Sustainable energy shift in the building sector – feasible or infeasible?

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Keywords

building industry, energy efficiency, renewable energy, energy systems, building developers, building users, public authorities, financial institutions, dynamic models, positive feedback, negative feedback

Abstract

Operation of the building mass accounts for 35-40% of stationary energy use in modern society, and the building sector presents perhaps the most challenging and rewarding opportunities for improved energy efficiency and increased use of new renewable energy sources.

The major focus for most property developers and owners, is the accumulated costs before the building starts to create income, and the competitiveness of a building in the market once it is operational. Accumulated costs have three main components: the actual construction costs, the lost generation of value (income) before the project is placed in the market, and finally financial costs. The second component means that planning, design and construction time becomes very important for the developer. This creates opportunities for society to make projects towards energy efficiency more tempting.

The paper discusses the deeper background for understanding change in the building sector, and considers a number of issues at interfaces between developers/owners, users and public authorities. Some of these issues act as barriers to change, while others promote change either directly or through destabilisation of situations of equilibrium and lock-in.

The analysis is based on an overall description of the building industry in terms of activities, to allow use of both overall optimisation, and also dynamic economic models to describe negative and positive feedback patterns and identify structures of stability that are inherently hard to change, and structures of instability that offer windows of opportunity where change of culture, methods and technology can be initiated and implemented.

Introduction

While our current energy supply and its infrastructure at present serve us well, there is increasing recognition and concern that it is not sustainable. The “RES-E” directive of the EU (2001) states a goal of 22.1 percent renewable electric power by 2010, meaning, if reached, that at this date 78% will be non-sustainable. The main headaches are insecurity of supply resulting from deepening dependence on other nations, together with global and regional environmental impact. Extensive research work has failed to turn up any easy answer to these problems. At the same time earlier deep changes in the energy infrastructure such as from coal to oil, have taken many decades (cf. Grübler et al, 1999:265). Change towards a new sustainable infrastructure for energy supply must likewise be expected to require extensive time. Hence it appears prudent to consider the time element involved. The task is enormous and difficult, but it may be seen to open for large scale creation of value in building a new, sustainable energy infrastructure. The extent of practical change achieved so far is disappointing.

The overall goal of sustainability may be approached both through generation of new sustainable energy, e.g. from wind, and also through improved energy efficiency, i.e. obtaining more value from the energy that we are using now.

This latter course will always make the overall goal easier to reach. Reclaimed energy is just as useful as new energy. In fact it is much better: it is adapted to user needs, it does not load the grid, it is free from pollution and it is delivered free of charge. The corresponding electric power is paid for by the end-user at 3-5 times the price paid to utilities for new electric power delivered on the grid. The observation may further be made that where alternatives exist to generate the same value with less use of energy, a situation of wastage is present.

The building sector provides a particular opportunity with respect to reclaiming of energy: it is a large consumer of energy (in modern societies like in Norway 35-40% of stationary energy use), and there are a number of promising approaches. However, ownership is widely dispersed and decentralised, and the sector is served by a large number of individual firms in the building construction and maintenance sector. The sum of their individual interests will go in many directions (possibly mostly private economic) that will not coincide with the goals of sustainability of society at large. *A central task is to align short-term, (annual) commercial outlook, with the long-term, generation-based value of sustainability.*

The present paper seeks to shift part of the focus from what to do in terms of technology, to how to get things going. In this we need goals or aiming points, and we also need to understand both the paths leading from now to there, and the processes that physically implements change.

The "what to do" picture

We live in a world of becoming (Prigogine, 1997). There are many possible futures, and we end up in one or another of these depending partly on where we seek to go, and partly on what the surroundings happens to be while under way. Time is ever changing continuity: things do not develop into stages that subsequently remain stable; there is continuous running change. However, in discussing where we want to go we need concepts or ideas that reflect some sort of stability in time, and we perceive change in terms of shifts from one stable situation to another. The stable situations are perceived as scenarios. These vary in how easily they may be reached, how optimal they are (in several different contexts), and how they lead on to new scenarios or create locked-in situations. Our concept of "now" ("at present") also qualifies as a scenario in this respect.

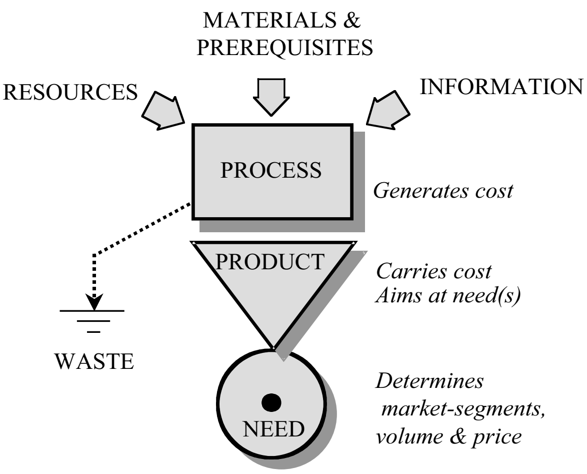

Figure 1. *The formal concept of a value-oriented activity.*

FROM SCENARIOS TO TECHNOLOGICAL SPECIFICATIONS

Scenarios are overall descriptions at a high level of abstraction. If we are to effect change this needs to be translated into a detailed set of physical activities, with specifications of what to do, when it is to be put into effect, and who will do it. In the following we describe a rationale for going from scenarios to technology, developed by H. Gether (2002). It has come to be known as "value sequences", and has the merit of following closely the practical concept of "activities" in project planning and –management, familiar in the building sector.

The outset is that human needs are met by a set of *end-products* (products and services in the hands of consumers), and that *value* consists in meeting/satisfying *needs*. This means that value is described both qualitatively and quantitatively in terms of needs. The more end-products there are, the better designed and the more freely available, the greater the prosperity. All tools meant for further provision of end-products are themselves considered as end-products. With respect to end-products we introduce *end-users*, which are those consuming end-products. End-products compete in markets, and they pay for all upstream activities leading to them. The set of upstream activities for a given end-product is called a *value sequence*. This is reminiscent of concepts like "supply chains" or "value chains" from the field of business strategy, but is independent from individual firms, and is divided into activities that may vary from end-product to end-product. Furthermore, the activities may be considered in a wide set of contexts, not only as the flow of materials. By example, flow of information among activities may be quite different from flow of materials. When observed in actual practice, activities in value sequences correspond to "routines" as introduced by Nelson and Winter (1982).

Value sequences are constructed from *value-oriented activities*. A value-oriented activity has a description of value in terms of the need(s) it seeks to meet, in addition to information conventionally associated with activities. A formal outline is given in Figure 1.

Value-oriented activities may be subdivided in such a way that a set of daughter activities create the outcome of the parent activity. This is done in order to describe reality in further detail. The value of a daughter activity is the contribution it makes to the output from the parent activity, again described in terms of meeting a need. Daughter (sister) activities always interact at the same level of detail. The subdivision into daughter activities is illustrated in Figure 2.

This subdivision of activities may be carried out recursively to any required level of detail. It is helpful to fix the levels of detail for consistency, and we have found the following levels appropriate:

By following *value* (i.e. description of needs) back towards the root we may describe the value of any particular detail within the larger context of the end-product, and the activity's contribution to prosperity as mediated by the end-product in question.

The next step is optimisation of the provision of the end-product. This is driven by the competition of end-products

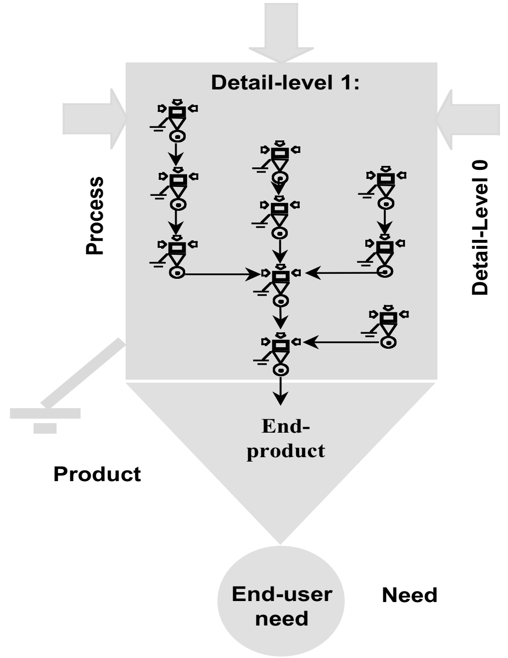

Figure 2. Subdivision of parent activities into sub-activities.

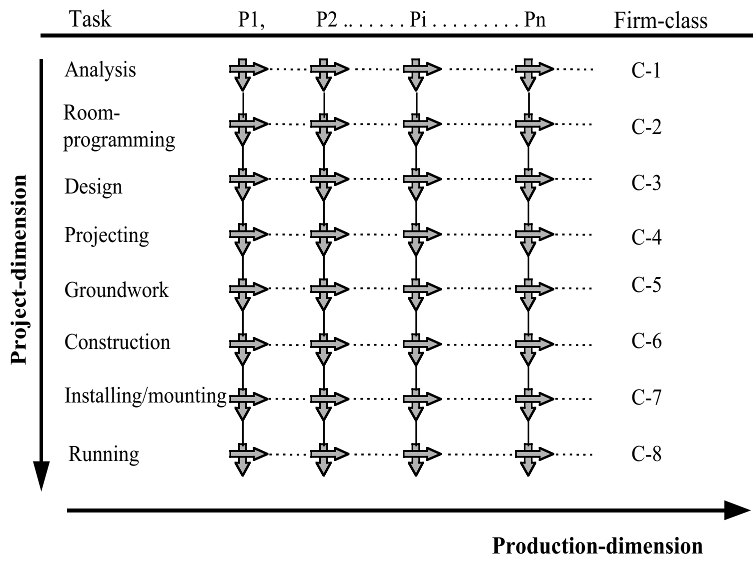

Figure 3. Interaction between projects and firms.

with alternatives that aim to meet the same need. This optimisation is "global" rather than local, as it cuts across all participating firms. The actual outcome (i.e. the value sequence) depends on how the division into sub-activities is done, and the efficiency with which each activity may be performed. The substitution of activities with more efficient activities is the alter ego of improvement and innovation. The optimisation is partly a continuous process that takes place in real life, where it takes the form of adapting and adopting of activities that are ever more efficient, individually or in contributing to efficient interaction between daughter activities. This process is reminiscent of biological evolution, and is anything but straightforward. It is different from "mathematical" optimisation in that it allows qualitative and "new" factors to be taken into account.

The optimisation may also take the form of "paper studies" based in improvement by "human ingenuity". The outcome is identification of new options ("optimal futures") that constitute strategic *opportunities* for firms: something that the firms may take advantage of, or perhaps guard against. In this way we obtain the required tools (and a language) for translation from scenarios to required technical detail. Working backwards, the process identifies scenarios that combine technological efficiency with goals sought by society, such as sustainable energy supply. The movement towards *sustainability* through improved energy efficiency means *to exchange current activities with activities that use less energy* to achieve the same.

PRACTICAL CHANGE THROUGH EXECUTION OF ACTIVITIES

Practical change will not come directly from scenarios, but will result from activities carried out in the construction industry. This industry consists of individual firms, that each will seek, and must have, a sound economic basis. This means firstly that there must be projects leading to sustainability (i.e. increased energy efficiency) that firms in the building industry may take on, and on which they actually will earn money. Secondly, it means that where several alternative projects exist, those will be selected for execution that return the highest reward. This reward will to a considerable extent be economic in nature, but may have aspects of positioning for further tasks, i.e. aspects that relate to competition. An example is the learning of new capabilities. The process of selection of projects by firms may be seen alternatively as *a competition among projects for execution*.

The other side to this is that the actual choice of projects will determine the course of transition from scenario to scenario, and what scenarios will actually be reached. It will thus determine where we actually end up. The interaction between projects, and between firms that carry out the projects, is complex. Some idea of the nature of this complexity may be gained from Figure 3.

Table 1. Detail levels for subdivision of value-oriented activities.

Detail level	Description
0	End-product/end-product need
1	Level of individual firms
2	Main operations within firms
3	Unit operations
4	Individual execution within firms

As shown in Figure 3 there are two main dimensions in the interactions between firms and projects. Within projects there are chains of firms leading from start to completion of the individual project. Simultaneously, as firms complete their engagement in one project they start up (in a production dimension) in the next project. Efficient work (and earnings) is highly dependent on efficient coordination of this integrated and intermingled system, which is highly sensitive to time overruns. In economic slack times there may be sufficient reserves to cope, but otherwise problems in one project will tend to spread both to other projects and to other firms. This is an area where it may be possible to systematically increase competitiveness of project alternatives that lead towards sustainability.

THE COST STRUCTURE IN THE BUILDING INDUSTRY

In this section we consider the cost structure in the building industry in more detail. There are (at least) three different and independent sources of costs for a building-related project. The first is project costs proper, generated in the process part of the project activity, and imported from other activities through import of materials and prerequisites. The costs generated in the project part are highly dependent on the interplay with "adjoining" firms as illustrated in Figure 3.

Secondly, building projects are prone to "waiting costs", that arise because a project only earns income when it's finished. These costs may be substantial, and are a highly motivating factor in seeking to complete projects as quickly as possible. This is another area in which society might contemplate ways of speeding up completion of sustainability-geared projects, without generating much costs on the society side of the ledger.

The third type of costs are associated with financing of projects. At least as experienced in Norway financing costs may vary widely. This is due in part to varying competence and cleverness in financing operations, and partly because some of the financing is handled through subcontractors that supply materials and equipment as part of the subactivities in which they participate. The end-result of such practices is that it becomes almost impossible to determine where costs actually arise. Participation by society with respect to financing costs might involve bylaws/regulations that lead to clear pictures of cost creation. A further area that would seem to be powerful, is to provide for cheaper loans in various ways, e.g. through reduced interest rates for loans towards environmentally sound buildings.

A fourth factor that appear important to the competition between projects to be executed, is the way net present value is conventionally calculated. This is a complex area that deserves more space and attention than available here, but the following seems to obtain:

- Sustainability-oriented projects are mostly of long-term nature, providing value in time-spans far outside ordinary business enterprises, and with very low risk.
- Conventional calculation of net present value assumes an unchanging, "business-as-usual" world where things are mostly unchanged and stable, whereas sustainability-oriented projects fundamentally seek to avoid serious calamities associated with a problematic fossil-based future.
- Conventional net present value calculations have their basis in the micro-economic world and thinking of individual firms and projects, whereas the societal issues involved with sustainability are macro-economic in nature.

The conventional use of net present value calculations appears to counteract change, and to do so incorrectly.

The dynamic picture

The previous section was concerned with matters of a static nature, that in a sense forms the "landscape" in which we move. In this section we will consider matters that are important in a dynamic sense, important to the actual moving. The central new element is *feedback*: we consider not only solutions to problems, but seek to understand what these solutions may lead to in the future. In the present context, feedback will either tend to either stabilise or amplify some trend or development, referred to as negative and positive feedback respectively. These situations lead to utterly different outcomes: negative feedback leads to equilibria, and output from a system with negative feedback is determined by the feedback control rather than by the system itself. Positive feedback on the other hand, leads to exponential growth until something holds the system back, and may give rise to bifurcations into quite new systems. Such situations opens windows of opportunity for change. An extensive introduction to dynamic systems and their modelling is given by Sterman (2000).

NEGATIVE FEEDBACK AND EQUILIBRIA

In relation to the problems in focus here, the most common situation with negative feedback is economic endeavour under diminishing returns. This is a basic outset for the central classical and neo-classical models of the economy. The result is generally equilibria between production and consumption, where the equilibrium determines prices in markets. A general property of equilibria is that a system returns to its former level when disturbed. Result: no change. The lesson to be learned is that attempts to change systems that are in equilibrium, will generally be in vain.

The symptoms we are starting to see with the existing fossil fuelled energy infrastructure, indicates a system where an equilibrium situation is becoming unstable. We may expect instability to develop further in the time to come, and the system thus to become more amenable to change. However, the present energy system is complex, and requires more extensive analysis of its dynamics in order to understand the development of instability properly.

POSITIVE FEEDBACK, INSTABILITY, PATH DEPENDENCE, LOCK-IN AND BIFURCATIONS

The basic understanding of these circumstances originates from Prigogine's analysis of open thermodynamic systems (cf. Prigogine, 1997), leading to the recognition of dissipative systems and bifurcations. A dissipative system is an apparently stable system far from equilibrium, based on a positive feedback that maintains a stream of energy through the system. If the positive feedback is disturbed the system abruptly "dies" or switch into a new phase through a bifurcation. Where it ends up depends on both the system itself and its surroundings at the time of the bifurcation, and may only be stated in terms of probabilities.

Arthur (2000) has applied this theory to economic situations, where positive feedback is known as "increasing returns". A range of mechanisms exist for this (cf. Sterman, 2000:349-406), by example:

- Product awareness increasing with sales, creating more sales.
- Spreading of development costs over a larger volume reduces costs, to increase volume further.
- Learning curves: Learning increases efficiency to lower production costs with increasing volume, to increase sales and further increase volume.
- Increasing usefulness with increasing volume, e.g. for telephones.

Such positive feedback locks in to either left- or right-handed driving and locks in to particular products and to particular patterns of behaviour. Our present energy system bears many marks such lock-in. Some of its features, in the same way as left- or right-handed driving, bears no relationship to optimality. Others may have been optimal (or at least good) at some time, although new technology may now allow more optimal solutions. Yet, the capital invested in the existing system, and our habits, prevent change. This is the phenomenon of path dependence.

The existing systems become unstable if the mechanism for positive feedback is disturbed. This would happen e.g. as unreliable supplies of, say oil, started to become really noticeable, with high fuel prices to consumers as a result. The ensuing instability opens windows of opportunity for change.

Our essential task is to detect and create such opportunities for instability, where sustainable solutions may take over without creating undue hardships. At present our most promising approach seems to be to continue our efforts to develop solid scenarios for a sustainable future e.g. as described in the previous section, combined with careful system dynamic analysis to detect possible path dependencies and lock-in, in advance.

Change to sustainability – feasible or infeasible?

The quest for sustainability may be the largest and toughest task ever encountered by man, and it has to be solved within a time span of perhaps two or three generations. Increased energy efficiency of buildings is a significant endeavour. The basic problem with attaining sustainability comes from the power of exponential growth, where an increase of only 2% each year will double the consumption of energy in 35 years. We are now approaching a situation where this kind of growth clearly cannot go on much longer. Yet this property of an almost insignificant change on a year by year basis also offers hope. If the same effort is turned around, it only takes 2% each year to reduce consumption of non-renewable fuels to halve present consumption. Provided that we may keep up supplies while this takes place, we would be that much better off. As stated above, the main challenge is to transfer the value of a sustainable future into short-term business value. Modelling tools now being developed should let us decide on suitable technology as described for activities in value sequences, and dynamic analysis should help us identify and avoid lock-ins as well as windows of opportunity.

A positive outcome would mean buildings in which we live and work, that provide the functionality we expect from buildings now, yet do so within energy budgets that are sustainable. An important task in the near future is to formulate the questions and derive answers as to what this really implies. What will be a justifiable level of energy used by a building fifty or a hundred years from now?

If we set as our task *to largely retain our existing infrastructure of energy supply*, and yet achieve a sustainable world one or two generations ahead, *that task appears infeasible*. However, man has always faced change, and has mostly overcome its exigencies. The main danger appears to be to run out of time before the problems are broadly appreciated and dealt with. The process of creating value by constructing new infrastructures that are properly adapted to our surroundings should otherwise see us through once more. It is tempting to close with a scenario of the development of the European construction sector, formulated in the "Atkins report" ten years ago:

> *"There are two scenarios for the future European construction sector. We have a vision of an industry which is high in public esteem, applying the best technology to improve Europe's landscape and living environment, building beautiful buildings and creating towns in which people are happy to live and work, providing good and affordable housing, and efficient uncongested infrastructure. People will be glad to commission construction in the knowledge that it will normally be free of worry and conflict, and their property will be safe, healthy and easy to maintain. School-leavers and graduates will be proud to enter a prestigious, rewarding, creative and secure career which contributes to improving the global environment. Designers and managers will have the computer tools to liberate creativity and to select well-tested products and construction details. Many of the more difficult site-tasks will be replaced by mechanisations, factory-produced components and easy-to-use materials, leaving craftsmen free to use their skills productively. Construction will be viewed by government as the tool for building the future society, by providing efficient infrastructure when and where it will promote useful development, and reinforcing Europe's strength of diversity of cultures, traditions and systems."*
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> EC, 1994:1

We must realise that a sustainable building mass really means a major construction- and reconstrction job. We shall require all the competence and talent we can muster in this endeavour. It is, in the longer perspective, a question of to be or not to be.

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