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Production systems aligned with distributed economies: Examples from energy and biomass sectors

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Abstract

This article builds on the introduction to the concept of distributed economies (DE) by Johansson et al. [Johansson A, Kisch P, Mirata M. Distributed economies – a new engine for innovation. Journal of Cleaner Production, this issue] and takes the discussion further by reviewing examples of production systems that, due to certain characteristics, can be seen as illustrative DE elements. Through selected cases from *energy production* and *biomass products* sectors, the environmental and business benefits provided by local, small-scale, flexible production units that increase value addition to local assets are exemplified. The factors supporting the development of such systems are also reviewed. The lessons extracted from these cases are designed to guide the development of other production and product systems aligned with DE.

Keywords: Distributed economies; Localised production systems; Small-scale production systems; Regional development; Sustainable development

1. Introduction

This article continues the discussion initiated in Johansson et al. [1], where the idea of distributed economies is presented. We are not aware of the existence of any industrial regional system, which in terms of its overall functioning, can be described as an operational example of DE. However, in this paper we take the concept of DE a step further through a discussion of certain aspects surrounding selected production systems including operational as well as projected ones. The systems we include do not represent distributed economies themselves. However, due to having characteristics aligned with those formulated by Johansson et al. and those we present in subsequent, they are deemed as illustrative elements that can be part of distributed economies. Besides elaborating on the operational attributes that make them desirable for improved sustainability, we also provide a closer look at the enabling factors for the evolution of such distributed systems as commercially viable units. Our overriding goal is to contribute to the transition towards more sustainable economic activities by extracting lessons from cases that can guide the evolution and spread of alternative production systems.

In the following section, we target the readers who are not familiar with the work by Johansson et al., also included in this issue, and provide a brief overview of the DE concept and highlight the elements relevant to our discussion. We then introduce the methodology that guides the development of our cases and analysis, before introducing our cases from the energy provision and biomass products sectors. The analysis section elaborates on the specific characteristics of these cases in regards to their contribution to sustainability and the development of distributed economies. The factors that support their development and sustained operation are

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also reviewed. In our conclusions we emphasise the importance of identifying and studying additional systems that exhibit characteristics aligned with DE as the knowledge such exercises generate will be valuable to catalyse developments towards DE.

2. Distributed economies for improved sustainability

In Johansson et al. [1], the problems associated with sustainability and sustainable development are discussed with particular emphasis on the issues surrounding large versus small-scale production units. Mainstream economic and business management models have been very successful in catalysing industrial growth and economically efficient production systems. On the other hand, growth that is dominantly driven by the sole rule of "production efficiency" often results in the increasing organisation of industrial activities in the form of centralised, large-scale production units. These units, mostly under the ownership of big and powerful corporations, have increasingly uniform product outputs that are mostly traded in global markets. However, the dominance of such centralised, large-scale production units bring along dynamics that undermine sustainability. Examples of such dynamics include:

- Increasing throughput of non-renewable material and energy resources to the economy and increasing waste generation;
- Increasing the movement of raw materials and products over larger distances, mainly relying on decreasing transportation costs;
- Distancing production from consumers and thereby hiding the environmental and social costs [2];
- Weakening the local actors' possibilities to have ownership and control over their immediate economic environment;
- Distorting or destroying cultural identities; and
- Limiting the diversity in regional economic activities [3–6].

In addition to such environmental and socio-economic drawbacks, Johansson et al. caution that the inflexible nature of large-scale, centralised production units limit their ability to respond to rapidly changing demands and thus, threaten their business viability [1]. All of these motivate the need for alternative forms of organising economic activities driven by a different set of values and priorities if a more sustainable state is to be reached. As one alternative, the authors introduce the idea of creating distributed economies (DE) through downsizing a selective share of production activities and distributing them to the regions in the form of small-scale, flexible, and synergistically inter-connected production units, thereby establishing a renewed balance between these and large-scale production units.

These authors further state that *social well-being* and *quality of life* should be the main values guiding the development of DE during which priority should be given to *good environmental performance* and *local peoples' preferences* regarding how they want to live [1].

One of the challenges facing the DE concept is to demonstrate that more desirable environmental and social outcomes may prevail through decentralisation and downsizing of selected production–consumption systems and finding a renewed balance between these and scale economies. Equally important is the challenge to demonstrate that such transformations can also provide adequate economic and business benefits at the right juncture.

3. Methodology

As stated, the purpose of this paper is to review selected production systems that can be compatible with the elements of DE and to extract useful lessons that can assist the development towards DE. The ability to do this requires criteria that can guide the selection of cases and, to a certain extent, their analysis. Here, we can find guidance from the 'fundamental areas of concern' as catalogued by Johansson et al. [1] intended to guide the developments of DE. However, these 'areas of concern' address a wide spectrum of aspects relevant to regional economies and in totality are too broad for the scope of this work, which dominantly focuses on production systems. Thus, we developed our guiding criteria through distilling several operational and organisational characteristics implied by Johansson et al. and by synthesizing them with those that Mirata et al. [7] proposed to guide the development of more sustainable regional production systems. Consequently, in our selection of cases, we selected locally and regionally focused small-scale production systems that satisfy any combination of the following:

- Increasing the share of *renewable resources* in economic activities;
- Increasing *wealth creation* for a larger number of people;
- Decreasing *pollutant emissions* and *waste generation* at the local/regional level;
- Increasing the *sustainable use of local resources* in economic activities;
- Increasing the *value addition to local resources*;
- Increasing the share of *added value benefits retained* in the regions;
- Increasing the share of *non-material* (e.g. information, know-how) and *higher added value material resources* in the cross-boundary resource flows;

- Increasing the *diversity and flexibility of economic activities*;
- Increasing the *diversity and intensity of communication and collaboration* among regional activities;

In our analysis, we focused our attention on the environmental, socio-economic and business related implications of these cases and highlighted the factors that assist their development and functioning.

The information used in the development of our cases is collected through a combination of, direct observations, face-to-face and telephone interviews with relevant regional actors and review of the relevant literature. These activities were performed:

- Directly by ourselves, as part of our doctoral research activities focusing on regional sustainable development at the 'International Institute for Industrial Environmental Economics, (IIIEE) of Lund University;
- By the IIIEE's master's students we supervised between 2002 and 2004 in their research for the fulfilment of the requirements of 'Applied Research in Preventative Environmental Approaches I and II' and 'Strategic Environmental Development' courses of 'Environmental Management and the Policy Masters' programme.

4. Cases of distributed systems of production and consumption

In the following sections, we provide brief accounts of selected *production systems* that satisfy any combinations of the criteria that we have outlined in the previous section and are therefore, considered compatible with DEs. Although they have elements extending to the wider region, our cases from bio-energy and biomass products have more of a local orientation. However, because such local elements form the building blocks through their inter-connections to enable a transition towards DE, they remain valid for our discussion, as well. Besides highlighting their desirable characteristics we also provide a closer look on the enabling factors for such distributed systems to evolve as commercially viable units.

4.1. Provision of biomass based district heating and electricity in Nordic countries

Apart from being one of the leading Nordic industrial clusters focussed upon export markets, the bio-energy sector, particularly in Sweden and Finland, has demonstrated its potential to boost local development. Through their employment of decentralised energy solutions at the municipal level and utilising locally and regionally available materials, these systems enable increased value addition to local resources and have reduced the regional dependency on fossil-fuels.

4.2. Co-combustion of gasified biomass and source separated waste in Lahti, Finland[1]

Developments from the Finnish city of Lahti help us to demonstrate the benefits associated with value addition to local and regional resources, in this case, mostly embedded in biomass and source separated waste streams. It also helps to highlight how such value addition is enabled through a synergistic linkage between a small-scale innovative technology and a large-scale conventional one.

Being one of the largest combined heat and power (CHP) units in Finland, the Kymijärvi power plant owned by Lahti Energia Oy produces more than 70% of the electricity and more than 90% of the heating needs of the city of Lahti, which has approximately 100,000 inhabitants. The plant was put into operation in 1976 and was modified in 1982 to switch from heavy fuel oil to pulverised coal – a decision motivated by the 1982 oil crisis. A gas turbine was installed in this plant in 1986 and was connected to a heat exchanger to preheat the boiler feed water. The measures employed by the plant to control SO_x and NO_x emissions are the use of low sulphur containing coal (only 0.3–0.4% sulphur) and the use of burners provided with flue gas circulation and staged combustion, respectively.

However, our prime focus in this case is on the gasifier unit that was installed and connected to the main boiler in 1997. This unit converts regionally sourced biomass, and source separated industrial and municipal solid waste into a fuel of low calorific value that is co-combusted with coal in the main boiler.

Energy recovery from locally available biomass – i.e. bio-fuels and organic fraction of industrial and domestic waste streams – is a desirable development, because: (a) it provides a means of reducing emissions (politically most important, those of CO_2) linked to energy production [8], and (b) it offers a preferable option over landfilling in managing certain fractions of separated waste streams. However, because the availability of such biomass is limited within regions and its transportation over long distances is not feasible (due to their low energy density), plants which can perform such conversions are generally smaller than fossil-fuel fired units. Moreover, due to their smaller size, these plants require

[1] The information given in this section was collected as part of a research project titled "Biomass energy systems and local economies – towards widespread adoption of decentralised production and consumption systems" sponsored by Finish Ministry of Environment and conducted by IIIEE.

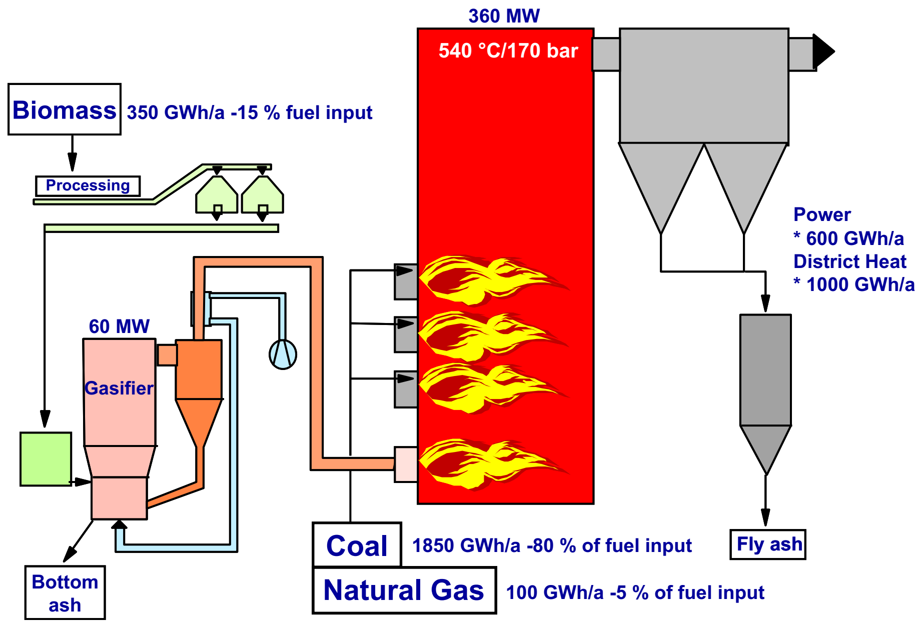

Fig. 1. Simplified process diagramme of power and heat production in Kymijärvi power plant in Lahti, Finland [8].

much higher specific investment and operation costs and have lower power production efficiencies compared to larger plants run on fossil-fuels. Nevertheless, the economic and technical feasibility of power production from such materials is enhanced if they can be used in existing medium- to large-scale fossil-fuel fired units. [8] This is enabled in Lahti through integrating a gasifier with a larger pulverised coal boiler, where the biomass and other waste derived materials are gasified in the former and used as supplementary fuel in the latter. The arrangement in Kymijärvi power plant is illustrated in Fig. 1.

In this case the decision to realise this transformation was motivated by the fact that it simultaneously offered environmental and economic benefits. This transformation reduced the plant's imported coal needs and reduced the emissions associated with its operations. This diversification of fuel base also provides flexibility to the plant and enhances its economic stability. On the other hand, revalorisation of resources embedded in waste streams with this scheme provides benefits for other local actors including industries, waste management functions and inhabitants.

There are plans in Lahti to build two new gasifiers equipped with a gas cleaning system. The cleaned products of the gasifiers will be combusted in a new 160 MW steam boiler that will feed a new steam turbine. If realised, this system will produce 45 MW of electricity and 90 MW of district heating through the increased use of locally and regionally available biomass and waste derived fuel. Furthermore, it will allow for further reductions in the amounts of coal combusted and pollutants emitted.

4.3. Biomass based energy system in Enköping with dedicated Salix plantations[2]

Our case from Enköping helps us to demonstrate the benefits linked to developing local capacity for increased local production of a renewable resource that fuels another local production unit. It also exemplifies some of the benefits provided through synergistic interconnections among different activities.

Enköping is a small town with 38,000 inhabitants and is located in central Sweden. Here, a biomass fuelled CHP plant was commissioned in 1994 and an oil-fired boiler was converted to be run on wood dust. Owned by Ena Kraft AB, these systems have the capacity to produce 45 MW of heat, which satisfies Enköping's entire district heating needs and also produces 24 MW of electricity, which is sold to the national grid. Since 1997, the energy production in Enköping has been based solely on bio-fuels.

However, the region does not provide forest residues in sufficient quantities and is therefore, a net importer of bio-fuels. Given the increasing demand for bio-fuels this external dependence was regarded as risky by Ena Kraft AB, and motivated them to look at the possibilities of increasing the local short rotation forestry. Today, Salix trees grown on 1200 ha of land by *local* farmers provide this plant with the possibility of substituting part of their imported fuels by locally produced ones. This

[2] This section is based on the information collected by IIIEE researchers and master's students as part of the "Applied Research in Preventative Environmental Approaches" exercise in the spring of 2004.

alternative and reliable fuel source provides increased flexibility and the foundation for enhanced economic stability.

As part of another relevant development in Enköping, since 2000, about 73 ha of Salix plantations adjacent to the town's wastewater treatment plant are irrigated by treated wastewater pumped through a 33 km long drip irrigation system. Besides reducing the nitrogen loading in the nearby river, this arrangement also accelerates the growth of the Salix trees and reduces their harvesting time from 4 to 3 years. Moreover, wastewater treatment sludge and bottom ash are also spread on the Salix plantations as fertilizers (further coverage of this case can be found in Ref. [9] included in this issue).

4.4. Community owned windmill parks in Nova Scotia, Canada[3]

Our case from Nova Scotia exemplifies a mechanism through which local investment, and thus, ownership, in a regional renewable energy development is stimulated.

During the past few decades, Nova Scotia's traditional economic cornerstones of coal mining and fishing have both experienced dramatic downturns and the economy has been underdeveloped for most of the second half of the 20th century. Recently, the province has experienced an economic recovery, with the development of a strong tourism sector and significant capital investment in an emerging offshore oil and gas industry. Nonetheless, Nova Scotia remains a net receiver of equalization funds within the Canadian confederation.

With the initiative of the regional development agency, windmill development projects were recently initiated in the region, coordinated by Renewable Energy Services Ltd. (RESL). The objective of RESL is to develop the capacity to generate 150 MW of electricity through the Scotian WindFields over 3 years: 25 MW in 2004/2005, 50 MW in 2005/2006 and 75 MW in 2006/2007 [10]. As part of this project, the first turbines will be commissioned in February of 2005.

The name Scotian WindFields refers to a group of 9 funds operating within defined regions in the province of Nova Scotia. These 9 funds share similar operating characteristics and a brand identity. Each of the WindField funds is a separate legal entity with its own investors and board of directors that make decisions regarding the energy generation assets in which it invests. The Scotian WindFields are analogous to traditional co-operatives, in that they are rooted in the local communities where they are located [10].

The 9 companies are financed through an innovative financial mechanism established by the government of Nova Scotia called Community Economic Development Investment Fund (CEDIF). Introduced in 1993, the CEDIF is a pool of capital formed through the sale of shares or units to persons from within a defined community [11]. It was designed to assist Nova Scotia's small businesses, co-operatives and community economic development initiatives in obtaining equity financing by offering a personal income tax credit to individuals investing in eligible businesses [12]. Investors receive a 30% Nova Scotia provincial tax credit and their investment automatically qualifies for inclusion in a self-directed Registered Retirement Savings Plan (RRSP). If used as a Retirement Savings Plan, contributions to the investment will also generate the federal RRSP tax credit offsetting federal taxes payable, at the marginal rate. Outside the Halifax urban area, the Province of Nova Scotia guarantees 20% of the investment against loss for the first 4 years [13]. The maximum annual investment for individuals is 50,000 Canadian dollars (~31,000 Euro), which yields a maximum annual tax credit of 15,000 Canadian dollars (~9000 Euro) [12]. Although there are no official limitations on who can invest in the companies, there are limitations on who can accrue the benefits; making Nova Scotia residents principal beneficiaries of the tax credits. Thus, there is a strong implicit bias toward local investors. Thus far, most of the funds raised have come from investors in the region where the project is located. This is expected to be the case for all of the funds [10].

4.5. Wood pellet production in Vansbro, Sweden[4]

This case from Vansbro demonstrates how enhanced utilisation of biomass resources can help the sustainability of a local community.

Vansbro has approximately 7500 inhabitants and is located in the mid-west of Sweden. There has been a net decrease in population in the area, coupled with increasing unemployment. Moreover, existing employment is highly dependent on the public sector and on a small number of relatively large companies that tend to invest in improved technology rather than in people. Local businesses feel the competitive pressures and are increasingly trying to produce more with less labour input. Nine out of the 10 sawmills in the region went out of business in the last decade, as they could no longer compete with the larger sawmills. On the other hand, currently available jobs are characterised as having inadequate attraction to keep people in the region.

[3] The background research leading to the development of this case was conducted in 2002 by Chad Park as part of his fulfilment of the requirements of Applied Research on Preventative Approaches for Environment course at the IIIEE.

[4] The information used in this section was gathered as part of the Strategic Environmental Development exercise conducted by IIIEE researchers and master's students in April 2004.

More external and consolidated ownership of businesses is also increasing. This undermines the autonomy of the Vansbro area and has adverse impacts on the social environment. For example, high levels of social support that used to be provided by one of area's major companies while under local ownership, has practically ceased, following its takeover by a multinational company in 1999.

The area has an abundance of high quality forests. However, so far only a small fraction of benefits that can be realised with the use of this important resource is retained in the region. This is closely linked to the fact that the majority of forest products are traded with a limited number of large actors outside the region. More specifically: firstly, the forest owners receive lower prices for their products because the region is regarded as being too far from the major pulp and paper plants, giving rise to higher transportation costs. Secondly, they have little power to negotiate better prices since the parties they can trade with are too few in number. Furthermore, there is room for improving the way the forests are managed, thereby increasing their productivity. Regular thinning activities that can lead to long-term economic gains are an example of this. Thinning has been neglected in the past few decades as they fail to deliver profits in the short run to private owners.

Besides its forestry resources, the region has certain social strengths, such as the existence of a tightly knit social net with open communication among local people. There are also numerous forward looking and innovative ideas in the community that can provide significant benefits to the region if supported and implemented. Nonetheless, these strengths are not effectively utilised.

A recent development in Vansbro, where a long standing idea fostered by a collection of *local* parties was finally turned into a real project, offers a good potential to turn some of these negative trends around. This project involves the start up of a company to produce 50,000 t/y of wood pellets. Wood pellets are an important product for which there is increasing demand in national and international markets. Conventionally, sawdust is the preferred raw material for pellet production. The supply of sawdust is likely to remain more or less constant, however, there is increasing demand for this material from various sectors (such as wood board manufacturing, district heating, etc.). Nevertheless, in this project the production of pellets mainly relies on the use of tree tops and other locally and regionally available biomass resources, including local forest thinning residues and regionally available wood waste. Moreover, the hot condensate, a by-product of pellet production, will be used in a wet condensate turbine to generate around 6.8 GWh/y of electricity [14]. The plant will also be integrated with the local district heating system so that the hot condensate from pellet production will be used as a heat source for local residents. To a lesser extent local and regional ones and dominantly national and international markets are being targeted as buyers of the pellets.

Currently, 9 private persons from the region hold the ownership of the project. Once the plant is operational and the uncertainty about its operation is reduced, up to 20% of its shares will be offered to the local forest owners.

5. Analysis

The cases presented provide examples of production systems that exhibit some of the characteristics fostered by the DE concept. They reveal important information both in terms of their contribution to improved regional sustainability and in terms of the conditions supporting, or at times hindering, their development. These are further elaborated in the following paragraphs.

Firstly, the cases from Lahti and Enköping demonstrate how significant efficiency gains can be realised through the use of CHP units (these units can achieve up to 90% conversion efficiencies), as opposed to conventional condensed cycle units that can usually convert only 30–40% of the energy contained in fuels to electricity. These cases also demonstrate how increased value addition to local resources can take place while simultaneously satisfying local needs by substituting locally available resources for those imported from outside the region. These developments reduce key regional activities' dependence on external resources and thereby, reduce their vulnerability to negative external changes. On the other hand, from a business perspective, the flexibility gained through access to a diversified fuel base provides the power plants with increased economic stability. However, a vital element of both of these cases is linked to their economic success. That is, these plants offer competitively priced heat and electricity to consumers and retain sufficient profit margins to invest in further research and development. Moreover, through partially sourcing their fuels from various regional activities, they provide economic benefits to other regional activities.

The gasification unit integrated to a pulverised coal fired boiler in Lahti currently enables a total of around 100,000 t/y of biomass and source separated waste to be utilised for power and heat generation. Besides diversifying the fuel base, this development enables the plant to reduce its annual imported coal consumption from 320,000 t to 270,000 t (a reduction of 15%). This is coupled with a 10% reduction in the plant's CO_2 and SO_x emissions and between 5 and 10% reduction in NO_x emissions. Moreover, this setting provides the power plant with a competitively priced fuel source as producing 1 MJ of output through the use of biomass and waste derived fuel is around 50% cheaper than producing the same output with coal. This is mostly due to Finnish taxes on energy produced by fossil-fuels and subsidies provided for certain kinds of wood based bio-fuels [15].

Through the developments in Lahti, value is added to various local and regional waste streams, providing benefits distributed to a wider range of parties. Local businesses benefit due to reduced waste management costs and in certain cases through the revenues generated by their waste streams. The municipal waste management company has an economically feasible and environmentally preferable way of dealing with waste. All these elements provide the local residents with a cleaner environment and competitively priced heat, electricity and waste management services. Through the installation of new gasification and CHP units, the use of an additional 250,000 t/y of biomass and fuel from source separated waste is planned. If realised, this development will multiply the above stated benefits.

Another important element of Lahti case is that it demonstrates the effects of two of the important design factors (emphasized by Johannson et al. [1]) for DE principles concurrently. That is, a *renewed balance between small and large-scale* is being established, and this is enabled through synergistically connecting small and large-scale operations. It is important to note that proper functioning of gasification units are highly dependent on the quality of inputs. In Finland, this important issue is successfully dealt with through the introduction of standards for waste derived fuels. It is also important to note that proper operation of the system is an outcome of the collective fulfilment of individual responsibilities.

The case in Enköping is unique with its element of facilitating the generation of an economically important resource locally. The use of approximately 120,000 t/y of locally produced Salix today constitutes 15–20% of the fuel used by Ena Kraft, thereby reducing their biomass imports from other regions. This dynamic primarily helps with the economic stability of both the power plant and the farmers. Although it currently does not provide the power plant with direct financial gains, local farmers earn additional income. It is estimated that additional employment, up to an equivalent of 20 full time jobs, is created with such dynamics. The company has plans to further increase the share of locally produced Salix by, possibly, up to 30% [16].

In addition, the recent synergistic connections between the wastewater treatment plant, the power plant, and the Salix plantations, the following benefits are realised. By using 320,000 m^3/y of treated wastewater that is rich in nitrogen content for irrigation purposes the amount of nitrogen discharged to the receiving river decreases from 130 t/y to 48 t/y [17]. Irrigation also enables the reduction of time between Salix harvests from 4 to 3 years. On the other hand, the use of wastewater treatment sludge and bottom ash as fertilizers on the Salix plantations provides an economically feasible and environmentally preferable way of dealing with wastes generated by the wastewater treatment facilities and the power plant. In the case of the wastewater treatment plant, this routine helps to divert all of the 1700 t/y of digested wastewater sludge from the landfill [17]. Another important characteristic of the developments in Enköping is that through the increased Salix plantation, value will be added to one of the area's underutilized resources – namely the "land". In other words, around 200 ha of currently unutilized land will be turned into Salix plantations and thus, will become productive. While the landowners will benefit through renting their land, growing their own Salix will provide the power plant with economic gains. Similar to the case in Lahti, the benefits provided by renewed dynamics in Enköping are, and will be, shared by a wide range of local parties, including the community.

It is notable that the developments in Enköping were strongly influenced by the solid commitments of visionary local decision makers. Running the local energy system based on 100% bio-energy was one of many goals of the local administration which have other on-going projects to make the region more sustainable. Moreover, the power plant has been, and still is, supporting the Salix plantations in various ways, without realising any direct financial returns. Such support is provided in the form of providing the farmers with long-term demand guarantees at attractive prices, and by spreading soil enhancers (i.e. bottom ash) on the plantations free of charge.

It is also important to acknowledge that developments in Lahti and Enköping cases have been strongly supported by national policy elements. Since the early 1990s, both Finland and Sweden have been promoting the development of bio-energy based energy systems, as a proactive measure for energy security triggered by the oil crises in the 1980s. The intensive R&D in the field of bio-energy in this period has indirectly contributed to both systems. Moreover, as part of their strategies the governments in both cases also provided direct financial support for the development of these systems (3 million Euro out of the total investment of 12 million Euro in the case of Lahti, and 4000 SEK (450 Euro) per kW capacity to power plant and 5000 SEK (560 Euro) per hectare for Salix plantations were provided to Enköping). Additional support for these plants' financial viability is provided by the fact that bio-fuels (or power produced by bio-fuels) are exempted from taxes that apply to fossil-fuels, and in some cases they even receive additional subsidies. These fiscal elements significantly support the economic viability of bio-energy implementations in these countries (more information on relevant Swedish energy policies can be found in Ref. [9] included in this issue).

Besides partially compensating regional electricity demands with a renewable and clean source, the main essence of the wind farms in the Province of Nova Scotia, in Canada, lies in their innovative financing mechanism. The fund and ownership schemes outlined in this study offer an attractive solution to the crucial issue of financing the diffusion of technologies allowing the emergence of distributed systems. The Scotian WindFields project demonstrates the feasibility of such a concept on a regional level and sets an important role model, particularly for areas where the possibilities for local investments have been under-utilised. With these schemes, not only is a mechanism provided where initiatives with dominantly regional benefits are financed locally, but also almost all the benefits provided by these systems are retained in the local communities.

On the other hand, the case from Vansbro demonstrates how adding more value to local resources through new, local initiatives can support regional sustainability. In this case, this is to be done by turning around 150,000 m^3 ($\sim$112,000 t of dry wood) of currently under-utilised forest resources and waste construction wood into wood pellets for which there is a growing market. This initiative has several important dimensions. Firstly, it will increase the capital flow to the region and create more income. Around 50 million SEK ($\sim$5.6 million Euro) investment will be made into the region and the pellet production is projected to have between 50 and 60 million SEK (5.6–6.7 million Euro) turnover per year. This is likely to pave the road for further developments. Linked to this project, creation of between 25 and 30 new jobs (10–15 jobs in forestry and 10 in the pellet plant) is also expected [14]. With this project the forest owners will be paid for the top 5% of the trees and for the forest residues, for which the conventional buyers do not offer anything. As the forest owners sell their trees as a whole rather than selling different fractions to different customers, this will increase their negotiation power with other conventional buyers who are mostly interested in timber and pulp wood. Also, linked to this is the possibility of the local pellet company buying the whole trees, parts of which can then be used locally to provide other added value timber based products. These developments will also provide incentives for the forest owners to better maintain their forests and thereby improve productivity, as the thinnings can also be sold for pellet production.

Moreover, these benefits are likely to be sustained because the projected development has operational characteristics that will enforce its long-term economic and technical viability. As the supply of sawdust is at its limits but the demand for it is increasing, its price is estimated to increase in the near future. Therefore, the use of locally sourced alternative materials in this project is likely to provide competitive advantages in the future. Another strength of the operation is connected to the use of by-product condensate from pellet production. Instead of being wasted, the condensate will be used for electricity production (around 6.8 GWh/y) and for district heating thereby generating additional revenues. This will also provide the needed capacity expansion for district heating system at a lower cost and provide the system with extended flexibility and financial gains. Furthermore, the project has the novelty feature of using roundwood and green biomass in pellet production. If successful, the knowledge gained with this innovative initiative is likely to constitute an asset that can be traded in external markets for economic returns. Last but not least, the plant can enjoy close to optimum organisational conditions for its successful operation if the local parties who can influence this success, are provided with incentives to do so. Provision of such incentives is already planned and will take place through offering the forest owners the opportunity to own shares of the company that will produce the pellets.

Another important and positive aspect of the case in Vansbro is linked to the ownership structure of the company that will produce the pellets. Regional parties who are engaged in various regional economic activities dominantly own this company. Therefore, with this ownership structure, the economic returns of pellet production are more likely to be retained in the region and be used for further development. On a different account, the orientation of this project towards higher value addition also increases the possibility to create high skill jobs, which in turn may provide more diverse and attractive employment options and encourage education. Collaboration within and among companies as well as with public institutions is also important for the desired developments to take place and for them to remain viable.

Here, we underline the fact that increased value addition is at least as important for private companies as it is for the region, as a whole. Vansbro region's only surviving saw mill constitutes a living example of this importance. This company continues to maintain its economic viability owing mostly to its recent initiative where customised or further processed (e.g. painted) products, rather than solely sawn timber, is offered in their product range.

As indicated earlier, the successful realisation of such a project relies heavily on cooperation among regional parties, including the forest owners, pellet production, the district heating system and the logistical operations. Although, there is open communication among regional parties, the intensity of communication and level of cooperation is still remarkably low. However, this situation can be changed and the collaboration among regional parties can be improved if a body such as the local municipality assumes coordination roles. This will be a valuable exercise because, even by only focusing on the biomass resources of the region, the gains that can be achieved through improved integration and co-operation can go beyond those associated with pellets production. Ideas already exist in the region regarding such possible developments. The development scenario envisioned by one of region's entrepreneurial individuals constitutes one example of this. This scenario includes the development of a diverse range of activities and their synergistic interconnection with each other, as depicted in Fig. 2. At this stage, such a scenario remains to be qualitative. However, it demands scrutiny and further quantitative assessments as its realisation may bring along additional environmental, economic and social benefits.

6. Discussion

The examples reviewed in the previous sections illustrate common characteristics and some important success factors for production and consumption systems that could be elements of distributed economies. In the subsequent sections we draw attention to some of their attributes that play important roles in enabling the successful development and functioning of the cases reviewed here. These are important as the evolution of DE requires acquiring similar characteristics in a wider context, i.e. collectively, in as many of the production systems building up a regional economy as desirable. Therefore, they should be included among the factors taken into consideration in fostering the development of similar systems in other regions or sectors. In other words, the knowledge provided by examples, such as those presented here, should contribute to the knowledge base needed to systematically assist the development of systems aligned with DE.

6.1. Flexibility

The majority of our examples illustrate the benefits provided by their flexibility. The dominantly bio-fuelled CHP plants and the pellet production from unconventional raw materials have, for example, higher levels of flexibility regarding their inputs, which contributes to their economic stability. The flexibility of these systems is one of the important leverage points for small producers to gain a competitive advantage.

6.2. Local commitment and collaboration

Our examples highlight that successful developments aligned with the DE principles are tightly linked to the ideals and commitments of the people and institutions living and functioning in regions (see also Ref. [9] in this issue). As local development concerns a large number of stakeholders, it is crucial to develop a common understanding regarding targeted dynamics, develop

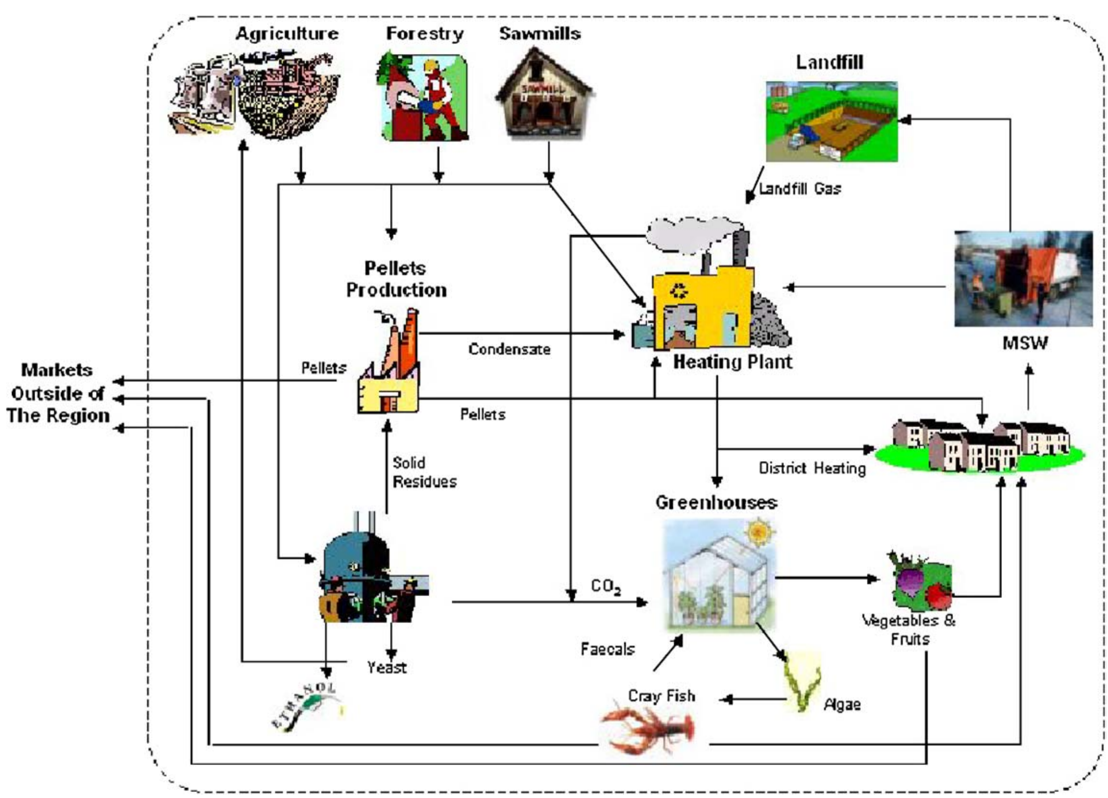

Fig. 2. A possible scenario for future economic activities in Vansbro (redrawn after) [18].

shared objectives and goals, and assure commitment among regional parties. Given its importance, this element needs to be systematically addressed. Creating an inventory of local needs and capacities constitutes a promising first step, as the heart of the DE is the ability to make the best use of a region's assets and the ability to deploy them for the satisfaction of local needs. The development of effective communication platforms where local ideas can be shared, common objectives can be created and collective action can be supported is also of prime importance.

6.3. Economic gains

Although the systems aligned with DE differ from the systems motivated by traditional scale economies in many aspects, they share the element of "economic profit" as an important driver for their development. Thus, it is important to underline that all the examples cited are coupled with adequate economic profits. Going beyond sole profit generation, the cases on biomass based energy production exhibit an improvement in their economic performance as compared to traditional fossil based fuels (mostly thanks to fiscal policies). With the anticipated increase in sawdust prices, the economic attractiveness of pellet production relying on local resources is also likely to increase.

6.4. Local ownership

In many of the reviewed cases, the local ownership constitutes an important factor, assisting both the improved sustainability profile of the systems and their successful operation. This is partly due to the fact that under local ownership, the provision of benefits to other local and regional parties is given more weight than what would be allowed under traditional economic considerations. Conversely, another aspect is related to the fact that under local ownership, the returns tend to be re-invested for the regions' benefit.

There are drivers for regional sustainable development and these call for a multi-disciplinary approach for devising and implementing effective strategies. Among these drivers, it is the social and environmental ones that deserve particular attention. This is because they tend to be underrated in real-life decisions where economic considerations dominate to the detriment of small-scale developments. However, through technology innovation and diffusion, the economic outlook can be turned around as exemplified in some of our cases. Although most of the examples reviewed provide sufficient economic returns, it should be noted that in other cases, or sectors, the benefits of locally produced goods and services could be linked to other values. The notion of *higher quality of local products* as compared to centrally provided goods and services is one that deserves particular attention. Acceptance and valuation of this quality aspect by the customers and the consumer community can both become a source for price premiums and provide loyal customers. Among other things, appreciation of the quality aspects of products and services provided by a DE is important for helping to offset the impacts of decreased economic transactions across regional boundaries due to the increased localisation of the material flows. However, it is among DE's main objectives to boost the local economies through the combination of both increased intra-regional transactions and increasing the share of higher value added products in exports and imports.

It is not only the economics that are influenced by technological development, as significant changes in enterprises' operational environments are also facilitated through new technologies. In some sectors, for example, economies of scale are no longer pursued for the "material flows handling" related benefits but instead focus on design, technology provision, and knowledge dissemination. This transition provides opportunities for innovative developments at the local level in the form of new local business solutions, technical systems, and ownership structures. The speed and direction of such transitions can vary among sectors. For instance, in the traditionally slowly changing energy sector, where the focus has been on centralised production and distribution systems, significant shares of new installations are small-scale or decentralised. If spread and sustained, this trend may lead to considerable system changes over the next few decades. Recent experience has illustrated that this kind of transition is more rapid in the information and communications technologies (ICT) sector, and in sectors that are better positioned to take advantage of ICT developments, such as the printing industry, and the "textiles and garments" industry.

Decentralised technical solutions constitute a central theme in distributed economies. This is dominantly motivated by the fact that currently the systems in pursuit of scale economies are likely to have developed further than what would be optimal. Thus, a search for finding a better balance naturally places the primary focus on more decentralised solutions. However, the decisions that support a more sustainable economic activity require finding an optimal solution after taking the economic, social, and environmental aspects into consideration. Therefore, required technological advancements need to have strong, or at least adequate, economic, environmental and social performance profiles as well as being able to allow economic activities to take place on a small-scale.

The important question regarding *how to foster a development towards distributed economies* still remains to be addressed. As noted above, the promotion of technological developments and the diffusion of system solutions aimed for the local scale and markets have a considerable role to play in achieving this. As discussed earlier, policy elements that support necessary research and development and that employ fiscal instruments in the form of tax relief or investment subsidies, are likely to play key roles. In particular, those that steer the economic activities towards acquiring characteristics aligned with DE. An additional approach that is important in assisting the strengthening of local economies is to create alternative market places and marketing channels for local products and services in areas where established markets create high barriers to entry for the local producers. Other propositions put forward by other scholars, such as local tax systems, currencies and ownership mechanisms deserve scrutiny for their effectiveness in creating changes toward the desired direction.

7. Conclusions

Distributed economies is an evolving concept and offers a promising basis for discussion about sustainable local and regional development as well as how technical, economic, political, and social systems at the regional level can be constructed to support a development aligned with its principles. It may not be revolutionary and is surely inspired by other streams of thought that are designed to improve environmental and social well-being. However, besides having environmental and social improvements as core objectives, DE differs from similar concepts by placing increased focus on the economic viability and business adaptability of small-scale, flexible schemes that concentrate on local value addition and take advantage of inter-sectoral collaboration. In other words, they are designed to build an innovative business case to promote the development of robust systems that are better aligned with sustainability requirements.

This paper has reviewed and discussed selected production systems and some of their attributes that contribute to their desirability as elements of distributed economies. It also highlighted some of the factors that affect their development and sustained operation. A common feature of such systems is that they have a focus on using local resources for the generation of value added products. This flexibility allows these systems to take advantage of a diverse range of inputs and their viability is enhanced by collaborative linkages with a diverse range of other activities. More importantly, they provide environmental, social, and economic benefits that are shared by a wide group of local parties. Therefore, these production systems provide useful building blocks for robust economic systems that are closer to local people and provide a higher quality of life – two of the main objectives of distributed economies.

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References

[1] Johansson A, Kisch P, Mirata M. Distributed economies – A new engine for innovation. Journal of Cleaner Production, this issue.
[2] Dahlberg K, Jansson AM. Sustainable regional food supply – analysis of food consumption patterns, local production and external dependence from the perspective of wholesalers and retailers of food. In: Dwyer S, Ganslosser U, O'Conner M, editors. Life science dimensions – ecological economics and sustainable use. Fürth: Finlander; 1998. p. 409–19.
[3] Hines C. Localization – a global manifesto. London: Earthscan; 2000.
[4] Korten DC. When corporations rule the world. West Hartford: Kumarian Press; 1996.
[5] Ekins P, Newby L. Sustainable wealth creation at the local level in an age of globalisation. In: Danson MW, editor. Regional Studies 1998;32(9):863–77.
[6] Page J. Globalisation explained. International Society for Ecology and Culture; 2002.
[7] Mirata M, Ristola P, Johansson A. Industrial symbiosis for more sustainable, localised industrial systems, unpublished.
[8] Kurkela E, Palonen J, Kivelä M, Takala H. Solid recovered fuel gasification for co-combustion in PC boilers. Finland: Espoo; 2002.
[9] McCormick K, Kåberger T. Exploring a pioneering energy system: the case of Enköping in Sweden. Journal of Cleaner Production, this issue.
[10] Watling B. Vice president development. Renewable Energy Services Ltd; 2002.
[11] Nova Scotia Business Inc. Guide to community economic development investment fund; 2001.
[12] Nova Scotia Department of Finance. Nova Scotia equity tax credit; 2001.
[13] Scotian WindFields. CEDIF investment opportunity; 2001.
[14] Eklund J. Chairman of Västerdala Bioenergy AB; 2004.
[15] Takala H. Operating engineer – Lahti Energia Oy; 2004. Lahti.
[16] Johansson E. Managing Director – Ena Kraft AB. 2004: Enköping.
[17] Pilo U. Head of water and wastewater department – Enköping kommun; 2004. Enköping.
[18] Braman N-E. Vansbro; 2004.