field of evaluation and diffusion of resource efficient technologies and products. Many of the challenges experienced during the project can be traced back to lack of data concerning the resource use of technical solutions. This point is particularly prevalent with respect to lifecycle-wide data and prospective studies. It is, therefore, difficult to assess the various identified solutions in a consistent manner. Further action in research heading towards the development of international standards – allowing consistent potential assessment – is required.

The assessment of resource efficiency is particularly important in the development stage to ensure a targeted resource-efficient technology development and to minimize the risk of rebound-effects. As quantitative lifecycle-wide data cannot be gathered at the innovation phases, qualitative criteria need to be included. Furthermore, in order to minimize the risk of rebound-effects it should be considered that resource efficiency in technology and product development is only one (even though an important) criterion besides others in sustainability assessment.

Based on the results and the applied methodology the collection of examples should be expanded. In addition, technological solutions in or from developing countries should be included. One aim could be an expanded Resource Efficiency Atlas aiming at low-tech-applications in developing and emerging markets. In order to achieve the best possible dissemination of gathered examples, the project website should be linked with existing databases presenting efficiency examples (such as the PIUS information portal of the Efficiency Agency NRW, available in German, and the Cleaner Production portal of German Federal Environmental Agency).

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6 Appendix

Interviewed experts in the project

Nr.	Name	Organisation	Country
1	Dr. Kunihiro Kitano	AIST Hokkaido	Japan
2	Dr. Jeffrey Morris	U.S. Environmental Protection Agency	USA
3	Prof. Martin Charter	Centre for Sustainable Design, UK	UK
4	Dr. Heinz Leuenberger	UNIDO	Austria
5	Dr. Robert Wimmer	Center for Appropriate Technology, Vienna University	Austria
6	Henrik Österlund	Motiva Ltd., Finland	Finland
7	Dr. Renzo Tomellini	European Commission, DG Research	Belgium
8	Dr. Willy Bierter	Product-Life Institute	Switzerland
9	Patrick van Hove	DG Research Energy conversion and distribution systems	Belgium
10	Dr. Andreas Kleinschmit von Lengefeld	Forest Technology Platform (FTP)	Belgium
11	Prof. Dr. Kornelis Blok	Universität Copernicus Institute	Netherlands
12	Prof. Jacqueline McGlade	European Environment Agency (EEA)	Denmark
13	Dr. Olga Sergienko	St. Petersburg State University of Refrigeration and Food Technology	Russia
14	Tomoo Machiba	OECD, Directorate for Science, Technology and Industry (DSTI)	France
15	Prof. Dr. Holger Wallbaum	ETH Zürich	Switzerland
16	Dipl.-Ing. Christopher Manstein	Faktor 10 Institut Austria	Austria
17	Germán Giner Santonja	Clean Technologies Center. Environment, Water, Town Planning and Housing Department of Valencian Government	Spain

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internationalen Experten/-innen zu Themen der Umsetzung von Ressourceneffizienz dargestellt (Kap. 2.1). Dem folgt ein Überblick zu den Ergebnissen der Recherche nach innovativen, ressourceneffizienzsteigernden Leitprodukten und Leittechnologien (Kap.2.2). In Kapitel 3 wird eine Auswahl von 21 ausgewählten Technologien und Produkten genauer beschrieben. Kapitel 4 beinhaltet die Ergebnisse einer SWOT – Analyse, in der Stärken und Schwächen sowie Chancen und Risiken einer Entwicklung von Ressourceneffizienztechnologien dargestellt werden. Zudem werden Ansatzpunkte erläutert, wie die Weiterentwicklung und Anwendung dieser Technologien und Produkte in Deutschland gefördert werden könnte.	
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The Resource Efficiency Atlas is the core result of the project "Resourceefficiencyatlas". In the report, conclusions from the interviews with international experts on resource efficient technologies and products are presented (chapter 2.1). The process of searching for innovative and resource efficient products and technologies is presented including an overview of the results in chapter 2.2. Some of these products and technologies, 21 in total, are described in detail in chapter 3. In chapter 4, a SWOT-Analysis is presented giving information about the strengths and weaknesses as well as opportunities and risks of developing resource efficient

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