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Article

Creating Synergies from Renewable Energy Investments, a Community Success Story from Lolland, Denmark

Silvia Magnoni [1,*] and Andrea M. Bassi [2]

[1] Baltic Sea Solutions, Højbygaard Papirfabrik, Fabriksvej 2, Bygn. A, 4960Holeby, Denmark

[2] Millennium Institute, 2111 Wilson Blvd, Suite 700, Arlington, VA 22201, USA; E-Mail: ab@millennium-institute.org (A.M.B.)

* Author to whom correspondence should be addressed; E-Mail: sim@bass.dk; Tel.: +45-2938-3436.

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Abstract: The island of Lolland is a showcase example of a remote local community being able to stand up to the challenges of facing environmental and social consequences of climate change while creating economic opportunities. This island has had many years of experience in implementing renewable energy (RE) projects as a way to combating peripheral poverty and promoting economic growth in a relatively remote area. The development strategy lies within the unique concept of Lolland Community Testing Facilities (CTF), which creates a forum between the private sector, research institutions and local political authorities by exploiting synergies among green investments and providing an international testing and demonstration platform for renewable energy technology and products. The present paper aims at giving an overview of integrated longer term energy planning based on Lolland CTF, its components and main features, while highlighting those critical characteristics that could make the CTF model successful and relevant for RE-based local development worldwide.

Keywords: remote areas; sustainable development; renewable energy; peripheral regeneration; environment

1. Introduction

Remote and peripheral communities have to face various challenges, particularly as today's world has got more and more interconnected and relies on centralized global hubs for all sort of business, including manufacturing and technological development, among others. Remote areas need therefore

to deal with global markets that often bypass them, thereby creating severe limitations in their economic, social, functional and spatial evolution. In particular, peripheral regions have to cope with a few unique characteristics, such as:

1. Remote location. This element is highly related to a relative lack of accessibility to economic activity, which, according to some literature, "determines the locational advantage or disadvantage of an area relative to all other areas considered" [1].
2. Low population density. Highly dispersed population makes it difficult for the implementation of effective and economically affordable strategies and projects that would increase efficiency (e.g., energy and water use), productivity and mobility.
3. Prejudicial demographic structures. Subject to out-migration–particularly of young people–remote areas have to accommodate a small population and elderly inhabitants, resulting in adverse demographic dependency ratios.
4. Weak urban networks. Peripheral regions generally show a lack of cities in their territorial area, or develop behind the shades of a sole, main urban settlement. As a consequence, they might find it difficult to connect with neighbouring regions (in both physical and functional terms) and gain from the involvement into larger markets.
5. Fragile economic development. With low connectivity, adverse demographics and higher logistic costs, remote areas normally show lower employment rates and less developed economic structures.

All along its historical development, the island of Lolland has been going through all these challenges, but it has gradually identified a model of development that has finally allowed this peripheral area to get out of economic stagnation and social poverty by recurring to local sustainable resources: Lolland Community Testing Facilities (CTF). Such a solution represents a comprehensive growth approach based on RE, preservation of natural capital and sustainability.

The present study intends to review the CTF approach put into practice by the local knowledge-catalysing organisation Baltic Sea Solutions (Bass) and the Municipality of Lolland, and identify the key characteristics that have made it a successful development strategy in this remote area. More specifically, the main objective of this paper is to shed a light on a model of growth that has proved to be successful in taking a peripheral area, with all its challenges as described above, and leading it through a recovery path based on sustainable renewable resources. By presenting the Lolland CTF, and investigating its potential replicability, this paper would like to contribute to the research dialogue on rural areas by displaying a meaningful, flexible, replicable long-term growth model for peripheral communities.

2. Lolland and the Lolland Community Testing Facility

Lolland is an island located in the south-eastern part of Denmark. Together with the neighbouring island of Falster, with which it forms a Danish geographical sub-region, Lolland covers an area of 1,797 square kilometres [2] with a population of nearly 112,000 inhabitants [3]. The sole Lolland Municipality, real motor behind the renewable energy development in the region, covers only half of the geographical Lolland, 892 square kilometres [4], with a population of approx. 48,000 citizens. The

three major private economic sectors are construction services, the metal industry and agriculture, followed by tourism. High levels of skilled workers are employed within the metal industry and construction, compared to the national average, but the agriculture and tourism sectors recruit primarily unskilled (and seasonal) labour [2]. The island is only 150 km from Copenhagen, but is considered a peripheral region in Denmark. This perception of remoteness goes along with relatively poor infrastructure, the continuing emigration of younger well-educated people and with having a higher percentage of its labour force on permanent welfare than the national average. Without any cities of critical size on the island, Lolland has put economic recovery and development as key political priorities and, in the past 30 years, it has been embarking upon an innovative green growth strategy that has resulted into improved social and economic conditions. Such a strategy, named Community Testing Facilities–CTF, has brought about over the recent years concrete benefits to inhabitants, municipalities and private businesses, by making renewable energy a growth driver. The returns of this unique investment have been transforming Lolland into an island with much to offer in terms of clean-tech expertise, business opportunities, and availability of human and natural resources.

2.1. History of Lolland

The growth history of Lolland stems from the effort of the public sector in supporting a specific development strategy that would help the island come out of a period of strong economic depression and related social problems. Lolland was severely hit by an industrial recession in the mid-eighties. The shipyard in Nakskov–in western Lolland–which was providing jobs to a good number of the employed workforce on the island, was closed in the mid nineties, leaving some 2,000 workers unemployed, and starting a distort vicious circle of increasing poverty, brain drain, inflow of social clients from the metropolises attracted by the cheaper cost of life, increased dependency on national subsidies, disinvestments, *etc*. This status of chronic economic depression was complicated by a skyrocketing unemployment rate: in the sole town of Nakskov, the unemployment rates registered soon after the breaking out of the crisis and business closures reached 35% for skilled and 40% for unskilled workers, registering in 1994 an annual unemployment rate of 19.3% (see also Figure 1). Further, 10% of the municipality's inhabitants moving away in the period 1981–1998 [5].

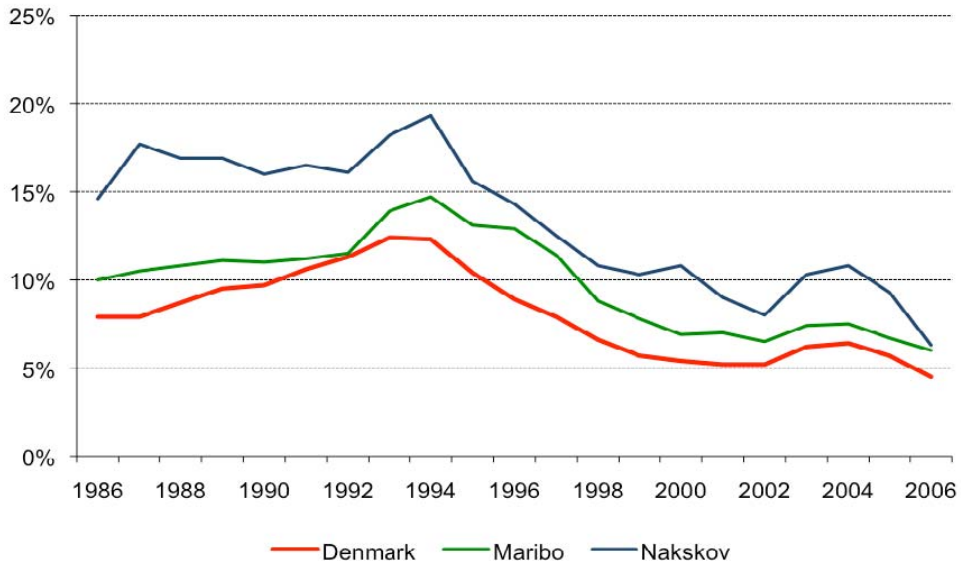
In 1998 a relevant political shift took place in the Nakskov City Council, which took the lead and embarked upon an effective action plan aimed at revitalising the city in collaboration with other municipalitiesin a shared effort of increasing employment matching the free labour force, and injecting economic regeneration (at that time the current Lolland Municipality–which was officially created in 2007–consisted of seven different municipalities, who were sharing common economic and social problems). It was at this time that local politicians targeted the environment as their strategic choice for development–also in view of the rising international focus on climate change and volatile oil prices. The road to be travelled was long, and difficult decisions had to be implemented in an already disrupted area. One of the first actions taken by public authorities was to increase both municipal and local government taxes by 1% [3], so as to pool resources that would have been used for reindustrialising the area.

In 1999 and 2000, the Nakskov harbour was adapted to the new local needs, old buildings were torn down and the ground cleaned. This was the largest environmental cleanup ever undertaken in

Denmark, amounting to DKK 50 million (about EUR 7 million) [6]. Nakskov Municipality acquired and developed the new industrial area, called Nakskov Industry and Environment Park (NIMP), a vast spot (1.2 million sqm) destined to host new businesses and an agro-industrial site. Vestas Wind Systems was the first company to establish a factory there in 1999, and it was (and still is) the largest such enterprise, with some 600 employees registered in 2008 [6]. In collaboration with the other municipalities, the town started developing a range of different actions aimed at achieving local prosperity, while focusing on "green" sustainable development based on local resources and renewable energy: new businesses were attracted, regional partnerships were activated, and infrastructures were improved. As a result of these positive initiatives, unemployment fell consistently in 2003 to 10.3% (as compared to the 6.2% national average at that time), with relative social benefits for the local population (see also Figure 1) [3]. In 2004 the Danish government agreed on a new public structure in Denmark, which came into effect in 2007, when the, when eeMunicipality of Lolland was created and took the reigns of the business development strategy for the island. On January 2007, a unanimous Lolland District Council decided to develop the concept of "Lolland Community Testing Facilities" (Lolland CTF) as the Municipality's leading industrial policy commitment. Waiting for national initiatives was not enough in such a region as Lolland, without universities or large clusters of industries, and with a severe need to compete in the market environment.

While economic and social indicators for the whole of Lolland Municipality for the past two decades are at the moment not available, due to the 2007 incorporation of the seven municipalities, a couple of key data for the two main towns on the island, Nakskov and Maribo (former municipalities), can certainly be very relevant for visualising the socio-economic development trend of Lolland following the implementation of the CTF strategy.

Figure 1. Unemployment rates in Denmark, Maribo and Nakskov.



As shown in Figure 1, the unemployment rate has followed a relative decreasing trend from the beginning of the nineties, recording high-target figures in 1993–1994, when the economic crisis and

business closures hit strongly. Nakskov, where the harbour and other important economic activities were closed, is the town on Lolland that has registered the highest unemployment rates, reaching figures up to 7 percentage points higher than the Danish average.

In Maribo, the economic recession was less felt, although the town also recorded unemployment rates 2–3 percentage points higher than Denmark's relative figures. From 1994 until 2002, both Nakskov and Maribo registered a steep relative decreasing trend in unemployment rate values, reaching figures standing at 8% and 6.5%, respectively. This means that the municipalities on Lolland have been able to achieve a consistent decrease of nearly 10 percentage points in less than ten years while maintaining a personal income growth of about 2.5% per year [3]. A similar trend is also achieved at national level, as a consequence of Danish policies aiming at spurring economic growth at national level through policies highly supporting a Danish RE and energy efficiency industry. Certainly, the success of the Lolland case has also been strongly dependent on national policies and strategies towards a Danish "green economy" (see Section 4.5), but the specificity of Lolland's RE-based economic development lays on the fact that an entire rural community, with no relevant industries, local resources nor human capital has been able to take the lead in the Danish efforts towards a sustainable and greener economy, achieving remarkable results in relatively short time.

2.2. Lolland CTF Vision

The CTF–an international platform for testing and demonstrating renewable energy technology and products–is a locally-initiated, bottom-up strategy, which was put in place to help the island create and optimise economic 'spin offs' from existing and new projects, as well as attract new businesses, create jobs, and strengthen research and educational activities. Over the last few years, under this public framework, Lolland has been going through a notable development, with improved socio-economic conditions, and an additional positive branding as "the green island". By focusing on local resources (people, land, natural elements, waste), Lolland has been able to enter a new stage of development and combine two priorities into one single strategy: economic growth and environmental sustainability.

Through the CTF, the island has been transformed into a platform for the testing and demonstration–full scale and in real communities–of renewable energy products and technologies. The vision behind Lolland CTF is to create innovative partnerships to combine the industry's interest for testing and demonstration with the Municipality's need for sustainable growth and development. By proactively incorporating RE products and technologies into Lolland's energy and environment sectors, industries have the possibility to test and demonstrate new technologies on a full scale and in real communities. In turn, the Municipality can benefit from the presence of new businesses on the island, which stimulates local growth and employment, while providing good sources of renewable energy.

A key success factor of the Lolland CTF, often underestimated in a climate of rapid technology development, is that the concept implemented on the island allows for testing various technologies in isolation, while also creating synergies among them. As a consequence, the private sector can run tests and measurements to further improve its products, while the Municipality maximizes the utility of the various projects, practically applying a zero waste policy made possible by careful longer term urban and industrial planning. The latter additionally allows private companies willing to move to Lolland to

incur in low costs and fast transitions, since the Municipality is at their service with strategies for finding an optimal location and minimizing settlement costs (e.g., the Municipality takes into account all needs of the company, including energy and water, and plans ahead to reduce its waste and generate profits for both parties out of recycling and renewable energy production).

Table 1. Lolland CTF benefits.

Lolland Municipality	**Industry**	**R&D**	**Policies**
• Sustainability • Branding • Economic Growth • Competitiveness • Population Growth • Job Creation New Education • Innovative Supply Systems	• Branding • Cheaper Test & Demonstration • Faster Access to the Commercial Market • Society Tests • Real Situations, Real Systems, Real Population, Real Society	• Full Scale Research • Technical Knowledge • Socio-economic analyses • Well-defined geography, demography, economy and energy systems	• Bottom-up tools to reach macro-political goals for sustainability and competitiveness • Growth in the peripheral areas of the EU

The CTF activities on Lolland comprise several renewable energy supplies (RES), such as wind energy, biomass, bio fuels, solar energy and hydrogen/fuel cell installations. These facilities are spread all over the island, and offer good possibilities for testing RE products and technologies in real communities, thereby advancing research and producing innovation. As a matter of fact, Lolland CTF is a concrete implementation of the Triple Helix model of innovation, highly praised by the European Union and based on the involvement of close synergies between academic, industrial and municipal actors.

A leading role in framing the green development strategy carried out on Lolland, coordinating the CTF programme and its distinct projects, aggregating all the private, academic and private actors involved in each activity and—fundamental—providing the technical knowledge necessary for an appropriate implementation of the new development direction was the local no-profit organisation Baltic Sea Solutions (Bass), which was initially founded as a business development public agency of the local authorities on the island of Lolland (Bass became independent from Lolland Municipality in 2007, when the increased number of projects and activities handled by the organisation in the field of sustainability and development required for a more autonomous legal status). The role of Bass as strategic partner of Lolland Municipality has proved essential for providing the island with technical knowledge, domestic and international network, ideas and access to regional and European funding sources: a primary mix of elements necessary for the successful implementation of strategies and programmes framed with a long-term perspective. The involvement of a local organisation in the various energy projects on the island has also contributed to a reduced gap between the municipal authorities and the citizens, representing Bass a reliable and objective means of communication for exchanging opinions and positions through a lean bottom-up approach.

3. The Challenges of Policy Formulation

The case of Lolland is not only interesting because of the positive results of a RE-based economic development strategy pursued at community level. An important element to take into account is the context in which policy formulation has taken place, and the elements and processes that local policy formulation has gone through before coming out with a successful, long-term business development policy.

In order for policies and strategies to be successfully implemented in small remote communities, policy makers and the public have to establish a relationship of mutual trust, which can be achieved by combining the knowledge of the context in which policy making takes place [7] with an objective cross-sectoral evaluation of the impacts on society, economy and the environment. The CTF was developed with the understanding that the local community was a key driver for the success of a longer-term strategy on renewable energy, and several meetings and public hearing were held to make sure that both issues and options were clearly understood.

When abstracting the key characteristics of the growth strategy presented in this paper, we can identify: (a) a participatory approach in identifying issues and defining long-term strategies (*i.e.*, a vision) and (b) a process geared towards the successful implementation of policies. As a consequence, the approach resulted in: (c) creation of dialogue and (d) consensus on energy issues by explicitly comparing different options and by focusing on synergies (e.g., one single investment in RE may not be profitable, but its ramifications and complementarity with existing policies and needs make it more attractive and economically sound). The main guidelines to increase relevance and credibility when communicating and interacting with policy makers identified in the Lolland case include: understand the context, clearly explain, attempt continuing dialogue, tell a story that makes sense, do not overreach, compare and collaborate.

Since reality is complex and characterized by feedbacks, non-linearity and delays, the public and policy makers on Lolland have themselves faced these challenges, and had to take into account these properties in order to correctly analyze the potential longer-term outcome of their decisions. In consideration of such complexity, and with the intention of taking informed decisions within a medium to longer term strategic planning, they had therefore opted for the implementation of strategies that would, for instance, minimize delays (e.g., companies can locate their facilities on Lolland in a considerably lower amount of time–18 months–with respect to the rest of Denmark) and create synergies (e.g., accounting for feedbacks, by combining private and public investments in implementing a zero-waste strategy concerning energy generation and use. See also Section 4.5). Further, the Municipality opted for the development of an advanced analytical simulation model that, through the running of integrated dynamic scenarios (the so-called T21 Lolland model), could help them test the cross sectoral impacts of their policies and investments [8].

Taking feedbacks as the first point of analysis, "Feedback is a process whereby an initial cause ripples through a chain of causation ultimately to re-affect itself" [9]. The concept behind Lolland´s strategy lays on the fact that investments in RE lead to revenues at the industrial level, but also to the creation of jobs and higher income for employees, which in turns can spend their salary, further stimulating economic growth that may result in additional investments in RE (e.g., through private

investment, or public expenditure -driven by higher tax revenues- possibly resulting in new public private partnerships).

By linking the energy sector to other dimensions of society, economy and environment, feedback loops contribute to the representation of the context in which different energy issues are analyzed. Using feedback loops and wider boundaries to analyze energy issues allows for the identification of side effects, elements of policy resistance, and potential synergies that would make policies more effective. For instance, investments in RE and higher GDP may drive population growth in the longer term (e.g., through a reduction in out-migration or an increase in in-migration driven by better job opportunities) increasing the need for public services (e.g., schools and hospitals) and possibly public infrastructure (e.g., roads). If the Municipality is not able to deliver these services, the private sector would have to face "old" challenges, such as finding a skilled and motivated workforce, with the consequence that they would have preferred to relocate to better serviced areas.

An important element considered in the formulation of Lolland's energy and industrial development policy has been the existence of delays, in the system and concerning policy implementation. When formulating policies, it is indeed crucial to take into consideration time delays, "a phenomenon where the effect of one variable on another does not occur immediately" [10]. These can in fact lead to political instability, among others, due to the fact that outcomes do not directly follow actions. In this respect, integrated complex systems–as a community is–are dominated by inertia in the short-term, therefore the implementation of policies normally does not produce immediate significant impacts. Furthermore, when the short-term performance of the system is negative or below expectations, which is usually the case when costly interventions are implemented, policy makers tend to change direction hoping to move towards their desired goal. The outcomes of such shift tend not to be encouraging due to both the additional implementation cost and the lack of short-term positive outcomes (again due to the inertia of the system). Such strategy, very common in our present political structures and mainly driven by short-term pressures and agendas, prevents the system from effectively adjust to the proposed interventions and improve over the longer term. For this reason a longer time frame of analysis and longer-term political and community support are needed, and, in the case of Lolland, this–through the regular update of medium term urban development plans, as well as the minimization of the time needed to locate facilities on Lolland–has been the baseline followed for the implementation of its sustainable development strategy.

4. Lolland Energy Strategy

The strength of the CTF vision lies in creating a sustainable local business environment out of renewable energy investments. The Municipality and Bass work together with private companies interested in localising their demonstration facilities on the island, offering them the possibility of benefiting of customised infrastructure, full-scale testing fields and the possibility of integrating their RE products and/or technologies in real communities. In the case of Lolland, therefore, investments are not only seen as an opportunity to market a "green" effort, or to reduce the use of more unreliable fuels (e.g., fuel oil, characterised by volatile prices); instead they are part of a strategy aimed at creating a longer term economic driver for the community, while decreasing pollution and adapting to climate change. This goal has additionally led to the identification and concretisation of synergies among the

various investments and energy sources at place on the island, so as to go beyond the economic assessment of one or the other investment choice, and eventually make the best possible use of RE for the entire community. This means that the business, energy-based strategy adopted by the island in the past decades does not only aim at injecting more industrial development at local level, but also at the exploitation of synergies between the various energy sources–and plants–located on the territory, in order to make these investments both economically viable and environmentally sound.

In this section, an overview of the energy areas where the Municipality of Lolland is investing with PPP projects is offered (certain specific information on processes and technologies utilised in the different RE projects is at the moment not available due to the fact that these projects are still in a testing and demonstration phase), in combination with some data regarding Lolland´s socio-economic development and utilisation of synergies.

4.1. Lolland CTF-Wind

Recurring to wind as a resource for business development is not so surprising in Denmark, a country where wind power accounts for 20% of the national electricity consumption [11] and with the ambition of reaching 50% by 2025. Lolland´s development in the field of wind energy is thereby in line with the Danish policies for supporting the national wind power industry, through substantial subsidies (from 2001–2005 the yearly subsidy has been USD 340–519 million) that have highly increased the potential for employment and export revenues of this manufacturing industry.

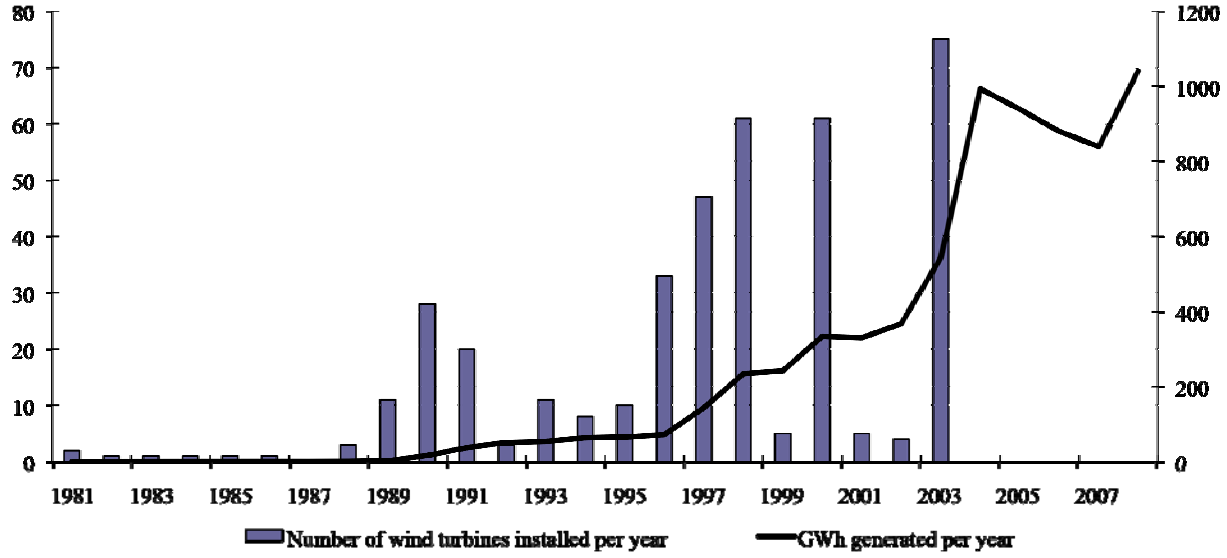
The specificity of Lolland, however, is that wind turbines on the island are producing more electricity per inhabitant than any other place in Denmark, and the electricity network of Lolland receives energy from 500 "power plants", as every single wind turbine represents an independent unit [6]. Since the 1980s, electricity from wind turbines has been produced on Lolland and the neighbouring island Falster, being Lolland-Falster the first Danish region to construct and install wind turbines.

The near-shore and flat landscapes of Lolland-Falster are particularly suitable for offshore wind turbines. Power production from the turbines has increased with a factor of 12 during the last 10 years and is at present producing about 1,000 GWh. This is the equivalent to the consumption of 210,000 private households or approximately the annual electricity consumption of one million people.

With the inauguration in 2003 of the "Rødsand", offshore windmill park off the coast of Nysted, the wind capacity was almost doubled. In 2004, these 72 turbines alone produced over half of the wind energy of the islands. The decision to expand the park has recently been taken, which will increase the total wind production to approximately 1,500 GWh, 50% more than the island's consumption. The Danish company Vestas Wind Systems, the world's leader in the production of wind turbines, has opened in Nakskov a branch for the production of windmills´ blades in 1999, thereby confirming Nakskov and NIMP as optimal business and logistical investment destinations. Demonstration activities in the field of wind energy are also carried out, with the three Savnsø offshore turbines (3 MW each) being tested onshore, with the ultimate goal of achieving higher production capacity at lower costs.

Wind turbine development on Lolland is shown on Figure 2. After the first wind turbines were installed in the eighties, the world's first offshore wind farm for commercial purposes was installed outside Vindeby, on Lolland's northwest coast at the beginning of the nineties. The increased turbine capacity and public state subsidies to wind energy gave a strong development to wind energy in the late nineties. Finally, in 2004 the world's biggest offshore wind farm–Rødsand I–came into production in late 2003, contributing to more than MW150. Rødsand II offshore wind farm of MW200 is planned to start operations as of 2012.

Figure 2. Wind turbine developments on Lolland.



Source: Danish Energy Authority [12]

4.2. Lolland CTF-Biomass

Being Lolland a rural and agricultural area, it is natural for the Municipality to have agriculture playing an important part in the island's RE production and, hence, representing a relevant input for RE-based local companies. The visions behind Lolland's commitment to biomass-related projects entail the establishment of a full-scale physical platform for exploitation of biomass resources from several technological generations.

Heating plants that burn straw, woodchips and wood pellets supply Lolland with district heating. This is CO_2 neutral biomass heating supply and therefore differs from the rest of Denmark where natural gas, coal and oil play an important role. Some buildings are heated by the so-called "neighbour heat". These are miniature district heating plants of less than MW1, where the heat usually comes from straw owned by a local farmer. The district heating plant (straw and woodchips) in Nakskov, with its delivery of 101 GWh per year, further distinguishes itself by being the Nordic reference plant within the structure of the Danish District Heating Association.

In addition, a privately owned bio-refinery facility in the agricultural industrial area outside Nakskov is planned to be in operation by late 2009. Biogas will be produced from manure, straw and other vegetable matter–a non-fodder CO_2 neutral energy source. To ensure that straw and other vegetable matter can be gasified, innovative technology for pre-treatment is integrated. The vegetable

matter is pressure cooked to enable the micro-organisms to convert it into biogas. Four phases make up the whole process:

- Phase 1 and Phase 2 use second generation biomass (straw, vegetable waste, manure) to produce lignin, biomass and ethanol, used as fuel in heat and power production. Fertiliser is a useful by-product.
- Phase 3 utilises by-products from the first two phases (fertiliser, CO_2 and molasses) and combines them with wind energy power to produce methanol.
- Project Phase 4 solves an environmental problem by using 4th generation biomass, like urban and industrial waste, for biogas and methanol production. The by-product dried waste pulp is used for heat and power production.

The facility will be established in close cooperation with prominent Danish research institutions and internationally acknowledged businesses in order to further develop the complex and challenging technology adopted. A functional symbiosis between Nakskov District Heating, the agriculture sector and the waste management business will function as the main driver of this project.

4.3. Lolland CTF-Biofuels

From a general consideration of sustainability, biofuels are also ideally generated on rural Lolland, and can represent the point of collaboration of many Public-Private Partnerships (PPPs). Different kinds of bio fuels have been developed through new process techniques, which are being and will be tested in one or more of Lolland CTF plants: rapeseed oil (cold or warm pressed), biodiesel from algae cultivation and bio-ethanol from agricultural production.

Rapeseed oil, of which Lolland is rich, is used for heating of buildings and as transportation fuel in modified diesel engines. Rapsol I/S started production in Bandholm, in the northern coast of Lolland, in August 2007. The produced oil is to be used for decentralised municipal plants that currently are operated on traditional oil. As a matter of fact, on Lolland-Falster traditional, collective district heating plants do not represent efficient solutions, especially due to some relevant distances that are present from one house farm to the other, when moving outside the main towns. Instead, the combination of decentralised heating with centralised control systems could be implemented on island communities just as cost effectively as on the mainland, independent of geography. On Lolland-Falster there are approx. 17.000 domestic boilers that could be replaced with more efficient heat supply, with low running costs and CO_2 neutral operations (running on rapeseed oil).

As far as algae are concerned, the island hosts two different projects encompassing algae cultivation for diverse purposes–biomass and purification of agricultural surface water. The harvesting of algae for biofuel generation has now started being tested, for identifying an appropriate type of algae that can be grown in open-air basins for producing algal fuel to be utilised in alternative to traditional heating oil in those parts of the island still not reached by district heating.

4.4. Lolland CTF-Hydrogen

Lolland's commitment to promote community development, while supporting energy and environment efficient technologies has been further implemented through Lolland Hydrogen

Community, a testing site where village households are integrated into a system which provides electricity and heating distribution based on sustainable energy sources, combined with hydrogen and fuel cell technology. In 2007, a test and demonstration facility set-up through PPPs opened on Lolland, showing how to convert surplus wind power into hydrogen through electrolysis. The demonstration plant in Nakskov was part of the national commitment "Demonstration of micro combined heat and power, μCHP based on Danish fuel cells" within the structure of The Danish Energy Agency, aiming at developing and producing Danish market-ready hydrogen technology, components and fuel cell systems.

During 2008, the use of hydrogen has been tested in the village of Vestenskov as the primary energy source for domestic consumption. Fuel cell units for the production of both electricity and heat (μCHP), with a decentralised electricity generating capacity of 2 kW, have been installed in each house, with the objective to provide the same amount of energy as an ordinary domestic boiler. The fuel cell unit is installed as a secondary facility in the house and is connected to the existing energy facility. The hydrogen supply is adjusted for each individual household and surplus electricity is sold back to the public electricity grid. The conversion of turning hydrogen into electricity and heat is made by an electrochemical procedure. This process is extremely efficient with approximately 50% electricity production. The combined efficiency of simultaneous use (electricity and heat) is approximately 90%. Additionally, an adequate hydrogen distribution network (micro-grid) from a centralised electrolyser—running on wind power- to each household has been developed. Five households are already supplied with hydrogen, and about ten more will be soon connected to the hydrogen grid, with the medium term goal of making Vestenskov Europe's first hydrogen community by the end of 2010.

4.5. Synergies Emerging from Lolland's Energy Strategy

Thanks to early investments in wind power, which started after the oil crises of the later seventies and early eighties [13,14], Denmark managed to create its own niche in the renewable energy sector. Continuous support to RE over the years and a coherent strategy for market penetration made so that Denmark, and Lolland as a leading example, managed to successfully diversify and grow a domestic profitable RE industry [12]. In line with this, the island of Lolland has profitably involved its communities in the design of longer-term sustainable development by pursuing a zero-waste approach and a truly synergetic strategy under different perspectives. Synergies are identified at three main levels:

1. Synergies at partner level: by adopting the Triple Helix spiral of innovation model when implementing energy-related activities on the island, synergies of competences, human capital and financial capital are established among the public and private sector and the academia. Each new RE project starts with an identification of the best composition of partners, in terms of technical expertise and monetary commitments, for the successful implementation of the initiative under analysis.
2. Synergies at technical level: when dealing with RE sources, a main problem has to be faced– intermittency. By investing in more RE initiatives, Lolland Municipality is trying to maximize its investments in intermittent sources of energy by creating synergies among the various

processes and projects, so as to make each single investment more appealing (and economically efficient) and leverage higher results. Many can be the examples recalled in this instance:

a. The surplus of wind power available at night, instead of being sold at very low prices outside of the island, is used for hydrogen production and storage in the hydrogen village;
b. The oxygen obtained through electrolysis in the hydrogen generation process, instead of being simply released, is used to increase the efficiency of water purification in the municipal water treatment plant. This increased efficiency and a direct access to reduces the treatment plant allows the nearby sugar factory to reduce its fresh water needs by about 50%;
c. The dikes created to protect the shoreline from sea level rise are now hosting algae production testing grounds, with the goal to capture CO_2 and produce biofuels;
d. The use of biomass (*i.e.*, straw) for combined heat and power production, and the use of manure in the biogas plant, were specifically designed to create a revenue stream for local farmers. This, in turns, alleviates the economic burden created by the increased taxation level on Lolland.

The final goal is to have an energy sector on the island that is on his way towards full integration and high-level efficiency. Efficiency is also pursued through the use of local natural resources as energy inputs, so as to avoid the economic and environmental costs connected to the procurement of external resources. In this respect, as mentioned above, straw coming from the abundant agricultural land replaces fossil fuels in the generation of power and heat; rapeseed oil, extracted from the yellow flowers that are already used for the production of animal feed and vegetable oil for human consumption, replaces traditional heating oil in private households and a few municipal buildings; and surface water from the fields, rich in fertilisers, is used to grow algae thanks to its high nutrients content, and therefore automatically purified before being discharged into the Baltic Sea. Future technical synergies might also be soon on their way to Lolland. Investments in electric cars are becoming more and more appealing for the island of Lolland, whose energy system presents high levels of renewable intermittent energy. Electric cars seem therefore an appropriate means by which pursuing energy storage through synergies among electricity production, the electrical grid and transportation. They can help make better use of the surplus of wind energy present on the island, while at the same time cutting down on fossil fuels and thus enabling Lolland Municipality to realize even higher renewable energy contributions to the Danish national energy consumption.

3. Synergies at policy level: the relevant achievements the island has been able to reach in the past decades, both in terms of socio-economic development and in terms of RE production, are in line with, complement and implement the policies and strategies pursued by Denmark in the past 30 years. In particular:

a. The island has focussed its efforts in developing a decentralised energy system based on alternative sources of energy, including CHP and the sectors of wind power and biogas production, highly subsidized in Denmark.

b. Lolland has benefited from national and regional funding available for the demonstration of cutting-edge RE technologies, as well as for local development. By welcoming demonstration facilities on its territory, Lolland Municipality has contributed to filling the gap between research and commercialisation, and has therefore qualified for the national available funding put at place for these specific purposes. Further, given the close link between demonstration activities and business development at local level, the island has also been able to take advantage of the EU funding (Structural Funds) available at regional level for the promotion of socio-economic development and the revitalisation of the area, against structural difficulties. Finally, the Municipality of Nakskov founded in 2006 a local energy holding company, LOKE A/S, specifically created for financing future energy related initiatives on the island. LOKE's capital amounts to approx. US$ 13 million, which is intended to contribute to local growth and development through co-financing of public-private energy related projects. Although official statistics are still not available, in 2007 only, 15 projects in the field of testing and demonstration of technologies were co-financed by LOKE through loans and venture capital money. As from Lolland Kommune's website, new energy-related projects are coming on the island in the next future (*i.e.,* biorefinery, micro district heating through methanol, solar energy testbed; cluster of climate-related companies) in the form of private-public (and academia) partnerships, where LOKE is also involved as co-financing sponsor. This shows that new companies (and new jobs) will therefore take place on the island.

c. The greening of Lolland economy has evolved in line with the national objectives of GHG emissions reduction, increased energy security, and development of technologies for export markets. Also, the increasing outflows of clean electricity from Lolland to the neighbouring Danish regions contribute to the country's greening of the energy supply, less dependence from fossil fuels and self-sufficiency. Finally, by demonstrating innovative technologies, Lolland and its entrepreneurs contribute to the development of unique RE products that can be representing new sources of export earnings at national level.

d. The creation of interactive relationships among companies, Lolland Municipality and the academia addresses the national priorities of increased research collaborations among these stakeholders for the development and demonstration of new technologies. The whole of Lolland CTF strategy lays on the establishment of strong Public Private Partnerships between local authorities, private companies and the academic sector, aiming at exploiting mutual synergies and capabilities, while moving from basic and applied research through to validation and large-scale demonstration.

By making use these three types of synergies at a local level, Lolland Municipality and its implementing partner Bass seem to have found good ways to make renewable energy investments very attractive, in the view of achieving a high return on investment not only from an economical perspective, but also from a social and environmental standpoint. The social and economic development overall is likely to create new synergies and opportunities going forward, both within and

outside Denmark. One example is the construction of the new bridge (Fehmarn Belt) connecting Denmark and Germany via Lolland, likely going to support the development of new businesses on the island in the field of renewable energy, as well as services (a couple of national consultancy companies have already created local offices on Lolland) and transport/logistics. Also, a good deal of the new companies established in Lolland Municipality in the past 5 years belong to the service sector–tourism, culture, information and communication [15], which can be taken as a sign of the overall development of the island, where the energy-related companies that have been created in the past 10 years as part of the Lolland CTF strategy are now stimulating a service economy, attracting local intellectual capital and thereby bringing important knowledge-based resources on the island.

A point worth mentioning with regards to the establishment of new businesses is that precise data showing the industrialization of Lolland as an effect of Lolland CTF strategy are still not available via the Municipality. Statistics in this respect are still under preparation, but some conclusions can anyhow be suggested by the authors. If the trend of unemployment rates and personal income/GDP on the island is taken as starting point, two developments are visible: declining unemployment and growing resilient economy, being these already a clear sign of the improvement of social and economic conditions on the island, through the ability of creating new jobs for the locals and providing additional sources of income (e.g., by producing double electricity than the one consumed at municipal level, and having a large surrounding market, Lolland Municipality and its private partners can sell the surplus of electricity back to the national grid, through a system of feed-in tariffs).

5. Critical Variables and Replicability

Community-based development is nowadays praised by international research and development institutions in their approach towards a sustainable growth [16-18]. Under this framework, bottom-up, community-driven initiatives are positively considered in view of their ability of spurring territorial development, while accounting for the needs, opportunities and constraints at local level.

In light of this stream of research, it is interesting to analyse the Lolland CTF model of development, its profitable implementation and positive outcomes in terms of sustainable development, to identify the success criteria and extrapolate a CTF concept of business development that can be replicated elsewhere. By studying the case of Lolland, the following critical variables have been identified:

- Community involvement: involving the local population in the planning of energy initiatives and stimulating the ownership of shares in a local energy project can improve peoples' understanding and appreciation of energy generation and use. The level of social acceptance of renewable energy on the island of Lolland is relatively high. Local residents are consulted and included in the planning of extensive energy projects and communications and training is offered to them, so as to spread awareness about RE benefits, options and financing opportunities. Community ownership is also encouraged, through the creation of local associations owning testing energy facilities. From associations of citizens owning shares of wind turbines to an association of farmers establishing a manure-based biogas plant, the main purpose in stimulating local direct participation in an RE project on Lolland is to buy the individual commitment to the RE initiative by extending its economic benefits to the local area and offering attractive and tangible returns to both individuals

and communities. Public ownership of wind turbines or other energy facilities helps maximize the regional economic benefits of local resources and sense of involvement, and thus increase the grass root level of support for renewable energy and additional climate change mitigation measures.

- Political support: when implementing full scale RE demonstration projects in real communities, the presence of strong political support is fundamental in order to insert these initiatives into an overall long-term strategic framework. Politically determined visions and objectives are clearly defined on Lolland to stimulate the creation of economic activities, as well as environmental benefits in the form of a totally renewable electrical grid, through the exploitation of local resources. The Development Department in Lolland Municipality represents the internal mechanism of influence for the municipality; it combines the implementation of the local industrial policy and the energy one through ad-hoc RE projects bringing new companies or services on the island, and defines to a large extent the decision of the municipality to realize projects determining future possible economic activities. A strong political support is also needed for allowing the municipal co-financing of RE testing projects, and therefore the assumption of a partial share of the implementation risks behind the demonstration and integration at community level of cutting edge technologies and processes.
- Targeted funding: appropriate and well-scaled funding for research and demonstration projects is a needed element in implementing RE activities and it shares the financial risk of the projects among the Triple Helix public and private partners. A well-sorted combination of local, regional, national and European funds allowed the island of Lolland to form a solid financial playground for the proper implementation of its long-term RE activities and to embark upon highly pricey projects, that would otherwise not have been implemented with local money alone.
- Advanced and rational planning of local areas: a well-structured land use planning system is a key ally for meeting the challenges set by the implementation of RE technologies in small communities. The constant dialogue kept between Lolland Municipality and private companies, as well as the establishments of different Public-Private Partnerships for various energy projects allow for the creation of adequate infrastructures for the accommodation of new businesses. Well-developed local governance and engagement structures work towards the setting-up of planning mechanisms at local and neighbourhood level that take routine and well-informed account of renewable energy issues and facilities.
- Strong strategic partner: good partners are key for complementing knowledge and resources when handling complex, cross sectoral and technical RE projects. The existence of a reliable partner for Lolland Municipality -Baltic Sea Solutions- has supported the local municipality in the development of the CTF by supplementing municipal competences with know-how, advise, local knowledge, network building and technical assistance. It has worked as facilitator among the various public and private partners involved in the different RE projects and has identified opportunities for synergies and symbiosis at local, national and international level.

All these aspects have contributed to the flourishing of renewable energy on the island via the Lolland CTF model. By taking these variables in consideration and adapting them into their local context, other communities can profit from the experience of Lolland as a source of inspiration in

defining longer-term strategies that account for renewable energy and climate-sound investments (for adaptation and/or mitigation).

In line with the current goals of the Global Green New Deal [19] proposed by the United Nations Environmental Program (UNEP), and the Territorial Approach to Climate Change [18], a United Nations Development Program (UNDP) and UNEP joint initiative, some island communities have already started a bottom-up "green" approach for their development strategy. Learning from Lolland's longer-term strategy and using the longstanding experience in supporting national development programs from Millennium Institute, a US-based non profit organisation informing public debates through policy formulation and evaluation, the island of Maui, Hawai'i, as well as the Republic of Mauritius are taking a systems approach to social, economic and environmental development, in analysing policies and actions that can help preserve the environment while creating jobs and generating value added.

As in the case of Lolland, the analysis of the local context through integrated dynamic planning scenarios is helping these islanded communities achieve an improved understanding of their local context, as well as of the impact of the various initiatives already at place in different sectors: from creating jobs and spurring economic growth, to decreasing reliance on fuel oil for electricity and heat generation and increasing resilience to climate change, while creating research and business opportunities. A systems analysis, based on feedback, delays and nonlinearity, allows for the estimation of social (e.g., demographics, education intake, unemployment), economic (e.g., GDP, government revenues and expenditure, personal income) and environmental (e.g., land allocation, energy demand and supply, air emissions) impacts in an integrated manner (see for instance Bassi *et al*. [20]). This brings consistency in analysing apparently disconnected areas of intervention and supports the monitoring of impacts of actions over the medium to longer term. As the Lolland case has shown, investing in RE generates employment and opportunities for the private sector, in addition to intellectual capital. In order to retain businesses and intellectual capital, the local government has to create an investment-friendly environment (e.g., CTF) and accommodate the requests of its citizens (e.g., increasing the quality of education, improving the road network and managing congestion). If this strategy is successful, the Municipality is then likely to attract more people to the area (most probably young professionals and workers, thereby modifying its own demographic structure), as well as businesses, however incurring into the risk of turning short-term opportunities into longer-term problems if careful planning on social services is not into place–eventually resulting into businesses leaving and unemployment rising. All these elements have to be taken into consideration as starting points before any business development planning is carried out, and represent a critical part of the "replicability model" of the Lolland case.

6. Conclusions

Lolland is working towards the creation of a sustainable future, focussing on green energy and closely targeting the needs and opportunities of its natural, social and economic context. By using its own natural resources and potentials, Lolland has developed a comprehensive list of initiatives -under the Community Testing Facility umbrella- promoting effective technologies in the environment and

energy sectors. All of these have been contributing to the sustainable development of a remote area and the targeted tackling of climatic challenges.

Lolland is already recognized "bottom-up-based best practice". The Municipality has wind turbines at sea and on land; centralised heating plants based on woodchips and hay; Denmark's first hydrogen community based on wind power and much more. The Municipality actively involves existing industries, the region's farmers and inhabitants in a shared greener future. Thanks to Lolland Municipality's approach, implemented in concrete terms via dynamic synergies among public, private and academia stakeholders, the island has been able to regenerate its socio-economic context and preserve the quality of the environment. It has therefore positioned itself as a good example of a remote and peripheral community (within an interconnected power grid) taking up the development challenge in a proactive and sustainable way.

This paper proposes to analyse the strategy implemented by Lolland Municipality and its strategic partner Bass, as well as its replicability, in light of the local context, which results from the interaction of social, economic and environmental factors that are characterized by feedbacks, delays and nonlinearity. Under this stream of research, the following critical variables have been identified: community involvement, political support, targeted funding, advanced and rational planning of local areas, strong strategic partnerships.

All these aspects have contributed to the flourishing of renewable energy on the island via the Lolland CTF model. By taking these variables in consideration and adapting them into their local context, other communities could potentially profit from the experience of Lolland as a source of inspiration in defining longer-term strategies that account for renewable energy and climate-sound investments, while creating opportunities for local and international businesses.

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