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Constructing Engineering Systems - A Comparative Analysis of the Development of Two Project Based Industries the Construction and Wind Industry

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CONSTRUCTING ENGINEERING SYSTEMS

- a comparative analysis of the development of two project based industries the construction and wind industry

ABSTRACT

Engineering systems fulfils important functions in society like providing quality spaces for living and generation and distribution of energy. This study explores the development of these socio-technical systems by the analysis of the historical development of the building and wind industry. With the theoretical frame of the Multi-Level Perspective (MLP), the analysis shows how the engineering systems emerges out as a response to societal changes and challenges combined with development of new technologies and regulatory initiatives. The successful application of MLP demonstrates that it represents a promising framework for understanding the evolution of specific engineering systems. The findings further suggest that continuing developing the engineering systems require a focus on the dimensions: Technology, Markets, Industry, policy, Culture, and Education and Research – combined with a deliberate focus on the role of project, program and portfolios.

Keywords: Engineering systems, Wind power, Construction, Project organizing, Innovation system

Background

Today's society is heavily dependent on highly complex engineering systems. Such systems enable high quality of life, for example through generating and distributing energy, enabling global communication, improving our health, creating optimal working and living conditions or transporting goods and people.

Engineering systems (DeWeck, Roos, & Magee, 2011) are characterised by a high degree of technical complexity, social intricacy, and elaborate processes, aimed at fulfilling important functions in society. Examples include generation and distribution of energy, enabling global communication, creating affordable healthcare, managing global manufacturing and supply chains or building and maintaining critical infrastructure. Thereby engineering systems extends traditional research foci on organisations, products, projects and policies as typical objects of analysis to a broader perspective of value creation taking a holistic view of the built environment (Herder et al., 2008; Whyte, 2016; Whyte et al., 2016).

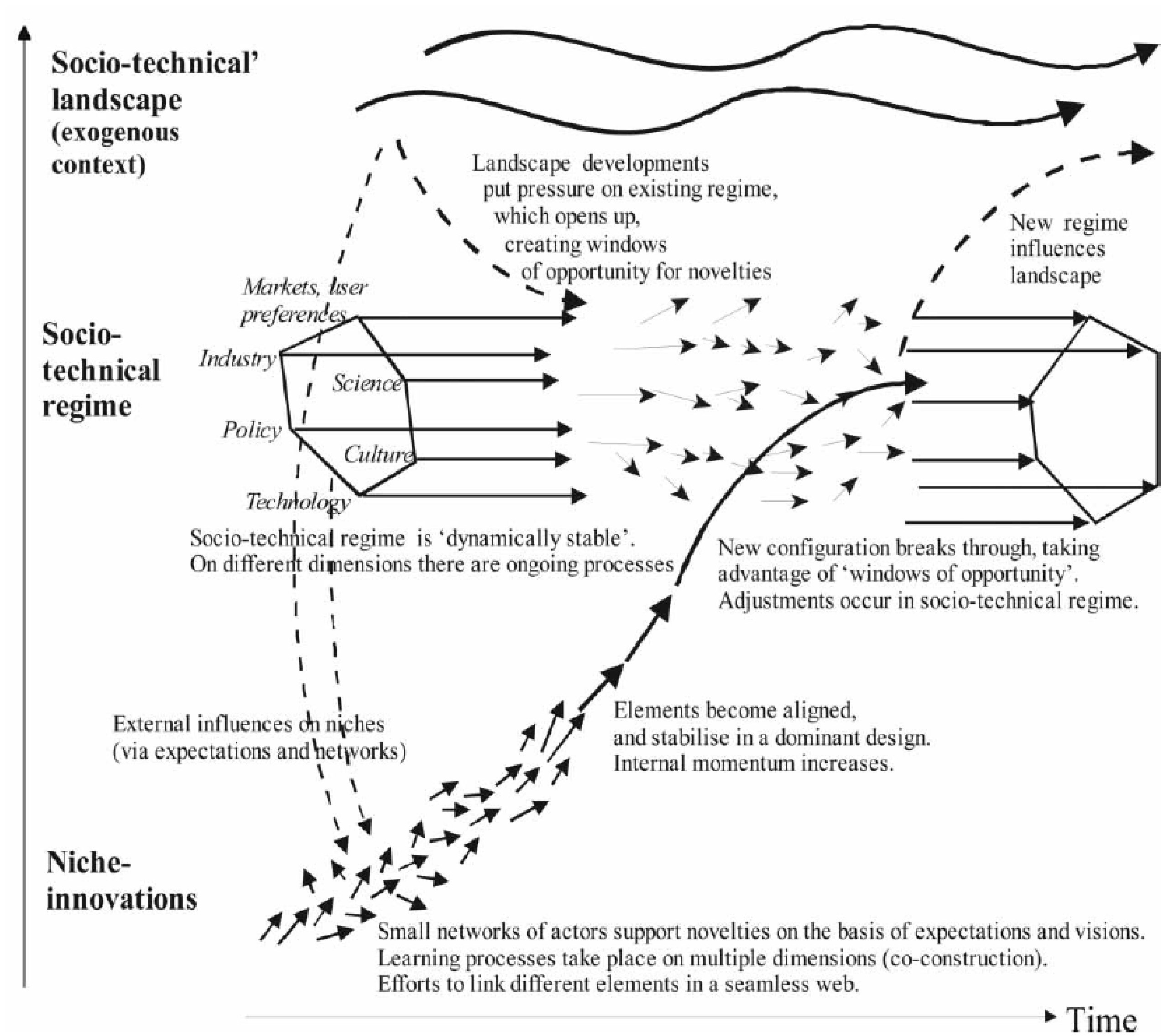
Value for society is not generated by any one element of these systems, but only when the system elements work together: a jumbo jet is worthless without an airport; offshore wind parks are worthless without complementary energy buffers; and chip foundries are worthless outside of vibrant electronic production clusters. This makes these systems large – they become complex and in their entirety require capital investments beyond the means of any single company, and sometimes even single countries. It implies long life cycles, as the systems cannot be easily replaced but instead evolve over time. And they are not "just" technical systems, but are closely linked to the way people use them, and the way they in return influence people. The systems thus evolves over time in a process that are partially shaped by intentional design and emerging properties of their use.

Research objective

The purpose of this study is to shed light on the development of engineering systems by the analysis of the historical development of the construction and wind power industry.

Theoretical framing

Numerous researchers have taken up the challenge on theorizing the transition of socio-technical systems. One of these - the Multi-Level Perspective (MLP) (Schot & Geels 2008; Geels 2004) - look upon transition as a socio-technical phenomenon and identify three levels of socio-technical interaction (illustrated in figure 1) within which development of engineering systems can be understood. This theoretical framing of transition is supported generally (Grin et al. 2010) and specifically for construction (Thuesen & Koch 2011; D. Gibbs & O'Neill 2014; D. Gibbs & O'Neill 2015) and energy systems (Verbong & Geels 2007; Verbong et al 2010; Kamp 2008)



Figur 1: Development in an innovation system (engineering system) explained in three levels (e.g. Schot & Geels 2008, s. 546)

The macro-level forms the socio-technical landscape, an exogenous environment beyond the direct influence of actors in the other levels (e.g. macro-economics, deep cultural patterns, macro-political developments). Here Gibbs and O'Neill (2014) suggest that the current environmental concerns and the policy shift to a green economy represent tensions, and thus creates a window of opportunity for exploration of new trajectories for green construction.

The socio-technical regime (the engineering system) forms the meso-level, representing the dominating stabilised socio-technical pattern of interaction, which is reproduced by institutionalised learning processes. A socio-technical regime can for instance be the building and construction industry (Thuesen & Koch 2011; Gibbs & O'Neill 2015), and is defined by a common set of (unwritten) rules for practices and processes, ways of handling specific things and persons, ways of defining problems etc.

Niches form the micro-level where radical novelties emerge. According to Geels & Kemp (2007), several researchers within sociology of technology and evolutionary economics have stressed the importance of niches as drivers of change, from where new socio-technical regimes can be developed (Levinthal 1998; Schot 1998). Niches work as incubation environments for new ideas by being protected from the traditional selection mechanisms of the marketplace. According to Schot and Geels (2008) transition can be facilitated by creating technological niches, i.e. protected spaces that allow the experimentation with the co-evolution of technology, user practices, and regulatory structures. By distinguishing between market and technological niches, Schot & Geels (2008) explain how innovation can be achieved through institutional learning processes linking technological niches to niche markets.

METHODOLOGY

Besides the theoretical frame of MLP the analysis of the development of engineering systems is based on empirical material collected from multiple sources like qualitative workshops, semi structured interviews (Kvale 2007), historical texts and existing analysis. The empirical material is collected in Denmark where we have access to detailed information and analysis about the development of the two industries. This was further supplemented with more than 15 interviews with practitioners within the two areas. The following table outlines key references on which the following analysis is developed:

The building system	**The energy system**
Engelmark (1983), Indenrigsministeriet (1946), Bertelsen (1997), Andersen (2005), Idorn (1997), Thuesen et al (2011), Gottlieb (2010)	Karnøe, P. (2013), Vindmølleforeningen (2008), Bruns, E. Køppel, J. Ohlhorst, D. & S. Schøn (2008):

Analysis:

The analysis falls in two parts one for each engineering system concluded by comparison of the different dimensions of the innovation systems and their role in shaping the engineering system.

The building system

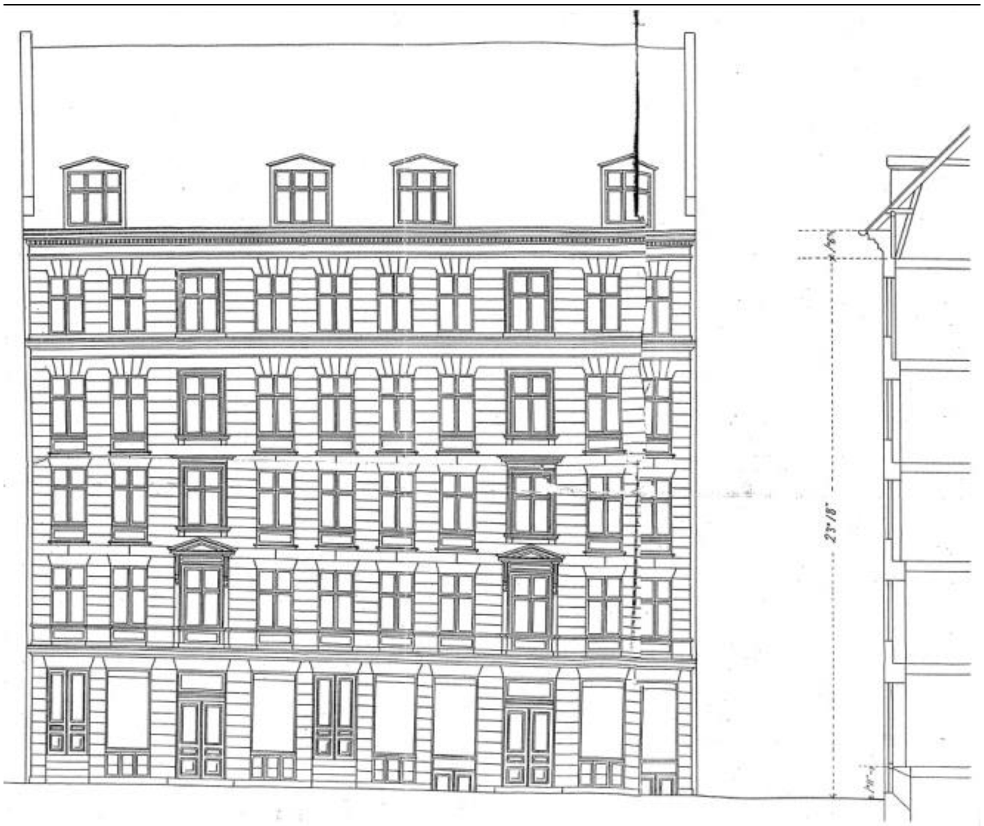
The building system is developed through generations in a process characterized by periods of more and less stability and moments of radical changes in the building products and practices.

Although the moments of change encapsulates periods of fundamental different building systems as between the premodern (-1945), modern (1960-70) and postmodern (1980-) buildings, the historical practices are to some extent sedimented in the todays engineering systems of buildings.

The premodern building systems

As an example of pre-modern building systems we will use the case of building works from Denmark in the period 1850 to 1950.

As this period was characterized by a growing urbanization a shortcoming of housing and a market for flats arose. The new citizens of the cities represented a rather homogenous group without any significant requirements for living rather than a job and a place to live. Addressing the growing demand for housing 5 stories buildings was developed around the medieval center of the cities. The buildings was produced by well know materials such as wood, tiles, and glass. An example of such building is illustrated in the following figure



The building was realized by professional craft guilds as carpenters, masons and joiners, developed around simple the well proven technologies / materials as wood, bricks, and glass. These crafts were sustained by apprenticeship learning processes ensuring a strong integration between design and production and the management of the crafts practices. The main design was made by a master artesian, with some few drawings showing the plan view, sectional view and elevations. The design was made on the basis of exact knowledge about the building methods to be used, and this material could be given directly to masters in the relevant building trade who, with a limited amount of detailed planning, were able to carry out the work with methods that were learned in advance and used in all building processes.

The apprenticeship learning principles ensured the transfer of knowledge from master to apprentice, and from design to production. The characteristic of this knowledge was that it is tacit, embodied, and thereby is not directly communicable. The codification of knowledge was thus playing an inferior role. This is reflected in the often very limited use of drawings and description. Thus, the vast majority of buildings was built with a basic overview and an illustration of the façade like illustrated in figure 6. The interpretation of the drawings was made possible by the tacit and embodied knowledge in the form of rules of thumb (such as the rule for designing stairs 2 x (height of the step) + the length of the step = 2 feet).

This symbiotic relationship between design and production was made possible as the master artesian initially was educated within a craft guild. The premise of being allowed to design buildings was thus to master the practices of one of the central crafts. In this way, it was made sure that the design effectively could be realized through the existing practices.

This development was regulated by several building laws/codes (1856, 1871, 1875 and 1889) by the cities. The codes defined the lowest construction standard allowed and thereby buildings' quality level. The code contained detailed demands for the buildings' construction and materials, for example wall thicknesses and lumber dimensions. The traditional building custom of dividing crafts according to the materials used, such as wood and tile, functioned in combination with the code. Together, they set a clearly defined framework for this type of building for about 100 years.

The modern building system

After the WW2, the urbanization continued but the pre-modern building system could not keep up with the demand for homes. In 1945 the Ministry's Committee on Construction estimated that in the period until 1976 was to be built just over 1.5 million dwellings, an assessment subsequently proved to be on the low side. Thus a later report estimated that need had been just over 2 million. As a comparison the population in Denmark post the WW2 was around 4 million people.

This market was satisfied by the construction of multistory buildings in the suburbs of the large cities – standardized homes for standardized citizens. Illustrated in the picture below. This building system was enabled by introduction of materials such as concrete and steel which had proved their durability from the 1920ies in other markets like bridges, railways, port facilities and other major infrastructure projects.

However not only the materials changed. Inspired by scientific management subsystems of the buildings were standardized like concrete elements and installation components integrating water, central heating, ventilation and electricity in the buildings. This development came off - unlike the rules of thumb in the pre-modern construction – with a major focus on precision, tolerances, and measurement.

In addition, the organization of the building industry underwent major changes during this period. As the growing population in the cities did not have any jobs, they represented an unskilled resource. Thus, large national contractors like Rasmussen & Schiøtz and Larsen & Nielsen started to employed them as hourly paid workers. The contractors were the primary actors in the production of the buildings covering design of the buildings, prefabrication of concrete elements, and assembly at the construction site ensuring efficient supply chains. Central to this develop was the introduction of the planning engineer as a profession, who had the total overview of the building process from the design process, prefabrication to assembly. From being a craft oriented industry, construction became a science.

The development was inspired by scientific management know from Taylor (1912), thus were design and production now separated in clearly distinct phases symbolized by the phase model as "model" that provides overview and links the rational construction together, through clarity and transparency. This also developed drawings and documentation from having played a peripheral role in the pre-modern construction practices into important technologies for communicating design decisions, which all had to be taken in the design phase by the architects and planning engineers.

Central to the industrialization of the construction process was that they considered buildings as something standardized targeting generic human needs (standardized citizens). This is symbolized by the architectural credo "form follows function" initially formulated in 1852 by the American sculptor Horatio Greenough (McCarter 2010). This helped to develop the myth of the standardized building, which made the construction process transparent from a single point (the planning engineer), enabling long term planning of the construction from start to finish.

The driver of the development of the modern construction practices was a strong state intervention in the industry through regulation. It started in 1947 with the creation of the first ministry of Construction and Housing. Through a long series of laws and regulations, the ministry subsequently developed and enforced a shared agenda in industry. This included the development of sectorial research institutions in order to provide the scientific platform for the agenda.

The post-modern building systems

The modern building system managed to solve the shortcoming for housing. However the oil crises in the 70'ies introduced a new challenge – how to reduce the energy consumption in the buildings. At the same time, the flower power generation started to challenge the modern building practices and overtime post-modern building systems emerged.

From being driven by production of standardized multistoried buildings, the production of housing in the beginning of the post-modern era was driven by construction of energy efficient buildings with large variation targeting more individualized customers – unique project for unique users. Subsequently, the market became increasingly heterogeneous. The following picture of the concert hall of the Danish Broadcast association illustrates a typical example of post-modern architecture:

On the technological front, the post-modern building is characterized by an explosion of new building materials and technical and complex solutions that support the realization of customer's unique needs while at the same time lower the energy consumption. The consequence is an ever-increasing complexity in the buildings. An exemplary case on this issue is the post-modern installation shaft. Back in the modern period, installation shafts were mass produced just like the prefabricated concrete elements for the structural part of the building. However, from the 80' and onwards the shafts got increasingly complex, and contains a lot of new features. Consequently an average installation shaft consists of approx. 300 operations among 9-10 technical crafts, done on 0,6 x 0,8 m with one-sided access and impossibly working conditions. Thus, the installation shafts are illustrating the lack of ability to control the complexity of the construction process. Although everyone has a share in the design and production of the shaft, nobody takes full responsibility for the realization of the shaft.

Also the organization of the industry has undergone changes during the post-modern period through including new roles such as client advisors, new crafts, and material producers. In contrast to the modern construction, where the contractors had the contact with the professional client (the state), contractors today rarely have the first customer contact. This role is handled primarily by architects or client advisors who help the customer identify his or her individual needs. In parallel companies, providing energy efficient solutions grew in size. Today companies likes Rockwool and Velux employ more than 10.000 people worldwide.

This development put the contractors like Rasmussen & Schiøtz and Larsen & Nielsen under pressure, which resulted in a sale of their material-producing sections and acquisitions by international contracting companies such as NCC and Skanska. The consequence has been that the integrated value chain of the modern building system started to disintegrate. Thus, the construction industry today is characterized by having a fragmented value chain.

Design wise the architects freed from the modernist rationality illustrated in the post-modern architectural credo “form follows fiction”. The consequence has been a drift towards constantly exploring new architectural possibilities at the cost of closer integration with production. The more radical architecture combined with the introduction of new professions and an explosion of new technologies has made managing complexity the key challenge for the post-modern construction practices.

One of the strategies for dealing with the increasing complexity of the building system has been the adoption of information technology such as CAD and document handling systems. But also social technologies around new forms of cooperation have been used to manage the complexity through dialogue. These elements have been organized as tools and strategies for navigating in a chaotic and imperfect project and have been inscribed in a Project Management discourse differing from the inspiration in the scientific management in the modern period. The “project” became the vehicle for realizing buildings – and project management became the management principle.

After meeting the societal need to address a large unemployment and the provision of housing for the growing city's population, the construction industry gradually lost its urgent societal importance. It also meant that the effort to regulate the industry could not only focus on housing, but had to focus on the entire industry. This new focus was in particular illustrated by resource area analyzes up through the 90s. Through these analyzes, the industry was articulated as an industry which lacked behind other industries e.g. with respect to productivity. From playing a central and active role, the government loosened the regulatory intensity - except from the requirement for energy efficiency. With the public’s growing interest in sustainable solutions and political ambitions for addressing climate change the building industry is the facing a new regime shift.

The energy system

We will now turn to the attention to the evolvement of the energy system, where the wind industry have been central in the regime change towards renewable energy. We here follow two periods the Self-sufficiency energy system 1970-1999 and Renewable energy system (2000-)

Self-sufficiency energy system

Up until the 70’ies the energy systems of Denmark was relying on imported oil, gas and coal. However, this was challenged by the oil crises in 1973 – where energy prices rocketed. Thus, the politicians realized that they had to change the reliance on oil from the Middle East. This sparked initiatives for self-sufficiency initially by extracting oil and gas in the North Sea but more importantly also a continuous development of the wind resources from the late 70’ies.

The activities in the North Sea was initiated by the creation of the state owned company DONG – an abbreviation for Danish Oil and Natural Gas. Together with other international and national companies they started to develop the infrastructures for extracting, transporting and generation of electricity and heating to the Danish households.

A central premise for the development was a large degree decentralization with the establishment of decentralised powerhouses for district heating. The decentralisation of the energy system was supposed to create a more robust infrastructure as well as ensuring local ownership and acceptance of the infrastructure. This was also the case for the wind turbines.

Initially the wind turbines were deeply embedded in the Danish high school movement as well as to the Danish cooperative movement. Two exemplary turbines - the Gedser and Tvind turbine - are here illustrated in the two pictures below

Around year '83-84, village cooperatives (wind turbine guilds) spread, involving one farmer and the local community; dominated individuals and coops. The local wind projects was supported by an official requirement for residency in the near proximity of the turbines. This kept developers for entering the market until 1998 where the minister changed regulations that had secured local ownership, opening up the space for all types of developers. A further change to the support scheme in 1999 had a braking effect on the business, certainly for private individuals. However, the continuing technological development of the turbines and the increasing complexity of the regulations for obtaining approval for the wind farms themselves, led to yet another player entering the market: the 'professional' developer. As landowners and farmers realised that they no longer could manage the whole process themselves, they employ private 'professionals' to help them.

In this period, the turbines changed dramatically. Initially based on the corporative movements and later by the development of scientific and educational support for the industry. By the end of 1970s the effect of turbines was typically 22-48kW at the end of the 80'ies the turbine size was around 225-500kW – a size where local cooperatives were capable of ensuring the investment. However as the turbines grew bigger 500-850kW in the 90'ies and the risk profile of wind farm development increased (e.g. involving costly EIAs) the local cooperatives have difficulties ensuring the investment leaving projects to professional developers and large farmers.

Initially the manufactures of turbines came from the agriculture industry where there was capacity and capabilities for machines in agriculture. They started to produce other objects of metal that could be used in the wind industry. One of the example is Vestas which started out as a blacksmith and LM wind power that started out as furniture and boat maker but the 90ies made the transition to wind turbine blades. In 1986 Vestas had 60 employees and in 1990 LM Wind power employed 120 people including 4 engineers.

Besides the regulation on ownerships of the turbines the development was influenced by a wide range of policies. This included financial support for wind turbines based on a repayment of the CO2 levy. Establishment of council for Renewable Energy with budget for development of wind technology (1982). In the period from 1977-1996 the council gave 125Mio DKK to wind energy research. In 1992 and onwards regulation through feed in tariff from 1992 was established with different tariff for private and commercial suppliers. In 1999 gradual introduction of market mechanisms to calculate wind power remuneration and establish transitional schemes in relation to the current payment system. A part of this was the PSO (Public Service Obligations) tariff that taxed energy consumptions and created a revenue for subsidizing research and development of wind energy and other renewable energy sources.

These initiatives were a part of maturing the technology and industry. Thus when the government in 1996 as part of the energy action plan “Energi 21”required utilities to invest in wind power and the utilities subsequently gained access to a pool of capital as a result of the liberalisation of the electricity sector in 1999, a platform for a renewable energy system was created.

Renewable energy system

Denmark became self-sufficient with energy in 1997 and started exporting oil and gas along with wind energy from the increasing portfolio of on and off shore and wind turbines erected around the country. This enabled the evolvement of new configuration of the energy system.

As electricity utilities late 90’s-early 2000s started to enter the wind power business the number of erected turbines has increased dramatically. However, since the liberalization of the energy market in the 90’ies, there has been a continuous consolidation of utilities in Denmark. 20 years ago, there were around 150 utilities in Denmark, now there is only a third left.

One of the striking examples of this development is the company DONG. In 2005 Dong was some of the most coal intensive power utilities in Europe but by 2016 they were that company that had the highest proposition of renewable energy. Recently DONG announced that it would sell of its oil and gas business. The main driver for this development has been a major program taking out the cost of the turbine projects. Thus, they have reduced the cost of offshore wind with more than 50% from 2012 to now. The result is that offshore wind today is able to compete with conventional energy sources like oil, gas and coal. Since this process is continuing, we are facing a situation where renewable energy becomes cheaper that traditional energy sources, thus fundamentally changing the market place.

As professional developers furthermore has teamed up with infrastructural investment funds e.g. pension funds. The wind power have become big business. As an example: Today Vestas employs more than 17000 worldwide and LM Glass fibers have more than 10.000 employees and 240 engineers just in R&D.

Since 2000, the size of turbines has changed form: 1-4MW (onshore), 3-8MW (offshore). Furthermore, more than 90% of the manufactured Danish turbines are now exported. Today wind farms are turning into power plants as wind turbine technology become more intelligent for grid integration. The wind power has become a ‘critical infrastructure’. The following picture illustrates one of these infrastructures - the offshore windpark at Anholt with 111 3.6MW turbines.

The increased activities from electricity utilities from 2000 created a rush for lands and thus the prices of land in the agreements with landowner have gone up drastically. As the electricity prices at the same time plummeted creating falling profit exerting large pressure to developers and owners to leverage economy of scale. This favored large developers and now there is a central concern that only the large developers (e.g. Dong) can survive during the current uncertainty regarding the implementation of a new tendering scheme and state-support rules.

A range of policy instruments and initiatives supported the development of the renewable energy system. The overall direction was set in the Energy Agreements in 2008 and 2012. In 2008 a contract between the government and the association of municipalities for areas to be identified for a specific number of MW. At the same a Wind Turbine Task Force was established to help municipalities identify promising locations and supporting project development. In 2012 the agreement sets goal of 1800 MW new capacity on land to be installed by 2020, but no goals was set for the municipalities due to disagreements between the association of municipalities and the government. This created an uncertainty decreasing developer’s interest in onshore projects in favor of offshore projects – a strategy pursued by DONG.

The feed in tariff continued in the beginning of 2000 to be ‘25-øre’ above the market price for electricity. In order to cope with the increased number and size of turbines this changed in 2008 so the price supplement of 25 øre pr. kWh was only paid for first 22,000 full load hours. From 2014 the number of full load hours where the supplement is available, is calculated based on rotor diameter (weighted 70%) and nominal capacity (weighted 30%). This should serve as a certain 'bonus' for larger turbines.

The increasing sizes of the turbines and wind parks combined with less local ownership stimulated a growing resistance towards wind projects. In order to handle this the national plan for CO2-neutrality by 2050 (2012) required developers to openly announce information and hold public meetings regarding the compensation and co-ownership schemes, with a impartial actor (Energinet.dk) responsible for explaining the law at these meetings. However, municipalities now tend to push for promoting larger wind farms to avoid too much trouble with local people. That is, instead of developing many smaller wind farms, they prefer to deal fewer large projects, to minimize the resources they have to use.

Despite the growing resistance, the transition towards a renewable energy system is well under way. Today 45% of the electricity in the energy grid comes from wind energy with an expected raise to over 50% in 2020. Besides the obvious environmental benefits, the development has opened a new global market. The wind energy sector today employs more than 30.000 people and it accounts for over five 5% of Denmarks export.

The dramatically change of the energy system has been enabled by a long time commitment from the politicians to pursue renewable energy. This has created the "space" where the business know the overall direction of the strategy making long-term investments possible. Furthermore, subsidies and tariffs helped to establish the domestic market for the wind industry. Finally, the entrepreneurial culture among a wide range of SMEs created the space for experimentation.

RESULTS AND DISCUSSION

Throughout the analysis of the building and wind industry we have seen how the engineering systems emerges out as a response to societal changes and challenges combined with development of new technologies and regulatory initiatives. We will explore the development of the systems through the roles of the theoretical dimensions the MLP; Technology, Industry, Market /customers, Policy, Culture, Education and research.

Technology

Technology has been a core driver in the evolutions of the systems both in shaping products like concrete elements, insulation materials, wind turbines, glass fibers, and processes like prefabrication, CAD, new modes of collaboration. Common characteristic is that most of the technologies have matured through a long process involving experimentation and documentation resulting in a wide spread market acceptance. However, the technologies are also contested. Both wind turbines and concrete element is challenged by different part of the public.

Industry

Throughout the evolvement of the engineering systems, the organization of the industry and value chain was reshaped. With most of the new technologies (wind turbines & concrete elements) new players in the industry emerged (turbine producers, contractors) and old companies had to redefine their roles. The new companies were central in driving the maturation of the technology as illustrated by Rockwolls more effective insulation and LM Windpower production of increasingly larger turbine blades. However, the industrial changes not only stems from technology but also form the policies as when electricity utilities entered the wind industry due to a political requirement.

Market /customers

The existences of a market is a premise for the development of the engineering systems weather it was a market for quality housing or reliable energy supplies. However, a wide range of policy instruments carefully supported the development of the markets in both systems.

Policy

Both engineering systems are a result of political interventions at various dimensions. The market is regulated by incentive schemes and feed in tariffs. The technology through building codes and standards, and the industry through requirement for investments and different contractual forms. Furthermore, political regulations created a scientific base for the development of the systems by investing in research and education. While the analysis show that policies are one of the most powerful tools in shaping the engineering systems, both cases also illustrate challenges when the political level is uncertain about them long term direction of the engineering system.

Education and research

Education and research has played and supporting role in the development of both systems. Initially both systems was initiated by guilds and small businesses, but through investing in research and education both systems are now supported by scientific development and formalised educational programs.

Culture

Finally, culture shapes the emergence of the engineering systems. The modern building systems were situated in a modern culture characterized by optimism and faith in the future, based on the modern breakthrough in culture, science, architecture, technology, etc. In contrast, the flower-power generation requested individualized and sustainable solutions, which subsequently laid the foundation for the post-modern building systems and renewables energies like wind.

Academic contribution:

Besides the outcome of the analysis of the two engineering systems, the analysis suggests that the analytical framework of the Multi Level Perspectives (MLP) represents a promising analytical framework for understanding the evolution of specific engineering systems. However, more research is needed to explore the depth of the MLP and contributions to the engineering systems.

Practical contribution

The results show that the development of construction and wind industry have a lot in common although several differences exist.

Building and wind power development is two different engineering system but they exhibit some shared characteristics. Both engineering systems are heavily structured around project based production. When a wind park is erected, it follows some of the same processes as construction projects. The projects are realized in an interplay between clients, municipalities, locals (neighbours), consultants, developers, and supply chains all within a regulatory frame that is moving. Thereby the practices of developing the construction and wind power engineering systems are similar.

However, while they exhibit similar characteristics the maturity of the engineering systems are different. While construction experienced a systemization, institutionalization and professionalization in the 50-70'eis. This first happened during the 80 – 90'ies in the wind power sector. The shared characteristic and different levels of maturity opens several opportunities for cross industry learning both ways.

Future perspectives

Today the systems are supporting our lives in a way we take for granted, but these systems are of extremely importance for shaping our lives and the same time are we shaping theirs. As the analysis shows, no engineering system would exist without human ingenuity and labour. We have changed them and they have changed us.

This duality will continue future. We are today facing new local and global challenges that requires further development of the engineering systems within buildings and energy. Mitigation and adaptation of climate change requires radical improvements energy efficient buildings and renewable energy sources. While these systems traditional have been treated like separate entities there is a growing need for a fundamental coordination between the two systems.

The findings of the paper suggest that continuing developing the engineering systems require a focus on the dimensions: Technology, Markets, Industry, policy, Culture, and Education and Research. However, the theoretical frame and empirical material further suggests that design and management of project, programmes portfolios (MOP3) also play an important role. Projects are vehicles for change in both engineering subsystems. However, projects play a dual role on the regime and niche level. Firstly (and most important) they represent the "main" mode of production in the regime as buildings and wind parks are realized through projects. Secondly, experimental activity in the niches takes places in projects. This is e.g. shown in the development of the initial wind turbines (Tvind and Gedser). Thus, more research is need into the specific roles of MOP3.

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