Systemic Design in Energy sector: theory and case studies

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SYSTEMIC DESIGN IN ENERGY SECTOR: THEORY AND CASE STUDIES

ABSTRACT:
In the light of the growing concern about climate change, an important part of resource exploitation from industrial society is connected to energy use. Integration of companies through material and energy exchanges lead to a more efficient use of resources as well as financial, social and environmental benefits for the local entities involved, as Systemic Design approach proves.
This research analyzes seven best-practices in Sweden, which since the Eighties realizes green energy plants, to understand key-drivers and barriers. Research coordinators can facilitate the creation of self-sustaining network of companies.

KEYWORDS:
Systemic Design, Green-Energy, Zero Emissions, Local Economic Development, Multidisciplinarity

OVERVIEW

We live in an age that has achieved an extraordinary degree of sophistication in terms of products and production systems, and yet at the same time we find ourselves damaging our environment. Moreover, there is a widespread crisis currently afflicting the economic system, and the steady impoverishment of social relationships caused by exasperating goal of economic growth. Our industrial world follows a straightforward logic of gaining at the expense of social and environmental aspects: a linear industrial model characterized by cause/event phenomena, technical problems solved and spot strategies studied. [1]

The theories of Industrial Ecology and thereafter Systemic Design propose a complex industrial system, similar to web, where the material and energy flows are better used, in order to model our production and energy systems after nature. Material and energy loops are open because what is considered waste by one enterprise becomes resource to another; in that way the environmental impacts and the resource depletion decrease. Many industrial ecosystems have come naturally for better business, while others have been facilitated through external actors [2-3]. However, as these theories and ventures may be innovative and useful for industries, they are still no more than solving spot problems that arisen from environmental pressure and economical revisions. In order to provide further strength to an industrial ecosystem, broader vision and longer strategies must be design, involving new players and stimulating innovations. The theories of Systemic Design offer a scientific method to design a complex industrial system with environmental, economical and social benefits [4]. The development of industrial ecosystems leads to a multidisciplinary vision inspired by the dynamic operation of Nature.

METHODS

In order to make current industrial and energy systems more innovative and adapted to changes, Systemic Design theory should be applied [5]. The analysis of seven case studies developed in Sweden, in the field of bio-energy system, helps to review this theory and define a framework with drivers and barriers to the development of self-organizing businesses. The bio-energy sector is chosen because the access to a secure and affordable supply is crucial for socio-economic growth and poverty alleviation; and because the emissions associated with its generation and use is also central in many environmental issues. A key challenge for energy sector is that the provision needs to be achieved without unacceptable or inequitable loss of environmental quality. In that area, Sweden is one of the Countries in all World that has been taken in that and since Eighties practices innovations and experiences.

The best practices are chosen from a series of different cases as the best actually in Sweden for they complexity in solving problems not only technical, towards efficiency and sustainability, but also economical, social and environmental, further more they follow some of the Systemic Design principles. Current case studies are examined and compared each other to review the theory of Systemic Design.

The basic concept of this theory is that industrial processes should learn from natural world. The systemic approach is based on five principles that serve as guidelines of design processes and of analysis for the seven cases:

1- *Output>Input. As in nature what is not used by a system becomes a raw material for the development and survival of someone/something else, in industrial production the waste (output) of a system become an opportunity (input) for another one, creating new economic opportunities and new jobs. For example, the exhausted coffee powder resulted by the beverage production can be an excellent substrate for mushroom farming [6].*
2- *Relationship. The parties that compose the complex system are themselves the system. All over the world living systems can be found nested in other systems or as part of the community or organizations. The properties of it, whether living or not, are born from interactions and relationships between constituent parts. The study of the relationship affects not only the relationship between the system components, but also those that exist between the system and larger systems that surround it. For example in industrial model the competition disappears in behalf of cooperation, the boundaries of enterprises become more flexible and adaptable to the context.*
3- *Act locally. As an eco-system is deeply influenced and shaped by its habitat, so the same happens for any other kind of systems where it is extremely important the context that let it be "local".*
   The background enhances the resources typical of the area, not only the material ones but also the non-physical ones, as human and cultural resources. Based on these opportunities provided by the context, designers can create new systems, reducing the problems related to the adaptability of "general" solution. In fact, any systemic projects can be reproduced identically in other part of the world, because it was designed for that context and it works like it is just in its location.
4- *Autopoesis. Self-maintaining systems sustain themselves by reproducing automatically, thus allowing them to define their own paths of action, so a system is naturally led to balance and preserve itself alone. A system designed to live in a context is so strictly connected with it that will mutate together it, changing and adapting itself at new conditions.*
5- *Man at the centre of the project. The human being is inserted into the system in which it lives and activates its own relationship with the environment, the culture and the society. In this model the different activities of living and producing co-exist in balance, so every element have their essential function in the relational system benefit: no precedence over the other, but each exists thanks to all the others. The myth of "other-than-me" has been responsible for wars, the rape of the planet and all forms and expressions of human injustice [7].*

This model is inspired by the foundations of Generative Science, based on the assumption that as a result of any transformation of the resource, all by-products are designed to add generative value and subject to careful evaluation. Systemic Design (SD) provides a framework supporting the evolution of a new economy with different sets of industrial relations, where long-term sustainability and success of a network of interdependent activities are prioritize over maximizing economic growth, development or competitive advantage for individual entities [8].

CASE STUDIES

To understand the results given by the Systemic Design, in that chapter two best practises will be presented and analysed according to the guidelines explained before. The chosen best practises are divided for dimension in macro and micro systems, in the first case the projects involve an entire community or municipality, and in the second one they involve just a building or an industry (Figure 1).

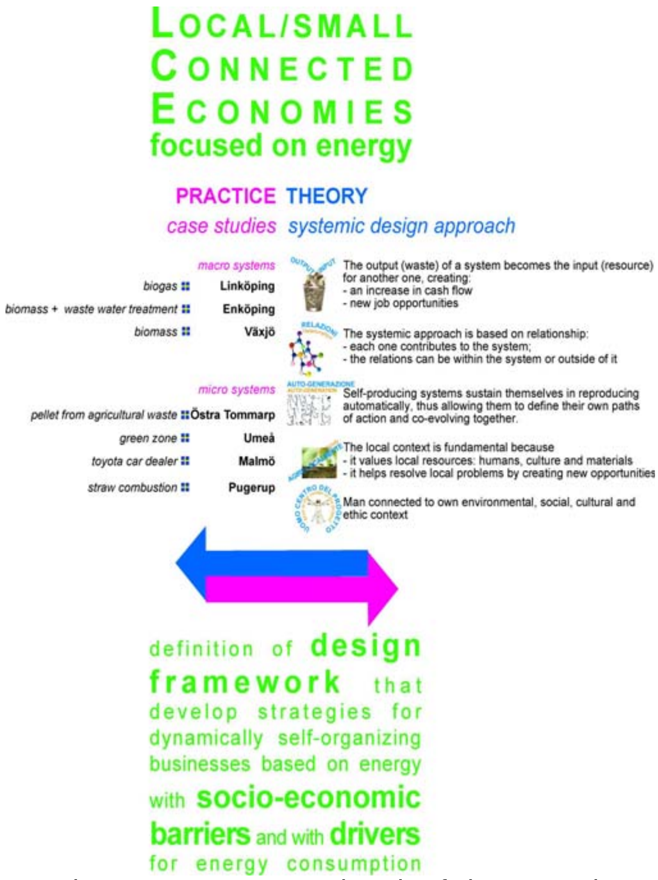

Figure 1 – Structure and goals of the research

Every best practice is analysed in according to a series of variables that include qualitative and quantitative aspects. The report gives the localization, the background and brief description, the environmental benefit, the creation of new jobs, the main actors and the main activities, the funds and financing, and the future projects related to it. For this paper just two cases are explained in details, one in the first group of macro-system and the other in the second one of micro-system, because they are enough to understand the method that conducts to review the theory and propose a framework to develop strategies for self-organizing businesses. Improvements for further innovation and future progress based on Systemic Design principles will then be produced based on the review of the cases. The goal of this research is to give a review of what could be done to better suit the industries for the future based on current best practices.

MACRO SYSTEM: LINKÖPING

In September 1989, the management of the city of Linköping, the transit authority, Tekniska Verken and KFB was taken to start up the first modern biogas project with modern equipment in the world.

In the town of Linköping, a test of biogas-powered buses began in 1991. In its first phase, 6 busses using converted diesel engines were used, but the whole initial year proved troublesome. 1992 started better and went better. Since 1997, all public transport busses (approximately 60) and some passenger cars run on biogas, and finally in November 1999 were taken the decision to re-write the contracts for bus operations and formally make the pilot. Biogas, has grown considerably since the introduction, there are now over 1200 personal vehicles, 89 biogas busses and 30 heavy vehicles in the Linköping region [9].

The objective of this project is to develop an integrated system for the transformation of difficult waste to useful biogas and to develop a public transport system with city buses fuelled with the biogas. The strategic aim is to connect city and rural areas to each other.

The cities insight in societal values by providing high quality environment was the driver of the initial project: noise and pollution has been reduced dramatically in sensitive areas during the expansion of the biogas project (Table 1).

Table 1 – environmental benefit

Greenhouse gasses	-80%
NOx	-70%
CO_2	-90%
Particulate matters	-90%
Noise	-50%
Performance in busses	-10%

Linköping were successful in providing early improvement in decision making among the staff. After that, the staffs were involved in technical and administrative development early and increasingly. Good timing, sufficient funds, dedicated staff and good portion of good nerves are some of success factors.

The basis of the region's unique expertise in biogas production is, of course, the joint biogas venture by Tekniska Verken, the City of Linköping and Östgöta Trafiken in early 1990s. A further factor underpinning the rapid development of this know-how is the close collaboration between Tekniska Verken and Linköping University. They joined forces to quickly learn what they need to know, the process was stabilised, and production could increase.

The system could not have been developed without external financial support. The lack of industrialization of the total concept made risk too big to carry the whole financial and intellectual burden by them. Attracting money also attracts willingness to contribute with know-how and intellectual capacity. If these type of installations have been more common, standardized and frequent, prices would have been low enough to provide it for lower cost at local risk [10].

The future plans aims for increased biogas production and new public refuelling station, because some of the bottlenecks are comparatively inexpensive to expand.

Biogas firms of the region tend to focus on large scale production plants located near areas of large material flows. Though more should be done to encompass small scale plants into the mix for greater expansion, material flows and coverage. In the future connecting local farms to a biogas grid may ease raw material handling costs, and allow for a larger network of biogas production.

The work of local organizations, researchers and businesses is by far not complete. Biogas research continues to expand as well. Biogas research also is beginning to become a major focus at Linköping University: recently an initiative was started to begin a Biogas Research Center composed of an interdisciplinary team of researchers digestion, methane separation, small vs. large scale developments, biogas to electricity production and biogas in the energy systems perspective.

The first guideline is always present in the selected best practices because it is the key to solve environmental problems, so also in that case there is a transformation from agricultural waste (output) to bio-fuel (input).

Furthermore, in that case study the guidelines that assumed more importance in the success of it is the relationships and the local action.

The cooperation among different partners is a strengthen point and it helps to reach common goal, because often the actors tended to have different views regarding energy, environmental or transportation related subject and had different interests concerning the fuel. The biogas, in this case, had importance for the cooperation between actors. The stakeholders have formed and executive steering committee to deal with mutual and arising issues. Each stakeholder was invited individually, starting with the one that would impact the most on other to join. This is an approach that usually brings the most difficult questions to the table up front. In the Linköping case, this was a successful approach as the critical issue as thereby was debated once and arguments formatted when coming in the next stakeholder or player.

An other important role, related to relationships, has be taken by the staff, that was so involved as decision *makers that we can define the process as co-design or share-in-design.*

Furthermore, that kind of approach helps to have a very close relation with the area. Manly staff comes from the region so they well know environmental, social, political and economical aspects of Linköping. The result is a strongly connection between rural area and the city. In relatively short time local farms can be connected with the biogas grid to reach a sort of distributed green energy production spread on the territory.

Finally, the last guideline pointed out is the autopoesis, because the area is naturally growing up in biogas knowledge and a factual event as the emergence of a new Biogas Research Centre is the demonstration of it.

MICRO SYSTEM: ÖSTRA TOMMARP

This project was carried out from 1 January 2006 to 30 November 2009 thanks to EU LIFE Environment Programme.

It was targeted towards developing and implementing an innovative method to reduce greenhouse gas output at the agricultural sector. It resulted in a complete facility for agricultural waste reduction, renewable energy supply, carbon neutral fuel production, as well as a demonstration system. The project involved the seed industry (Skånefrö AB), combustion technology industry (HOTAB) and academia (Lund Technical University).

The objectives of the Bioagro project was to successfully demonstrate an innovative technique that enables seed waste to be converted into energy in an integrated system comprising dose scales, mixer, pellet machine and heating boiler. The ash produced during the combustion to have green energy should be returned as nutrients to the agricultural fields. Carefully selected and tested additives should control the emission of sulphuric, hydrochloric acid, as well as reduce sintering of the ash. Skånefrö´s use of oil and electricity for heating can now be replaced (and only used as a backup security system in case of furnace breakdown) by heat produced out of residues from the company's own seed production operation. At the end of the project the pellet throughput is above three metric tonnes per hour. The pellets are showing the high quality characteristics of a dense structure with a smooth, hard surface for convenient feeding into storage and transport [11].

From the project finalisation, the beneficiary does not longer have to use electricity to heat the office and other buildings at the company premises. In fact the system now has district heating capacity and investigations are in hand to explore the possibility to link the Bioagro system to a new grid for providing heating to the nearby community.

The project set out to demonstrate an innovative method which is transferable to the whole European agriculture sector, constituting a breakthrough in finding an alternative to fossil energy and thus having the potential to assist substantially in reducing the discharges of greenhouse gases in Europe.

The Bioagro action consist in producing and using a high-quality pelletized fuel from grain, waste from grain, seed and grass in a small scale. The pellets will be demonstrated in small units (pelleting machine, heating boilers and burners) easily adapted to different agricultural crops, enabling quick change between different recipes with and without additives. Mixtures of additives together with seed waste will produce a homogenous, cost effective agro fuel (pellet) with low environmental impact. The system can be regarded as more sustainable in comparison with other agro fuel systems, since only non-food biomass is used.

The project implementation faced obstacles that made the process slow and difficult as for instance repeated formal complaints from neighbours delaying the planning and building permissions. Guarantee conditions imposed belatedly by the supplier of the main pellet press caused further constraints. Major technological problems in the material handling systems were faced, with equipment suppliers unable to suggest solutions applicable to the special conditions imposed by the variety of the biomass raw materials. The project management was able to overcome these challenges through a combination of persistence, positive attitude and innovativeness.

The results from the project are (table 2):

1- *Reduction of greenhouse gases*
2- *Reduction of combustible waste from grain production (with 100%) and total waste (with 95%): full utilization and capture of all seed residues from the beneficiary's production.*
3- *Eliminating costs for heating with oil and electricity (by 99%)*
4- *Ash is regained as plant nutrient (100%)*
5- *Less discharge of organic substances (with 20%), sulphur acid (86% in some measurements) and hydrochloric acid (70%) compared to existing techniques*

Table 2 – environmental benefit

Greenhouse gasses	reduction
Waste from grain production	-100%
Oil combustion	-99%
Suphur acid	-86%
Hydrochloric acid	-70%

To enable the Skånefrö's personnel to use and maintain the operation of the boilers, a partner technical company experienced in heating technology for biomass fuels (Hotab) held education sessions for the operators. These mandatory sessions were held during full-day workshops together with practical tutorials on the Bioagro boilers.

The Bioagro system strengthens regional development by generating more jobs in rural areas. The rural focus of it is also in congruence with the employment strategies within the Lisbon Strategy for Growth and Jobs, aiming towards the creation of jobs connected to rural and sustainable development.

The additional employment generated from the Bioagro system at current capacity is on average 9 *people working full time. The skill set required ranges from post-graduate engineers to high industrial experience. During the construction phase of the system some workforce as well as companies from outside Sweden has been employed. The number of staff is expected to rise as the capacity increase at the facility.*

In order to further promote the commercial development of the Bioagro concept, it was decided to form a new company: Bioagro Energy Österlen AB. It was formally established after the end of the Project, the 1st January 2010. It is a production facility that turns dry agricultural residues into a pelletized fuel and provides district heat supply to the local area. The aim is that the new company shall promote pellet production and pellet sales, as well as the use of the Bioagro development platform and its solution for countries in need of local, environmentally friendly and cost-effective fuel.

A future activity, which is at the planning stage, is to use the Bioagro pellets to produce biochar as a new "Carbon Negative" technology that transform charcoal by pyrolysis of biomass, and it differs from it in the sense that its primary use is for biosequestration. Biochar can be used as a soil amendment to affect plant growth yield (for plants that love high potash and elevate pH), improve water quality, reduce soil emissions of GHGs, reduce leaching of nutrients, reduce soil acidity and reduce irrigation and fertilizer requirements. By adding this production to the system, the whole project can actually remove greenhouse gases from the atmosphere.

In Östra Tommarp case the output taken in consideration is the huge amount of biomass generated by seed production. The agro-residues, no-food biomass, are an untapped potential all around the world, evaluated in 16 billion tons/year and 43 million only in EU-15 (source: European Biomass Industry Association). With that project this kind of waste becomes fuel (pellet) to produce heat and power.

As in the previous case, another important role is taken by local actions, generating development of a rural area and increasing job places and the relation with neighbours was a crucial point, in Bioagro project solved with many problems than in Linköping, because without their agreement the construction of a new building delayed.

An important guideline that stands out in that specific case is the man at the centre of the project, because all people involved in the project were trained and educated to conduce in the right way the boilers and manage the complexity of the system.

CONCLUSION

In the same way was analyzed the other five cases, but the result could be understandable also from these two, because the guideline that is crucial to reach in a systemic project is the transformation of output in input. If the theory and the practical actions don't start from that point, would be not possible to reduce (or avoid) the emissions into the environment and create the relationships named in the second guideline. The relations are so important that can fail the entire project.

Local actions of project and its autopoesis are strictly connected because only a system design in and for a specific context can live through fast changes.

The last guideline about the centrality of human beings in systemic project helps just to remind that social resources are valuable as the other resources (natural and economical).

In particular, in the field of renewable energy, these best practices teach how the creation of sustainable infrastructures and agile energy systems could develop a region. Green energy produced in small plants and distributed in the territory helps the success and the sustainability. Reading in the right way the environment is possible to design the right technology that produce bio-energy and that is connected with other renewable resources. Such agile system can be a new paradigm for both energy efficiency and reliability for any region or country (Figure 2).

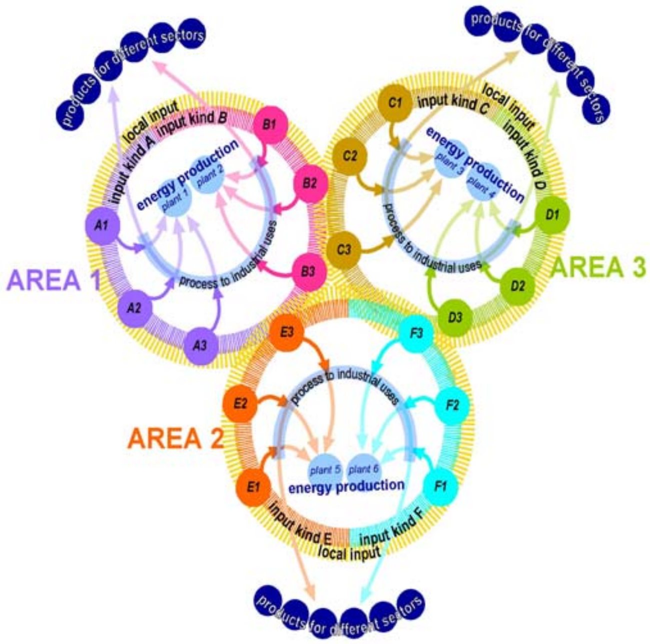

Figure 2 – Agile bioenergy systems

The lessons extracted from these cases are designed to guide the development of other production and product systems aligned with Systemic Design. Networks can bridge the gaps to sustainability and research coordinators can facilitate in the creation of conditions for a self-sustaining network committed to sustainable approaches [12].

Systemic Design generates Local Economic Development to establish the conceptual base and the analytical skills that are needed to harness local and regional economic change. Looking ahead the development of a multidisciplinary vision becomes crucial, in that way various skills are brought together, towards the emergence of a new culture of sustainable economic and technological innovation and process inspired by the dynamic operation of Nature that is the system for excellence.

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