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Conceptualizing good practices: adding efficiency by using intelligent systems and processes

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Abstract
Intelligent systems increase efficiency on many levels. Planning solutions affect need for transportation, heating, cooling and lighting of buildings. Design of buildings and transportation infrastructure affects functionality and flexibility. Solutions and behavioural influencing in business, work and social organization make better use of existing infrastructure and human or material resources. New technology reduces physical mobility, energy and materials consumption; new devices and machines, power plants and distribution networks become more energy-efficient.

Intelligent, flexible process aims to alter continuously due to the demand; in which experience and information are gained and used to improve the organization and implemented system. This will optimize control by changing output in real time according to real needs.

Intelligent systems are usually designed for a specific purpose in a narrow subsector. The solutions, policies and practices developed are usually recognized and used in the same zone only. Copying existing models can lead to unsatisfying results as situations and background conditions may differ significantly. By conceptualizing results to a more abstract level, good solutions found in different fields can be better utilized in an interdisciplinary way.

We will formulate methods for conceptualizing good practices and solutions of intelligent processes and systems, and show examples of case studies covering intelligent systems such as software automation, modularisation and prototyping. More specifically, potential decline in electricity use will be discussed in this context. This includes policies as well as technical solutions such as intelligent systems for lighting in which the lights have the ability of dimming as required based on a learning artificial intelligence system. The proposed actions allow a significant potential in saving energy in residential and commercial buildings, which will be emphasized in the life-cycle costs.

Introduction
Energy efficiency is important already because of its positive effect on economic prosperity. Even more important may be the contribution of energy efficiency to sustainable development. In many cases, better energy efficiency is closely related to the reduction of emissions. In this paper, energy efficiency and system efficiency in general are discussed from different viewpoints.

Increasing efficiency may be a complex issue. If the output of whole society and future impacts are considered, improving energy efficiency in one place – optimizing partially the large-scale system – may be tricky. It is relatively easy to understand the positive effects of making improvements into a process or part of a process, but improvements in a single sector may have unexpected effects in the larger sphere.

The issue of complex problems has been recognized in social planning. In fields like land use planning, transportation planning and architecture, tasks and problems concerned are often complex – they can be described as "wicked" – "malignant", "vicious" and "tricky" – (Rittel & Webber, 1973) or "messy" (Ney, 2009), meaning that there may be no perfect solution, but solutions with different advantages and disadvantages. Contradictory objectives and practical – for example, economical, financial or political – restrictions exist. To solve the problems, intelligent and iterating systems can be created.

Climate change is a globally worrying phenomena; together with the economic recession, and social and financial problems to be solved, it is an example of a wicked problem. To cope with it, a holistic approach is needed, in which energy efficiency may have an important role.

COMPLEXITY

An example of a complex problem can be found in how sustainability is currently pursued: the most common pathway towards more sustainable society is based on decreasing emissions; there are attempts to holistic approaches, too (Kuehr, 2007). Impacts of transportation and building sector are given a lot of attention to. In addition to focusing on air pollution and ozone depletion, other concerns – like forest destruction and emission of radioactive substances – should not be forgotten. It is difficult to produce energy without any environmental impact, but increasing energy efficiency can help to reduce impacts. Holistic sustainable development is made up of societal, economic, environmental and technological sustainability (Dincer & Rosen, 2007).

Impacts and energy use related to the building sector originate from production, maintenance and demolition of buildings. The emissions related to the transportation sector include emissions from vehicles in use, production, maintenance and demolishing of vehicles and infrastructure as well as transportation and logistics of materials and parts, and production and distribution of fuel. In all of these segments, improving energy-efficiency is obviously one of the methods that can be used to reduce total lifecycle emissions.

The total lifecycle impact of industrial products or processes can be precisely assessed and methods are developed to decrease the impacts (Veleva & Ellenbecker, 2001). However, the impacts of car traffic are quite complex.

An important impact of automobility, however, is created as a consequence of land-use: car-oriented mobility makes cities geographically larger, occupying more land for parking and roads, and increasing travel time and distance (Shin, 1997). Therefore, car-oriented urban structure is not energy efficient nor economically favourable.

Urban design affects energy use for transportation: the higher the intensity of people living or working in an area, the less energy is used for transportation per capita (Newman & Kenworthy, 2006).

When location of large industrial parks, power plants or logistics centres is decided, or their internal organization is designed, lessons from urban planning could be useful in reducing energy use for transportation.

Dense, pedestrianized urban environment is more likely to create opportunities for new ideas and new economic activity to grow through agglomeration effect. Even if new technology

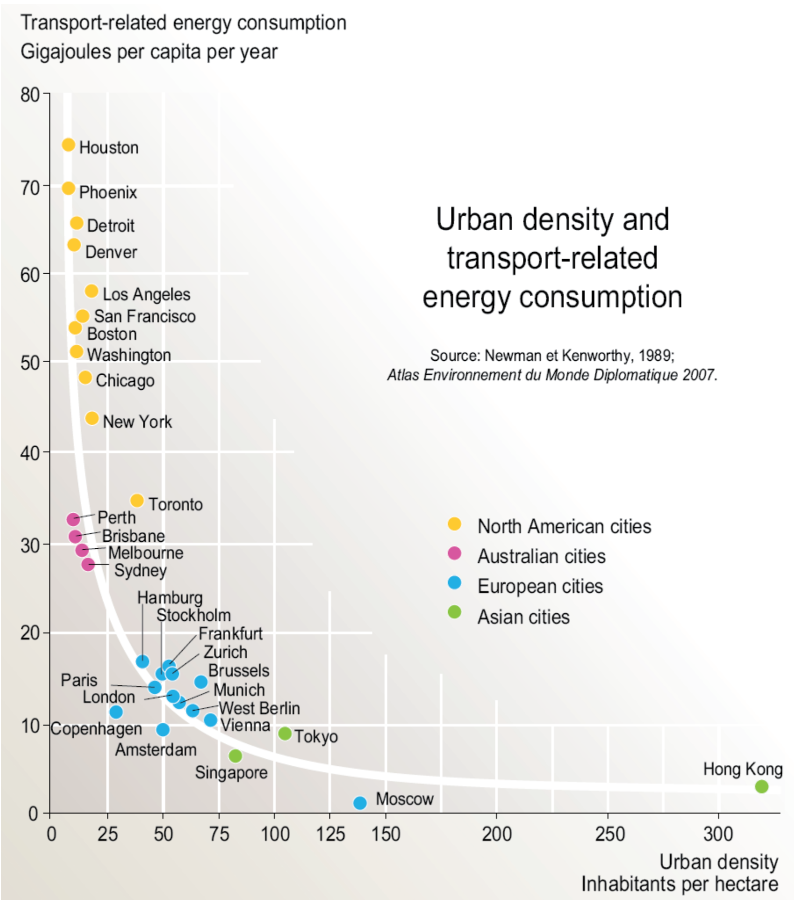

Figure 1. Per Capita Passenger Transport Energy Use versus Urban Density. Source: Kick the Habit – A UN Guide to Climate Neutrality, UNEP 2008.

may allow energy be produced and cars be operated with better energy efficiency and without producing carbon emissions or pollution, land use will remain a worsening issue; the importance of which is underlined by the rapid urbanization globally.

This line of thought has been generally acknowledged and decreasing automobility and its side effects is a major contemporary planning policy. Having less car traffic should decrease carbon emissions, improve the quality of living environment and give possibilities to build more dense cities improving efficiency of land-use and allowing more economic and efficient infrastructure to be built and maintained. Rail traffic is favoured and communities are planned to be supported by it.

In general, transportation projects can be ambiguous: development of transit system – even a rail-based one – can increase mobility and equity in short-term, but in the long-term it may increase urban sprawl, private car use, congestion and environmental social inequity due to displacement resulting from rising land value where mobility is improved. Attempts to improve equity and sustainability can be contradictory, and in the long-term it may be difficult to make any interventions that have positive effects concerning either equity or sustainability.

It turns out, that sustainability is mostly related to the lifestyle and highly dependent on consumption habits. Even if the people living in countryside travel more by car than people in cities, they create a smaller carbon footprint as their total consumption is smaller – the most important part of which is the consumption of goods and services mainly related to the level of average income (Heinonen & Junnila, 2011).

There is obviously a correlation between energy use and total production; thus, comparing societies that produce a level of welfare that is concerned adequate by the citizens, a society producing less is likely more energy efficient. Of course, the energy efficiency of production technology and what is produced will have an effect on both emissions and energy efficiency. Still, cutting the total production is clearly an option to reduce energy use and emissions. On global level, total consumption and emissions are at least as important as efficiency relative to output unit.

A technology fix reducing emissions with current or more mobility, or reduction of mobility, may not alone be a sufficient solution. A social lifestyle change would be needed, too: consumption should be more focused on non-material services than material goods; production of food and necessary goods should be more local, reducing global logistics and freight networks. If consumption profile is not changed, the increased efficiency of production may lead to increased production of physical goods and growing demand of raw materials.

As the example shows, when we talk about cars and energy efficiency or emissions, it is not only about fuel economy or energy efficiency in production plants, but widens into a complex global problem.

That being said, existing systems need to be improved and new policies are needed to tackle with the existing wicked problems and uncertainty of future. Even maintaining existing infrastructure may turn out to be economically or environmentally unsustainable. Also, any new investments – either private or public – have to be rationally justified to assure the decision-makers. Therefore, credible methods are needed. Specialized studies are done in different disciplines and fields, but it is not easy to take advantage of their results in other disciplines. By conceptualizing problems and solutions, it is easier to transfer the collected knowledge between disciplines.

MOTIVATION BEHIND CONCEPTUALIZING

The tasks planned and realized can be conceptualized to a more abstract level. For example, a process can be conceptualized to the very principles based on questions "how" and "why". Traditional engineering has usually concentrated on the first question, and starts thinking from product first. The problem has been noticed the engineering education (Mills & Treagust, 2003).

To make the production necessary, demand may be actively generated by influencing people (for example, by advertising or subsidies). A more contemporary viewpoint is based on the second question and starts from demand: systems have to be developed and changed to meet the changing requirements. If we want to support sustainability, generating excess demand is not desirable; therefore, adaptive systems should be focused on.

Investments are usually done for a long period of time, and predictions are needed to justify decisions. Long-term predictions have become especially challenging due to economic growth: a consequence of increased welfare is that people have more choices (of course, some existing options are reduced, but they are replaced with many new possibilities). Increasing the impact of this is, that choices made by people are not always fully rational in long-term. When people have more economic opportunities, their actions may become more unpredictable. Thus, simulations and predictions have to be used wisely and it must be remembered that alternative paths of development are possible and can be chosen, too. Also, it is important to open to question the justification of projected development. Usually the responsibility to do this belongs to public administration, but market-driven development has also taken place and corporate social responsibility is growing. In fact, this can be seen as an adaptive mechanism, too; however, difference between marketing action and real adaptation to social demand may sometimes be difficult to distinguish.

Land use planning and transportation planning are connected to each other, but integrating them is another wicked problem. Integrated planning and transportation planning would allow many possibilities to increase system efficiency and save energy used by the infrastructure, buildings and transportation.

One possible approach to improve the collaboration between land use planning and transportation planning is to construct a sophisticated behavioural model, which can be used to forecast future development and impacts of planned land use and transportation system interventions. A behavioural model is an intelligent system, which can be programmed to take into account rules for trip generation, prevalence of trip looping as well as car pooling or modal shift. A behavioural model requires a lot of data to be collected and updated, and is valid only in the single context the data covers, which makes it expensive to establish. Behavioural models often suffer from "black box syndrome", as an adept is needed to set up the model and generate results – thus leaving it a mystery to decision-makers on what basis and chain of reasoning the conclusions were made. Another problem is, that complex models are computationally expensive, and it takes a lot of time to calculate iterative alter-

Table 1. The differences between Transport Planning and Land Use Planning conseptualized (Gakenheimer, 2013).

Key Differences	Characteristics of Transport Planning	Characteristics of Land Use Planning
1. Objectives	Primary objective is metropolitan level accessibility	Objectives include serving residential quality, social equity, economic development, etc.
2. Planning Methods	Quantitative focus on accommodating travel demand	Multiple concerns for land values, compatibility of land uses, affordable housing, redevelopment, etc.
3. Scales of Planning	Large scale; focus on metropolitan connectivity and continuous transport links	Includes small-scale neighborhood livability and other use localities
4. Implementation Powers	Governments have substantial power for reliable implementation	Private actors have more decision-making power; public powers limited
5. Scales of Investment	Large capital budgets, including state and national support	Mostly local funding and private-sector actions
6. Scale and Length of Future Vision	Deals with long-range vision for new transport system additions	Deals with small-scale incremental growth towards long-term change

natives. They can give useful information of projected traffic volume and property value changes, though.

An alternate approach is to assess the different aspects of the two fields and try to bring them closer to each other category by category. For example, The Finnish Ministry of Transport and Communications has launched a development programme "Transport Revolution" to change the scope of transport planning from sparse big infrastructure projects into continuous maintenance and affecting demand instead of forecasting traffic volumes based on current trends and conditions, as well as making initiatives to influence modal share to change in favour of walking, cycling and public transportation. Even though the programme mainly aims to make road administration investments more effective, it may also make the context and scale of transport planning to move closer to land use planning, which may facilitate the co-operation of the two fields.

Successful land use and transportation plans may reduce time and material resources spent on traveling either by allowing more efficient transit system or by decreasing trip demand by allowing co-location of functions and/or by preventing residential displacement due to gentrification. Business as usual model will lead to significant increase in transport-related energy use globally.

Solutions in planning and architecture can increase energy efficiency in many ways. Passive solutions include taking advantage of natural light or using natural ventilation to decrease need of electrical systems as well as adding insulation or physical sun protection. Active solutions include adaptive control systems. The volumetric layout of buildings can affect local climate and smaller external surface may reduce need for heating or cooling, whichever is needed depending on the geographic location. By increasing the utilization rate and decreasing average personal space in buildings, less buildings are needed altogether.

As contemporary buildings in developed countries are relatively well insulated and heat recovery systems are used, energy use for heating is going down. Even the older buildings can be heated efficiently with district heating based on Combined Heat and Power (CHP) production, so heating (or cooling) is not a major problem anymore.

Increasing amount of energy is consumed for other purposes than transportation and heating or cooling, surpassing the two. Better technology may cut energy use for electrical equipment and devices, but benefits may be lost by the increased number of devices. In general, energy use has been growing despite the introduction of energy-efficient technology. It has been observed, that happiness of people on individual level increases as more energy is consumed – especially concerning driving a car (Veenhoven, 2004). On the other hand, in developed countries the growing gross energy use doesn't seem to add average happiness anymore.

Not to be forgotten is the cultural development, which gives a framework for economic activity. Understanding it on a conceptual level can contribute to preparing better models and systems responding to the changing needs in future.

The concept supermodernity (or hypermodernity or ultramodernity) addresses the aspects of the ongoing cultural change the intelligent systems are part of. Multinational post-industrialism is followed by global market and informationalism; free availability of information is growing instead of secretive policies; a concept of theory and finding exact answers is changing into more blurred and fuzzy use of intelligent systems provid-

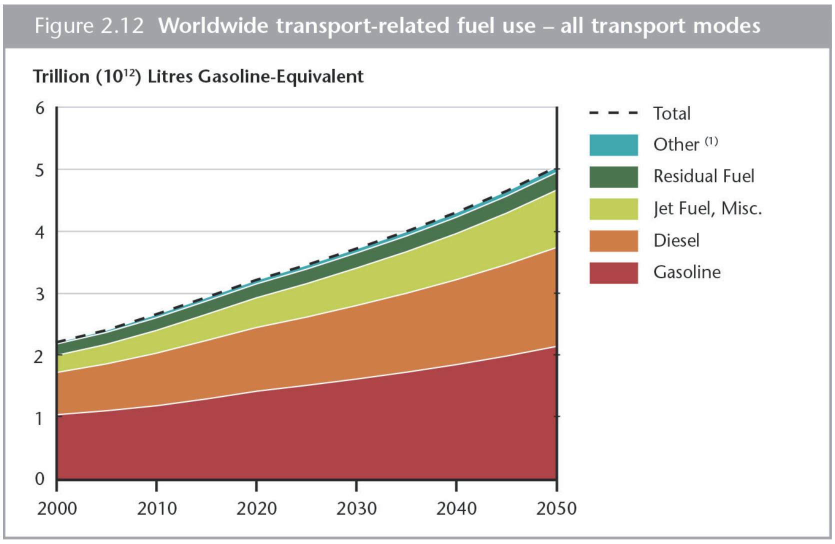

Figure 2. Estimated fuel use in transportation. Source: Mobility 2030: Meeting the Challenges of Sustainability (Sustainable Mobility Project calculations), page 37.

ing "little truths" or plausible truth. The role of society is more about allowing opportunity than giving security as was the case in the modern and postmodern eras; economy is changing from service-centered into knowledge-centered, thinking and doing are inter-related. Networks of smaller entities can challenge big corporations and organizations. Also, the individual-centered culture is changing into a more communal one.

Demand will change following the cultural change. Concerning large-scale infrastructure projects with a timespan over decades, it is necessary to take into account that social and economic development can change course over time. As was mentioned earlier, long-term predictions are difficult to make; thus, it is necessary to change planning objectives to include reuse and recycling as elementary parts of design, and to change design methods to more iterative and modular ones to be able to dynamically respond to changing environment during design and implementation phases of a project. Emphasis should be put on processes instead of projects. Prototyping-based, adaptive systems allow design and implementation to faster respond to the changing needs and environment.

Intelligent and adaptive systems do not make strategic decision-making unnecessary, but they either help to make systems more adaptive to changing regulations or demand, or they can be used to assist decision-making by comparing alternatives and analysing decision-making process. Conceptualizing and assessing the systems may help to understand how they function and what kind of cause and effect relations exist. An interesting variation of reasoning maps has been presented by Nopadon Kronprasert: it is based on Dempster-Shafer theory using Bayesian reasoning to model uncertainty (Kronprasert, 2012). It opens up new opportunities in including uncertainty of knowledge into information models.

Methods

Learning from experience in other fields can be fruitful. It is more straightforward, when the fields in question are close to each other, like projecting lessons from fixed line telecommunications systems to electricity networks (Pollitt, 2010). To take advantage of what has been learned in more distant fields, processes and policies may need to be conseptualized.

Intelligent systems are often software-based, but it is not a necessity; they can be implemented with low-tech tools, too. Usually, an intelligent system represents and models real world processes; to do this, existing conditions and parameters have to be assessed first. The practical experience we have learned using several methods for implementing intelligent systems will be discussed here.

ASSESSMENT, CATEGORIZATION AND GROUPS

In a research and development project for a Finnish construction company (Rantanen, 2013), we created a categorized hierarchy of internal construction elements in a building, including surfaces, appliances and equipment. Classification was used to implement a Building Information Model (BIM), in which each object was linked with corresponding titles in a database to integrate up-to-date product information including pricing into the BIM-model.

Software automation was used to add dynamic interaction between objects within the model, following scripted rules. Tools were included to assist furnishing rooms and automatically creating required documents for clients, construction and purchasing. The whole design and construction process was made more efficient.

In addition to hierarchical categories, there are other forms of interaction and classification overlaying. To define them, we found useful to define groups for titles.

Groups consist of different titles from various categories. They can be used to define products from same manufacturer, or products from same product line that are supposed to be used together. Environmental, energy efficiency or safety classifications of products can be implemented with groups, too, making it easy to select elements based on criteria required in each case.

RELATIONS, POLICY PACKAGING AND VISUALIZATION

To achieve goals wanted, a combination of policies is often more effective than a single policy – this is called policy packaging, It is used to define a set of policies both effective and

I. An organizational typology.

Key characteristics	Organization type			
	Premodern	Modern	Postmodern	Hypermodern
Size	Small	Large	Flexible (i.e. small, medium or large)	Hyperflexible (i.e. size can change rapidly to match market opportunities)
Key source of competitiveness	Labour	Capital	Knowledge	Acceleration (excess speed)
Technology	Hand tools	Large scale mechanical production equipment	Information and communications technologies	Internet and mobile communications
Nature of assets	Distributed	Heavy and centralised	Mixed	Light
Main period of dominance	Pre 1900s	Late 1800s-1970s	1980s →	Transient
Nature of the economic system	Proto – capitalism	Capitalism	Informational capitalism	Hypercapitalism

II. Enron as an exemplar of the hypermodern organization.

Key characteristics	Hypermodern organization	Enron
Size	Hyperflexible (i.e. size can change rapidly to match market opportunities)	Appearance (and disappearance) of business units and ultimately the organization
Key source of competitiveness	Acceleration (excess speed)	Acceleration evident in rate of innovation and management of staff as well as business practices such as mark-to-market accounting
Technology	Internet and mobile communications	Internet, use of mobile devices such as PDAs, etc. Prevalence of ICTs in employees work and home lives
Nature of assets	Light	Light assets embodied in the minds of employees in terms of knowledge, intelligence and creativity. Also in reputation and confidence of the financial markets built up through persistently high performance
Main period of dominance	Transient	Emerged as a modern organization in 1985 transformed into a hypermodern organization in the late 1990s, collapsed in 2001
Nature of the economic system	Hypercapitalism	Capitalism focused on image and symbolic value

Figure 3. Characteristics of hypermodern and an example of hypermodern organization the flexibility of which makes it disappear in the end. Source: Roberts J & Armitage J: From organization to hypermodern organization: On the accelerated appearance and disappearance of Enron, Journal of Organizational Change Management 2006.

possible to realize, taking into account the existing economic, financial and political boundary conditions. Eventually, policy packaging is based on expert evaluation. Often the most significant selection criteria for policies is their economic and political feasibility. (Givoni, 2014)

Interactions between policies or entities can be described with hierarchical charts or maps. Interaction maps can facilitate evaluating how combinations of policies will perform. Interactions can be one-way or two-way; between two entities or multiple entities.

PROTOTYPING AND MODULARIZATION

In Product Lifecycle Management (PLM) and Product Data Management (PDM) applications used mainly in industry, prototyping and modularization are widely used. A simple form of these methods is copying existing plans and documents, making necessary revisions to them. More sophisticated version of prototyping is based on making easily modifiable modules, of which plans can be assembled efficiently. This allows project plans and offers to prepare quicker and more accurately, as well as makes it possible to increase efficiency of production.

Modularity makes it easier to realize projects in phases, adding or even removing modules as needed. Increasing complexity of products makes engineering and design work more challenging. To avoid errors and increase efficiency, it makes sense to divide tasks into smaller modules. PDM and PLM systems have been integrated with design software (Sellgren, 2009).

Together with modularization, analysis tools such as configurators can be used. For example, a configurator can be programmed to define parameters of local climate based on geographical location; they can be used to generate preliminary design documents with parametrically configurable prototypes.

An old, still usable form of prototyping is model books, checklists, guides and standards.

Prototyping was applied to support design of several private health stations in Helsinki region in Finland. Furniture, materials and equipment were standardized; room layouts, dimensioning and functional organization were modularized. Thanks to this, the whole process of designing and building new health stations speeded up. As instructions for installation and specifications for equipment were available early in the design process, errors could be decreased. Sufficient lighting intensity was defined for spaces and workstations depending on their function with contemporary lighting systems with programmable dimming options and proximity sensor where applicable.

VALIDATION AND VERIFICATION

Whether data is collected for analysis, simulation or monitoring, it is usually necessary to validate and verify it. With big datasets, software-based data checking is needed. The use of big data is growing, which brings new problems: validating the model used to be applicable with the dataset in question may be difficult and whole dataset can be biased leading into wrong conclusions (Verma & Nashine, 2012).

In either design documentation or control system software, data and parameters can be checked with software. If data is categorized, grouped and relations are defined, iterative rules can be applied to check combinations of these.

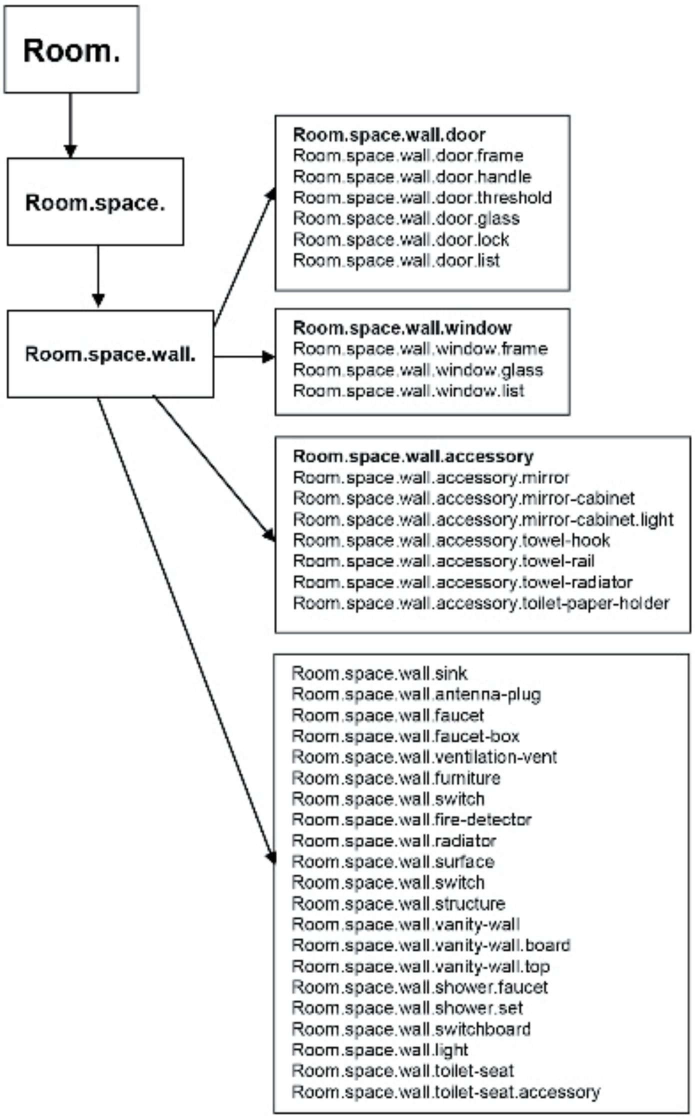

Figure 4. Logical categorization of entities visualizes their relations, too.

Possibilities

Electricity production consumes a considerable share of energy resources. In Finland, electricity consumption equals to production of industrial and district heat together. A major share of heat is produced with CHP plants, though, in which production of electricity roughly equals to production of heat or cooling. If the share is changed significantly, efficiency of production decreases and advantages of cogeneration are lost. Therefore, consumption of electricity and heat should be reduced at same pace regarding CHP production.

Different categories of spaces within a building can be used to define rules for controlling building services systems. Even the control of individual equipment can be adjusted based on classified location. Rules can be made based on spatial locations, for example sensor data can be filtered by spatial proximity or other rules, making it easier to program and re-program the control system. With an intelligent and adapting control system, lighting, heating and ventilation can be adjusted to save energy while giving good level of service for the functions in the building.

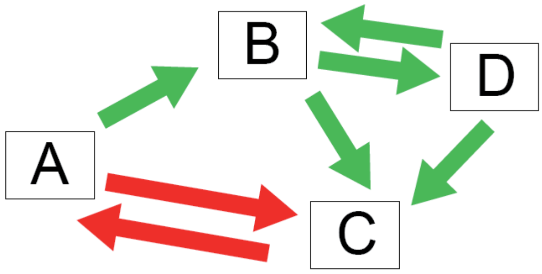

Figure 5. Visual map of interactions between policies makes it easier to understand chains of relations.

Concerning lighting, a base level of lighting can be maintained with reduced number of lamps in use. Lights can also be dimmed as required and take into account intensity of natural light. To detect people and natural light, sensors are needed. Currently, the amount of sensors is limited by their cost, because of which all floor space cannot be covered. Therefore, presence sensors are used with time delay or acoustic sensors can be included to improve the performance of visual sensors. As the price of sensors goes down, better coverage can be obtained, which makes it possible to adjust lighting more accurately to reduce electricity consumption as well as to allow better level of service. Making different equipment communicate with each other could allow elevators to provide information of the story they are approaching, having lighting switched on; and vice versa, sensors in elevator lobby could inform elevators of the amount of people approaching elevators.

With control systems adjusting all building services systems, energy use is reduced regarding both electricity and heating or cooling, which supports the use of existing CHP production.

Following the idea of categorization, we can compare different uses of energy use, too. The price-demand elasticity is different for each of them. Main categories are electricity, heat and traffic; categorization could be continued into subcategories within each main category, such as electricity consumption in urban or rural areas, in dwellings, hotels, offices and other workplaces. There would probably be variation, which could be taken into account when deciding which actions to take. For example, if even heavy taxation doesn't reduce consumption in one context, taxation will probably cause negative side effects as it will cut possibilities for other consumption and investments, too. In such a case, different actions should be considered for categories with different behaviour. Obtaining sufficient data for multiple subcategories is obviously a big challenge.

It seems that electricity consumption is most sensitive to change of price. On the other hand, this makes reduction of electricity consumption have most potential for reducing total energy use, and suggests that pricing incentives like taxes or flexible pricing could be an efficient method to use.

The grouping method could be used to define consumer profiles intersecting the categories. There seem to be different groups, sometimes called "tribes", of people with different mobility and consumption patterns (Kyttä, Haybatollahi, & Korpi, 2013). One group prefers to stay at home or spend time in nature as well as drive car; another group uses public transportation, wants activities in his/her neighbourhood and is most willing to move from one place to another; third group wants to live ecologically, uses public transportation or cycles and wants to stay in place. The best actions to affect the energy use of different tribes are probably different from each other; different incentives need to be considered taking into account different lifestyles.

Policy packaging and detection of relations can be used to understand chains of effects and to define the most plausible combination of policies. Concerning energy use, one common policy is to give guidance and information to add awareness of the importance of saving energy. Economic incentives may be used to increase the influence of information campaign. With flexible pricing, more even consumption and lower total consumption can be achieved. With technological solutions like smart grid, distributed production and more energy-efficient technology, consumption can be reduced. The risk of more energy-efficient equipment to allow people to acquire more units can be prevented by finding means to make products compete with quality instead of price, preventing the unit prices to fall too much. This can be done either by affecting demand (by giving information or by marketing) or by regulation and taxation.

An obvious application for prototyping and modularization can be found in both design and production of building services systems and equipment. In planning and architecture, modular design methods can speed up processes. During design and implementation phases, they make it easier to adapt and respond to changing boundary conditions and requirements. They also make it possible for investments, infrastructure and spaces to be used more efficiently. Low capacity factor of infrastructure and buildings increases the amount of resources and energy per operation unit invested in their construction and maintenance, therefore, making them less energy efficient during the whole lifecycle period.

Validation of data is a basic procedure for any researcher, big data bringing its own challenges. However, validation and verification should be applied to check objectives and means, too. Increasing energy efficiency is generally desirable, but in some cases it may make unnecessary excess consumption available.

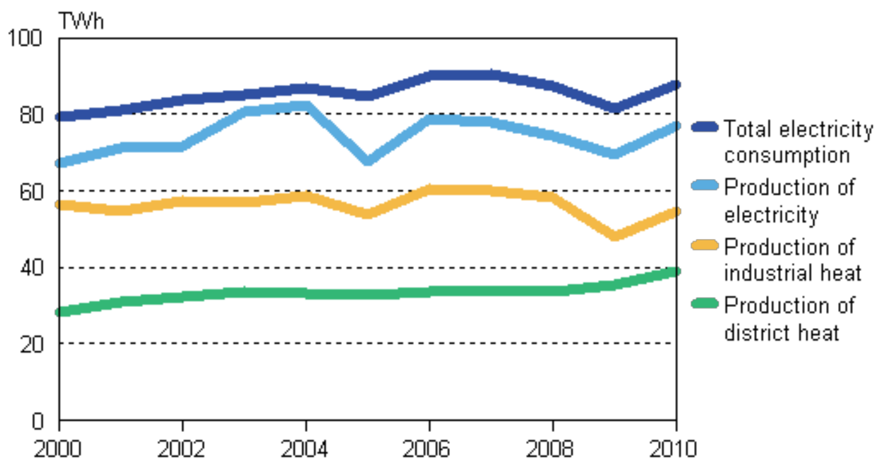

Figure 6. Production of electricity compared to production of heat in Finland. Source: Statistics Finland.

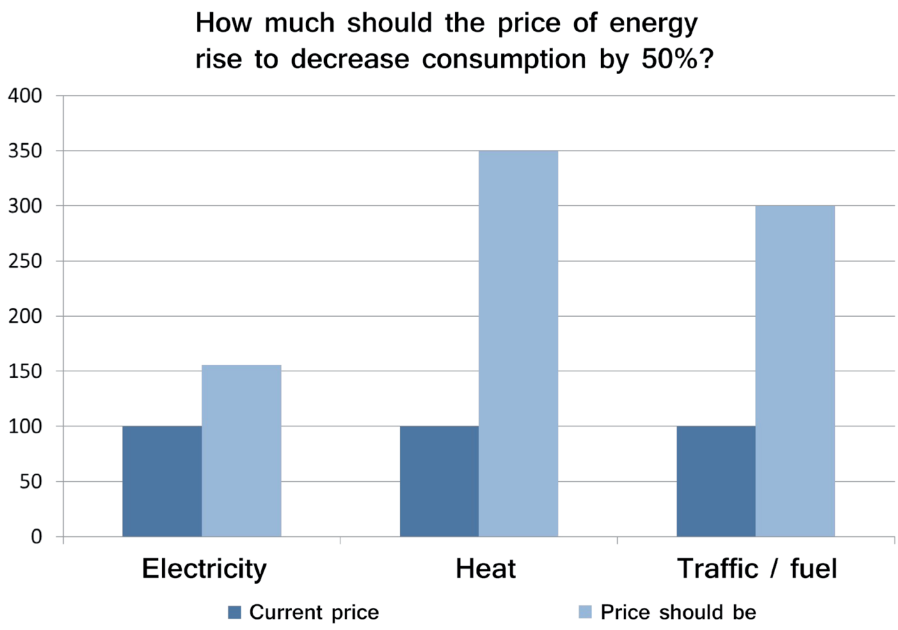

Figure 7. Elasticity of energy use in case of relatively high elasticity. Source: Rinne, S, 2012.

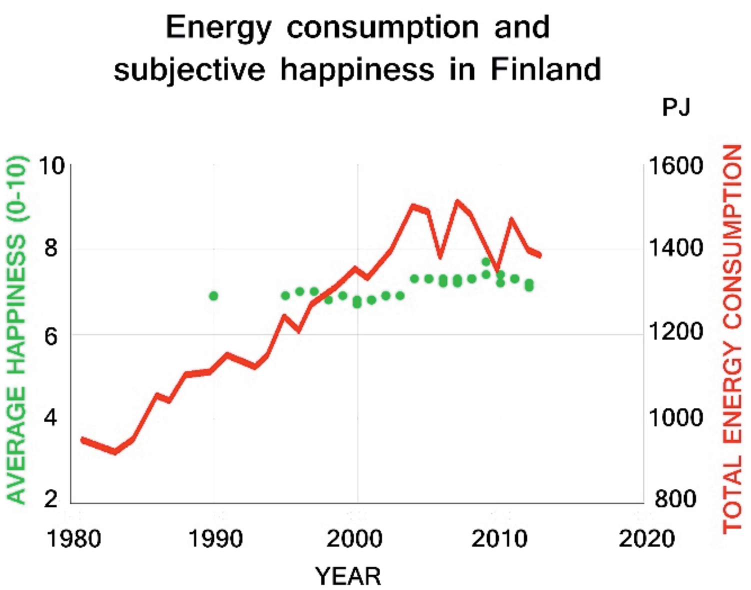

Figure 8. Energy use and happiness. Source: Statistics Finland, World Database of Happiness (Veenhoven R. , 2014).

Unnecessary meaning here that it doesn't clearly improve living conditions by increasing happiness, safety or welfare measured with other aspects than monetary value or number of gadgets and devices.

Summary

In contemporary world, economy and society create a complex unity. It is not possible to model it exactly or to make definite forecasts of future. However, it is helpful to use methods that unfold the complexity and interactions to choose appropriate actions. In order to use resources – including energy – more efficiently, more adaptive processes should be developed. Modularization and prototyping based methods can be applied to achieve this.

As regulations and research are focusing on "how" systems should be improved, question "why" they are improved and exist is not always given enough attention to. Instead of measuring economic growth to represent how successfully society is developing, it might be better to measure happiness.

The notion of energy use to increase happiness in general can be questioned. Some people are happy if they can consume energy in the form of driving a car; thus, making it more difficult for them to drive, may decrease happiness. If driving experience is produced with less energy, it is not necessary to allow energy use rise elsewhere, however.

As land use problems of automobility with their side effects still exist, housing areas should be developed to meet different preferences, making it affordable for people not wanting to drive car to choose to live where mobility needs are fulfilled by public transportation, cycling and walking. Rail transportation is very efficient regarding land use in urban areas, but aspirations of high speed rail connections linking urban areas with each other are not trouble-free, as increased speed causes energy use to rise significantly. To save energy, it may be reasonable to compromise speed to some extent.

It would be important to make it possible for those wanting to do so to live in urban environment, where dense urban layout and multi-storey apartment buildings allow better energy efficiency compared to single-family house areas. The ongoing global urbanization would suggest that there are many of them. Advanced technology should be used to decrease energy use, but means to prevent general consumption from growing as a consequence should be found. A general lifestyle change would be an effective solution both to reach more sustainable development and to decrease energy use, but it is difficult to see how to make it happen, especially on a global scale.

Energy efficiency in industry is usually improved by technological and organizational improvements. A holistic approach to society and economy may assist to perceive the functioning of global systems and to understand that there are unpredictable interactions. Therefore, practices and policies are needed to respond to the unexpected outcome of the existing complex processes. Adjustments to objectives are needed continuously and trends have to be questioned constantly. This approach may help to avoid unproductive investments and to cancel projects which turn out to have low benefit-cost ratios. In the contemporary world, past investments in the form of either material or intellectual property can lose their value in a short period of time. Technologies like 3D-printing and smart power grids are making production of goods and energy more adaptive and configurable. On the other hand, other technologies and cultural change may affect the demand for them. When it comes to consumers, especially in the long-term, it is impossible to predict their consumption preferences after fulfilling the basic needs. Changes in supply and demand affect the value of production, which relates to how reasonable it is to invest in better technology and research. In case of a market sector with low price-elasticity, regulation may be useful to promote better technology and organizational structure.

Glossary

BIM	Building Information Model
CHP	Combined Heat and Power
PDM	Product Data Management
PLM	Product Lifecycle Management

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