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## LOCAL SUSTAINABLE DEVELOPMENT: IN THE MUNICIPALITY OF TJÖRN

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# **LOCAL SUSTAINABLE DEVELOPMENT**

## **- IN THE MUNICIPALITY OF TJÖRN -**

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**The International Institute for Industrial Environmental  
Economics at Lund University**



cradle to cradle



islands

The Interreg IVB  
North Sea Region  
Programme



”Local sustainable development - in the municipality of Tjörn.” is a study by environmental students in the course ”Styrmedel för förebyggande miljöskydd” [Management of preventive environmental protection] at Lund University spring 2011.

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# 1.

# INTRODUCTION

## TJÖRN

Tjörn is located on the west coast, in the heart of Bohuslän, and consists of Sweden's sixth largest island and several smaller islands. The nature is strongly present with extensive sea views, sea breezes, bare rocks and a rich cultural landscape. During the summer months, the seemingly idyllic everyday life for the 15,000 inhabitants changes into a much busier one. The beautiful natural and cultural landscape attracts summer visitors, boating and other tourism, which at times almost doubles the population. Like so many other places all over Sweden and around the world, Tjörn has unique opportunities to meet the many external changes that lurk around the next corner. Energy insecurity, increasing world population, dwindling natural resources, higher commodity prices and climate change will undoubtedly also affect Tjörn. To what extent Tjörn is affected, rests largely on the decisions taken here and now.

## RESEARCH TEAM

We are a group of experienced and ambitious students who are studying the Master's degree program *Strategic environmental management* at Lund University. The studies are partly conducted at the renowned institution IIIEE - International Institute for Industrial Environmental Economics. The Institute's core values are based on that prevention is better than remedy. The research conducted within the institute has the overall aim to develop strategies and instruments that alter the production and consumption systems - to prevent environmental problems, and to promote the road to sustainable development.

## CRADLE TO CRADLE ISLANDS

A few years ago the EU project *Cradle to Cradle Islands (C2CI)* were initiated. The project aims to show it is possible to live as one with nature by creating innovative solutions for energy, mobility, water and materials. The reason for islands being selected is that they usually have the ambition to become independent and self-sufficient because of their limited availability of energy, water and transportation

systems. The reason is also to create visible and living examples of sustainable development. The project runs from 2009 to 2012 and Tjörn Municipality, together with the IIIIE has been involved since the project started. About twenty other islands and research centers in the North Sea area are also involved in the project.

### **PREVIOUS ACHIEVEMENTS**

In 2010 collaboration began between Tjörn Municipality and the IIIIE in connection with the project C2CI. Students at the Master's degree program *Strategic environmental management* was commissioned to investigate Tjörns opportunities to shift to sustainable energy, focusing on the islands Dyrön and Åstol. One of the students later developed the study in conjunction with their thesis (Ström 2011), and studied a solution for the entire island. The aim was to identify potential energy resources to investigate Tjörns prospects to make an energy transition to more renewable and locally produced electricity and heating.

### **RESEARCH OBJECTIVES**

This report is a further investment in C2CI and continues to explore the opportunities to convert into a long-term sustainable energy production. The idea is to kill two birds with one stone - the investments in renewable energy will lead to local development. Previous studies have resulted in visions; the idea is that this report will lead to concrete recommendations and an action plan. The aim is through a realistic analysis of local conditions, to provide recommendations on how Tjörn Municipality should proceed in the process of converting to more renewable energy. The goal is that Tjörn proceeds with the recommendations and that this will lead to sustainable local development.

Building on previous studies, the mapping of renewable energy resources in the municipality continues. The condition of the energy resources is to be analyzed, which is necessary if the report will result in recommendations and an action plan. To justify the proposed action, a background describing the challenges, possible solutions according to theory and real world examples is compiled. The project can be summarized in three points:

- Energy Resources and its prerequisites
- Recommendations and Action Plan
- Challenges, possible solutions and ways of motivation

## METHODOLOGY

The report is the result of qualitative literature studies and qualitative interviews. The starting point for literary studies has been Ström's report (2011) on energy solutions for Tjörn. Other documents studied are from Tjörn Municipality, the project C2CI, as well as documents and web pages on different energy, waste and sewage. A week has been spent on site on Tjörn to get a better understanding of local conditions, and to conduct interviews with officials at Tjörn Municipality Planning Department and Tjörns politicians, and other relevant actors active within the energy, waste and sewage sector. From the collected material, we have developed two scenarios, the "regional" and the "local" - two possible paths Tjörn can choose to position themselves with for the future. The "regional" scenario is based in principle on the current political direction today which ties together Tjörn with the Gothenburg region, while the 'local' scenario is based more on the Cradle to Cradle Islands basic theory on local development and the theory of decentralized economies. To arrive at these examples, we have used a contemporary external social and environmental analysis and a SWOT (strength-weakness) analysis. To get maximum benefit out of these scenarios, we have based on them developed specific recommendations and an action plan.

## REPORT OUTLINE

Initially, a brief introduction to the challenge is presented (Chapter 2) and what the latest research indicates as potential solutions (Chapter 3) to secure the future. This part ends with a brief presentation of the two possible main themes for the future, the 'regional' or the 'local' scenario (Chapter 4). After this introduction, we present our recommendations and action plan (Chapter 5 and 6).

Facts and data on the energy resources identified, as well as its conditions are presented in Appendix 1. The Appendix is the main basis for our recommendations and action plan, but the chapters on the challenges, solutions, possible routes and our experiences, as well as interviews and experiences in Tjörn are also underlying the recommendations.

## ...AND THEN WHAT?

It is a unique opportunity for the Municipality of Tjörn to get as much expertise in so short a time, which in addition is based on the IIIIE's latest research. We hope we have managed to get to know Tjörn well enough for our action plan and recommendations to be useful and USED! During our visit in the municipality, we found that Tjörn has great potential as a viable community in the future while coping with the many challenges ahead. We hope we can inspire you to feel the same.





# 2.

## THE CHALLENGE

**This report is mainly about energy. What is meant by a long-term sustainable energy production and why are energy issues so high on the political agenda? The threat of climate change and carbon dioxide emissions caused by energy production has been widely discussed in energy policy matters, but is far from the only angle of approach. Security of supply, security of delivery and competitive prices are no less important, and they become even more important in the context of rising prices and increased demand for energy. What challenges waits for Tjörn and the rest of Sweden in the future?**

The society and the economic system are entirely dependent on energy to function. We have built ourselves into structures where long disruptions in energy supplies can cause serious problems for public services, businesses and individual users. The vulnerability to disruptions also increases as the energy dependence is growing. Security of supply and delivery are keys to long-term sustainable energy - in order to reduce high energy prices, energy shortages and disruptions.

In Sweden there is an ongoing energy transition from fossil fuels to renewable energy. The main reason for the conversion is to achieve the right to security of supply, which was noted as necessary already during the energy crisis in the seventies. The Swedish government says that "The investment in renewable energy and more efficient use of energy strengthens Swedish security of supply and competitiveness" (Regeringskansliet 2008). The fact that burning of fossil fuels also causes environmental pollution, emissions of problematic air pollutants and greenhouse gases have subsequently reinforced the need for a conversion.

The Swedish transport sector is still almost entirely dependent on fossil fuels, (equivalent to half of Sweden's use of fossil fuels). The shortage of supply is due to the depletion of oil reserves and by the fact that Sweden is totally dependent on imports (Helby 1997). The prices of fossil fuels are unpredictable and strongly linked to what happens abroad, which exacerbates the situation. Changes in the international price of oil can instantly occur and cause major adverse impacts on Sweden, with high energy prices, energy shortages and disruptions.

The situation of the Swedish electricity production is slightly different, since the use of fossil fuels is small. Electricity production in Sweden is based on "two pillars" - hydropower and nuclear power. When only two types of energy are covering the whole of Sweden's electricity demand it increases the vulnerability to disruptions, since problems with either, affects the security of supply for the entire Swedish society. The Government of Sweden writes "In order to reduce vulnerability and increase security of supply there should be a third pillar being developed for electricity supply, thus

reducing reliance on nuclear and hydro '(Regeringskansliet 2008). The government also highlights the importance of the third pillar being consistent of renewable energy.

Without going deeper into the debate on whether nuclear power should be used or not, the domestic electricity production should be more diversified through investment in other energy sources - for an increased delivery reliability and security of supply. Another reason is to increase the number of players on the Swedish market to obtain competitive and maintaining competitive energy prices.

Electricity certificates were introduced in 2003 to increase the use of renewable energy. It is a market-based support system that works so that producers receive a certificate for each MWh of renewable energy it produces. Electricity suppliers must then obtain an amount of such certificates in proportion to their sales (Svensk Energi 2011). Producers of renewable energy gains through the system an extra income, which leads to better competitiveness of renewable energy (Billyvind 2011).

The competitive part of the price of electricity, about 40% of the price, changes depending on current production and consumption of electricity (Svensk Energi 2011). In recent winters, customers have sometimes experienced record-high electricity prices (Svensk Energi 2011). This is because the cold winters has coincided with problems in the Swedish nuclear power, and low levels in reservoirs (ibid.).

**Over to the climate threat. The energy policy objectives of fossils independence, promotion of renewable energy and energy efficiency, are important for achieving the climate change targets because of decreasing emissions of carbon dioxide. Meanwhile, the climate change aggravate the supply- and delivery security. Energy and climate policy are therefore closely linked.**

That climate change is causing a rise in global temperature 97 percent of the world's scientists agree with (Hickman 2011). What effect a higher average temperature may cause, is more difficult to survey. Elevated sea levels, and different or extreme weather conditions are two effects that are generally accepted (Energimyndigheten 2009a). The most common causes of disturbances in the Swedish energy supply is already nature-related events such as changes in flood, floods, storms, lightning, extreme cold, heat waves and landslides. If weather conditions change or deteriorate there is an increasing the risk of natural events disturbing the Swedish energy supply.

Increased precipitation is expected to cause flooding and landslides that could damage critical infrastructure for energy, such as plants, distribution systems and power grids. Other consequences of changing weather conditions can be changed water flows for hydroelectric power or severe cold causing high electricity prices. Climate change complicates Sweden's ability to achieve security of supply and supply security and threatens to cause high energy prices, energy shortages and disruptions.

Different or extreme weather will also mean that there will be another need for electricity, heat and cold, which is very difficult to predict. The current electricity production is designed for today's needs and usage patterns. Any changes such as increased demand for electricity during the summer months due to an increased need of cooling, requires both preparedness and flexibility of energy systems.

**A sustainable energy production means therefore an increased degree of security of supply and delivery security, by investing in fossil-fuel independent renewable energy and energy efficiency. The natural result is that we emit less carbon dioxide, thus reducing the effect on climate. The energy issues is high on the political agenda because the society is with increasing energy dependence, extremely vulnerable to higher energy prices, energy shortages and disruptions.**

Security of supply, delivery security, energy planning and crisis management is a necessity to meet future challenges. The responsibility lies with all actors in society: municipalities, authorities, counties, businesses and individuals (Regeringskansliet 2008). It is in everyone's interest to secure energy supply through investments in fossil-fuel independent, renewable energy and energy efficiency. We all want a secure energy supply.

To achieve a sustainable energy solution in Tjörn it is also important to put the energy issue in a broader perspective with the entire island's economy and development in mind. We have examined this further in the next chapter on possible *solutions*.



# 3.

## Solutions

**Tjörns development is similar to many other smaller municipalities in Sweden, with a population of more elderly people, fewer jobs and move out to larger cities. This is a development with more retirees, commuters and interim accommodation, and reduced tax revenues and trade within the municipality. The economic situation is pressed, because the requirements on local labor and management are the same despite a smaller tax income. Many municipalities are handling this situation by investing in tourism, developing close relationships with the region and improving infrastructure for commuting. The goal is to attract more year-round residents, improve community organization and increase tax revenues. With these conditions, it can be difficult to get time and budget to go together to work proactively rather than reactively. There are opportunities to take up the challenge and change the existing conditions. But apart from what is already answered in the previous chapter about ensuring energy security, why should Tjörns municipality, businesses and residents invest in a long-term sustainable energy production?**

The vision is that investments in energy solutions can be a beginning of something much bigger - a sustainable local development. Tjörn has already created a vision of being the island of possibilities; we want to develop this vision, where the overall goal is to create a sustainable and prosperous society with more year-round residents and more jobs.

There is a need for a clearer distinction between local and regional initiatives. The reason is that local initiatives gives more positive local synergies, while regional initiatives have positive effects for the wider region. One way does not exclude the other. Cooperation with other municipalities and the region can be profitable, but one has to make sure the money stays within the Municipality of Tjörn.

The Cradle to Cradle Islands project is partly based on research on *Distributed Economies*. The theory is about transforming the industrial system with a large-scale and centralized production to smaller, regionally and locally based systems (Johansson et al. 2005). The reason is that today's heavily industrialized system has many weaknesses that need be addressed to achieve sustainable development. The weaknesses referred to include that the system creates a greater vulnerability and little flexibility, that today's production systems and over-exploitation of resources creates environmental problems and that it the relocation of industries to countries with low production costs continues. The old system is not abandoned, but it is about finding a sustainable balance between efficiency and quality.

The solution to the industrial system's problems could in theory be investments in regional and local development. An example is the successful industrial regions in Italy

that has long managed to maintain a high standard of economy, while a surprisingly high resistance to changes (Johansson et al. 2005). Key factors have been identified are product variety, quality upgrading and commercial specialization.

The idea is that increased investment in the local and regional level will lead to positive synergies that lifts the entire region, not only economically but also socially, culturally and environmentally (Benneworth et al. 2001). An increased local entrepreneurship will lead to more people getting jobs locally, and that unemployment and commuting to larger urban areas are avoided. This leads to more money traded locally, allowing for further development of local businesses. Increased employment and increased involvement in the home district and improved environment, are factors that also affect the social dimension in a positive way. Cooperation between municipalities, businesses and residents develop a common spirit and by an increased regional and local influence the residents' own ideas are being used. This will contribute to an increased influence over the local culture and an upward positive spiral of local development (Johansson et al. 2005).

The Swedish government (2009) also describes a similar opportunity for local development. An eco-efficient economy will mean less dependence on energy and raw material imports and thereby less sensitivity to global price changes. It also requires good collaboration between policy areas and between public and private actors. The government also claims that a switch to an eco-efficient economy in the world can give Europe a significant competitive advantage (or Tjörn before other parts of Sweden) (ibid.). Investing in a green economy in Sweden, both nationally and locally, is a strategy that will pay off in the future.

**Promoting tourism, regional cooperation and improved commuter options may be necessary for Tjörns municipality in the current situation. This approach is however not sufficient to secure the future of Tjörns municipality and its inhabitants. Tjörn need to work out an alternative or parallel strategy that favors Tjörn and only Tjörn. Although there is an economic challenge to conduct more activities locally at present, involves the local efforts of the big opportunities. The question that remains is what the municipality will build this long-term strategy? What should the commercial specialization be? An sustainable island - and the possibilities are endless.**

A decentralized and small-scale energy systems in Tjörn Municipality is the beginning of a larger perspective. With own energy production Tjörn can withstand future changes in prices of energy and prevent energy shortages and disruptions. Tjörn can also create more jobs and indirectly invite residents to increase entrepreneurship. A focus on local and small scale renewable energy resources like biomass, wind, sun and water could increase both the local and Swedish security of supply of energy - while creating a sustainable local development.

Now Tjörns municipality has the chance to be first with the latest. Differentiation, to specialize and brand themselves as a sustainable island - combines environmental management, increased job opportunities and increased tourism. The efforts should maintain and create new activities. It gives a reason for companies having conferences on Tjörn, see the sights in Tjörn and get people to move to Tjörn. Environmental

management is no longer a cost but an opportunity to generate income. At the same time it creates good conditions for Tjörn to cope with the many economic and environmental challenges lurking around the next corner.

These are not radical ideas without basis in reality. There is already a wide interest amongst islands around the world to brand themselves as sustainable and many islands have also shown that it is entirely possible. While the municipality is positioning itself for the future and meeting approaching, environmental challenges, they have great opportunity to get their local residents involved supporting this positive sustainable and local development.

### **THE EXAMPLE OF SAMSE**

The Danish island of Samsø is also involved in the C2CI project and has in less than ten years reached its goal of becoming self-sufficient in renewable energy (Ström 2011). When the conversion began in 1998 Samsø produced no energy (Stenkjaer 2009), all electricity was imported from the grid by the mainland and the fossil fuel by tanker (Ström 2011). Samsø managed to become self-sufficient in electricity by building more wind turbines, owned by wind cooperatives or private owners. In addition they invested in a biogas plant producing electricity and heat, and a district heating system fueled by straw, solar and wood pellets (Stenkjaer 2009). The few houses that could not be included in the system were offered energy efficiency advice and grants for conversion to bioenergy, solar or heat pump systems (ibid.).

Through close cooperation with its inhabitants, who also was the essential driving force, Samsø managed to succeed. Today Samsø even export renewable energy to the mainland, which brings in revenue to the island's inhabitants (Stenkjaer 2009). What remains is the improvement in the transport area. There are ongoing biogas and rapeseed oil but they are not fully developed yet. Residents of Samsø still mean that the island is carbon neutral because they export a lot of renewable energy (ibid.).

The year 2006 the Samsø Energy Academy opened, which will bring together the knowledge generated during the transition to a renewable energy system. They also offer courses and workshops in the area. Today Samsø is known as Denmark's energy island and has a lot of visitors for that very reason (Samsø Energi Akademi 2011).

### **MORE EXAMPLES**

The Swedish Environmental Protection Agency has collected many good examples of environmental initiatives that are successful and profitable (Naturvårdsverket 2011). Students at the International Environment Institute have conducted several case studies of distributed economies, even directly connected to the C2CI project (IIIEE 2009, IIIEE 2010).



## **ACHIEVING THE SOLUTIONS**

In order to better structure how Tjörn could do to achieve a sustainable energy solution, we have worked out two different concepts or visions for the future, which we call scenario “regional development” and scenario “local development”. These are presented in the following chapter. More information about the different energy resources and local conditions on Tjörn can be found in Appendix 1.

# 4.

## POSSIBLE WAYS

### 4.1 SCENARIO "REGIONAL DEVELOPMENT"

This scenario is based on the prevailing political will and understanding among officials of the municipality, and is essentially the approach Tjörn Municipality has been selected today. This scenario is based on a quest for closeness to the Gothenburg region, with the attitude that the municipality fails to meet residents' needs on its own and regional collaborations are therefore being initiated. The scenario consists of five main parts:

- Proximity to Gothenburg
- Improved infrastructure
- Enhanced regional cooperation
- Centralized energy systems
- Improved waste management

The goal is to obtain an increased occupancy, which is achieved through large investments in improved transport infrastructure. In this scenario the municipality's limited budget is used on infrastructure investments and investments in local and sustainable development is secondary. Collaborations with other municipalities and investment in infrastructure are expected to increase the share of commuters within the municipality, because of improved opportunities for commuting, and a reduction of jobs on the islands. Local trade will benefit to a less extent in this scenario, as the trade and purchase by the people who commute often occurs in connection with the commuting. Trading favors instead the Gothenburg region in general. Infrastructure investments are also expected to lead to increased tourism and more interim housing, through greater availability. The result is a higher load during the summer months and lost tax revenue since more properties are owned by interim residents instead of year-round residents. The problems Tjörns municipality experiencing today, therefore, in this scenario is to be strengthened.

#### TECHNICAL SOLUTIONS FOR REGIONAL ENERGY PRODUCTION

Beginning with the resources for energy production from wastewater and waste residue, regional cooperation in this scenario gives a centralized treatment of wastes and sewage. The municipality is investing in large-scale operations that might be able to lower their operating costs. Resources are transported out of the municipality and benefit the region as a whole and not necessarily Tjörns municipality. Dependence to other municipalities is increasing.

Since the scenario involves a slow path towards sustainability and a path of centralization, this is based on the waste system Tjörn has today. The system can be expected to be optimized to a greater extent. Of food waste becomes biogas, and with a technology development and cost advantages of scale, it becomes a high yield of biogas. The biogas is used regionally, and will not credit Tjörns municipality in first hand. This scenario is also based on the construction of a sewer to the mainland, which is a current idea in the municipality. Sewer shall be connected to Kungälv municipality which then together with their wastewater ends up in the Rya plant in Gothenburg. Bio-fertilizer and sewage sludge will be used in the region.

#### **SWOT – regional energy production from sewage/waste**

<b>Strengths</b>	<b>Weaknesses</b>
<ul style="list-style-type: none"> <li>- <b>Contributes to regional cooperation</b></li> <li>- <b>Economies of scale</b></li> <li>- <b>Reduced burden from private sewers</b></li> <li>- <b>No investment / operating costs required for the collection of food waste</b></li> <li>- <b>Regionally produced biogas</b></li> </ul>	<ul style="list-style-type: none"> <li>- <b>Cost of drain to the mainland</b></li> <li>- <b>No flexibility and lock-in effects</b></li> <li>- <b>Hard to motivate subscribers to act correctly</b></li> <li>- <b>No fertilizer to local farmers</b></li> <li>- <b>Long journeys</b></li> </ul>
<b>Possibilities</b>	<b>Threats</b>
<ul style="list-style-type: none"> <li>- <b>Cleaner coast</b></li> <li>- <b>Biogas production in the region</b></li> <li>- <b>Enhanced regional cooperation</b></li> <li>- <b>More efficient waste management</b></li> <li>- <b>Increased demand for food waste can reduce collection costs</b></li> </ul>	<ul style="list-style-type: none"> <li>- <b>High maintenance costs</b></li> <li>- <b>Increased energy prices</b></li> <li>- <b>Increased fuel prices</b></li> <li>- <b>Climate change</b></li> <li>- <b>Increased business environment demands higher waste and sewage charges</b></li> </ul>

As for other energy production Tjörns municipality chooses to maintain centralized energy systems and make smaller investments in renewable energy in this scenario. This means a slow trend towards sustainable development.

Electricity will continue to mainly come from the mainland by the main power grid. Thus, the shift towards sustainable energy will continue at the same rate as the rest of the country. Energy sources will primarily be based on hydropower and nuclear power (Swedish electricity mix), and the chances of a rapid development of renewable energy is very small. (Uranium is a finite resource and therefore not renewable). The municipality will still continue to invest in locally produced, renewable energy, but only on a small scale.

Fuel for the heat boilers will continue to be partly based on oil, but oil will continue to disappear more and more. The conversion to other fuels will be relatively fast but it will take time to become completely free of oil. The use of pellets will continue to increase in the municipality. The pellets will continue to come from outside and is not produced in the municipality.

Implemented energy efficiency measures will help the municipality continue to reduce their energy consumption overall. New homes and more technology in the home will contribute to the slow rate of decreasing energy consumption.

### **SWOT – regional heat and electricity production**

<p><b>Strengths</b></p> <ul style="list-style-type: none"> <li>- Large share of hydropower</li> <li>- Less sensitivity to variations in energy demand</li> <li>- Proven</li> <li>- High efficiency</li> </ul>	<p><b>Weaknesses</b></p> <ul style="list-style-type: none"> <li>- Does not take advantage of local resources</li> <li>- Depending on the outside world</li> <li>- Does not tribute to local development</li> <li>- Finite resources</li> <li>- Affects climate and environment</li> </ul>
<p><b>Possibilities</b></p> <ul style="list-style-type: none"> <li>- Regional cooperation</li> <li>- Less local power conflicts</li> <li>- Easier to invest in innovative solutions</li> <li>- Efficient and secure electricity supply</li> <li>- Produce pellets locally</li> </ul>	<p><b>Threats</b></p> <ul style="list-style-type: none"> <li>- Slow conversion to renewable energy</li> <li>- Less influence on type of energy</li> <li>- More expensive in the future</li> <li>- Energy uncertainty</li> <li>- Does not create incentives for conservation of electricity</li> </ul>

## 4.2 SCENARIO "LOCAL DEVELOPMENT"

Tjörn has like the rest of Sweden, the EU and the rest of the world, big challenges ahead of them, with global problems such as food shortages, resource depletion and climate change. In the near future, major changes need to be done to address the problems. Transportation costs and electricity prices today are very low and will increase substantially, thus increasing the need for society to function is at the most local level possible. This scenario of "local development" is designed to demonstrate the feasibility of a decentralized energy system in which local resources in Tjörn are being used. The scenario consists of five main parts:

Close to nature  
Local development and entrepreneurship  
Cooperation between municipalities, residents and business owners  
Decentralized energy systems and energy security  
Self-sufficiency and recycling

This scenario aims to promote a closeness to nature to overcome the challenges Tjörn face. Capital investments focused primarily on things that make the municipality self-sufficient. There is great potential for self-sufficiency on the island and many good examples, not found in other parts of Sweden already exist in Tjörn. For example, the farmers utilize the manure to grow grass or other crops on their own land or sell it to a neighbor. This scenario is based on increasing cooperation between the municipality, residents and business owners so that cycles can be closed and increased self-sufficiency occurs on the island. This scenario is based on the theory that an increased local cooperation leads to a local development and increased entrepreneurship, leading to more jobs and more year-round residents.

To take advantage of the resources available on Tjörn, increasing the degree of self-sufficiency and promote local development in the municipality, we have developed a scenario for a completely decentralized system of energy production. Unlike Scenario 1 the waste and sewage in the decentralized system are considered more as resources rather than waste. A resource that will be beneficial to the local energy supply and together with other local energy solutions, bring a greater degree of, or even complete energy self-sufficiency in the municipality.

### TECHNICAL SOLUTIONS FOR LOCAL ENERGY PRODUCTION

Regarding energy production from waste and sewage in this scenario, it is based largely on a proposal for an expanded treatment plant at Ängholmen and includes thermophilic digestion of sludge with biogas production to initially be used to heat the plant. Food waste can also be digested in the digestion plant built for co-digestion, thereby increasing the amount of biogas produced. Food is collected as much as possible, from households, companies and other businesses. Basing biogas on waste has the greatest potential, according to Sweden's biogas strategy, because the resource is often free.

This scenario also includes the use of sewage sludge and bio-fertilizer in some way in agriculture. On Tjörn growing of grass is widespread, and in accordance with the landscape it can be grown for biogas. The sludge could possibly be used for the production of energy crops that can be used in the biogas plant. Energy crops can also be used for the local district heating systems.

#### **SWOT – local energy production from sewage/waste**

<b>Strenghts</b> <ul style="list-style-type: none"> <li>- Revenue from biogas</li> <li>- Increased control on prices</li> <li>- Energy security in the municipality</li> <li>- The supply is regulated automatically to the demand when resources are seasonally variable</li> <li>- Contributes to local development.</li> </ul>	<b>Weaknesses</b> <ul style="list-style-type: none"> <li>- Investment costs</li> <li>- Slow payback</li> <li>- Requires information campaigns to the residents of behavior with regard to sewage</li> <li>- Required inspections of sewage sludge</li> <li>- Need for infrastructure to take advantage of the gas (petrol stations, boats, buses, etc.)</li> </ul>
<b>Possibilities</b> <ul style="list-style-type: none"> <li>- More properties connected to sewage systems (increased capacity)</li> <li>- Cleaner coasts and seas</li> <li>- Flexibility</li> <li>- Branding and marketing as a sustainable island</li> <li>- Positive feedback from C2CI Project</li> </ul>	<b>Threats</b> <ul style="list-style-type: none"> <li>- Increased demand for sewage for biogas (sanitation)</li> <li>- Unchanged approach to sewage sludge as fertilizer</li> <li>- Insufficient amounts of collected material</li> <li>- Lack of demand</li> </ul>

If Tjörn choose to move toward a more decentralized energy systems, this means a rapid move towards sustainable energy which Tjörn has the actual control over. To clarify how a decentralized energy system would work, we have painted a scenario that describes the energy evolution in Tjörn by a move towards decentralization. The scenario includes energy both in the form of electricity and fuel.

The electricity will be produced within the municipality and be based on renewable sources. Thus, the shift towards sustainable energy occur at a faster rate than in the rest of the country. Energy sources will primarily be based on wind and wave power and the chances of a rapid development of renewable energy is great. The municipality makes big investments on wind and wave power, combined with energy efficiency measures. The most important energy efficiency measure is to make investments contributing to switching from electricity heating to heating by renewable fuels (solar, geothermal, etc.)

Oil as fuel for boilers will completely disappear, thanks to major investments by the municipality to get rid of the oil. With the campaign to introduce units that use renewable fuel instead, the renewable fuels will quickly dominate the heating of the municipality. The use of pellets will stay at current levels but will primarily be produced locally, such as residues from forestry in the municipality.

### SWOT – local heat and electricity production

<b>Strengths</b> <ul style="list-style-type: none"><li>- Good conditions on Tjörn</li><li>- Free energy</li><li>- Small climate and environmental impact</li><li>- Available technology</li><li>- Cost-effective for the individual</li><li>- Self-sufficiency and renewable energy</li></ul>	<b>Weaknesses</b> <ul style="list-style-type: none"><li>- Impact on the landscape</li><li>- Investment cost</li><li>- Uneven production of electricity</li><li>- Unproven technology</li><li>- Some solutions require electricity</li></ul>
<b>Possibilities</b> <ul style="list-style-type: none"><li>- Contributes to local development</li><li>- Incentives for energy efficiency</li><li>- Technology development</li><li>- Subsidies</li><li>- Positive impact on the environment</li></ul>	<b>Threats</b> <ul style="list-style-type: none"><li>- Opinion</li><li>- Conflicts over land use</li><li>- Impact on fishing and outdoor life</li><li>- Unknown impact on the nature</li><li>- Operating costs</li></ul>

# 5.

## RECOMMENDATIONS

### 1. DEVELOP THE VISION OF “THE ISLAND OF OPPORTUNITY”

Although Tjörns municipality is in the project C2CI, it does not seem like the municipality has taken any major steps to create sustainable solutions in the areas studied. The idea behind the project C2CI is partly to help the islands to increase their self-sufficiency, as the islands are especially vulnerable to external changes such as higher prices for energy and transport. Usually there is also a broad interest to profile themselves as sustainable island - because of the ability to attract more visitors and businesses. In some parts of the municipality is the prevailing view that a tough economic situation leads to the loss of their independence and to focus on the environment is economically burdensome. However, there are many good examples around Sweden and other countries that show the opposite, that investment in environment and sustainable development can generate income and contribute to local development. Recommendation one is therefore to develop a vision of “the island of opportunity”, where there is also a business behind a commitment to sustainable development. A vision of a long-term sustainable energy generation and local development will create opportunities for Tjörn, such as increased immigration and more number of jobs - which ultimately provides better economic conditions. It requires that the municipality recognizes the opportunities and invests.

This vision must permeate the municipality on all levels - in order to take advantage of each other's ideas and to avoid conflicting decisions. A municipality that focuses on something different, something new and forward, creating a newfound community where municipal employees with residents can be proud of the development work and environmental work undertaken. The municipality should naturally be based on the economic conditions that exist - but with a common vision the money will be put in the right place without unnecessary detours. If a small island like Samsø manage to get as much media attention - Tjörn could probably also succeed to do so.

Svenskt Näringsliv [Swedish Enterprises] objected to the long growing demands in the environmental field. The organization argued that the requirements would create fewer opportunities for Swedish companies in the European and international markets. With hindsight, the Swedish Enterprises knows that the result was the opposite. Sweden's work on environmental issues gave instead Swedish companies a lead in the international market. Environmental initiatives resulted in competitive advantage and secured the future of companies and their employees. The same applies to municipalities.



A major success factor is to develop a business idea that is not already established in the market. Now Tjörn has the chance to be first - ahead of other islands in Sweden. It creates a reason for people, companies and businesses to choose Tjörn over other islands along the west coast, over other tourist destinations in Sweden. In addition, creating our environmental initiatives proposed a flexibility that ensures the future of the island and its inhabitants, see recommendations below. This is a very unique opportunity.

### **Why should Tjörn take the plunge and invest?**

- A great business idea with good conditions could distinguish Tjörn from other islands on the west coast. People and companies will have a reason to choose Tjörn. For those not familiar with the environmental investments before the visit or move to Tjörn, will be surprised by the future of thinking which contributes to an additional positive experience.
- A shared spirit of optimism and something for the locals to be proud of and talk about. Human creativity and entrepreneurship are procured, which leads to increased quality of life and social development.
- As prices rise for fossil fuels the island's commuters will be having financial difficulties (more than half of Tjörns population commute out of the municipality). Moving from the countryside becomes a natural step in this development and more homes will be summer homes - with reduced local revenues as a result. Higher prices for fossil fuels will also contribute to the price of truck transportation will be raised, which will cripple operations in Tjörn. With more jobs, this development can be prevented. Our recommendations may also lay the basis for electric vehicles, biogas or biodiesel.
- To become self-sufficient in energy and electricity production and using import of fuel and electricity network as a fallback solution, creates a security for residents, businesses and community organizations that dare to invest.
- Climate change will not spare Tjörn or any other place in Sweden or in the world. An energy system with high flexibility through small-scale and local production also creates greater security of supply - reducing the risk of increased energy prices, energy shortages and disruptions.
- Italian examples shows a high resistance to external changes, which will be a key to success in the future. The key words are flexibility and small size, product variety and commercial specialization.
- Legislation will undoubtedly be strengthened – investments makes Tjörn already prepared for future changes in law.
- The possibilities are endless. One of a thousand examples, the small municipality Värmdö in Stockholm who chose to install the urine separating toilets - a sewage faction within the municipality now known as "liquid gold" because it brings in both revenues, jobs and ensured the availability of manure as fertilizer prices soared.

- With a fixed concept, clear goals and visions it is more likely to get grant money through project applications. Environmental efforts will create revenue while municipalities can economize more. The payback period is short when all the positive synergy effects are included.
- Last but not least - gives Tjörns contribution to reduced greenhouse gas emissions and secure the future of children, grandchildren and great-grandchildren.

## 2. EXPAND ÄNGHOLMENS SEWAGE TREATMENT PLANT

**Waste is a resource, E24 by Aftonbladet writes: "Few think about the value of what we throw away. But if a blank caviar tube is useless for the household, is the more interesting for industry. After sorting and melting the consumers' aluminum trash is worth 60 million "(Bursell 2011). The article is called Garbage turns to gold, and notes that the recycling industry is growing in relation with the commodity prices rising in Sweden and the rest of the world. One of the many companies using this development is Veolia Environment, which in the near future is to develop technology that can take advantage of the valuable substances contained in waste water (Andersson, 2011c). Right now Tjörn plans to lock itself in the infrastructure that leads to resources leaving Tjörn and other municipalities benefits instead. Recommendation number two is to expand Ängholmens wastewater treatment plant and utilize its resources for local gains.**

After having identified the resources for biogas production and investigated conditions in Tjörn Municipality, we have found great opportunities, both now and in the future, for a healthy and prosperous biogas system that can save operating costs, generate revenues and contribute to local development. The components of the biogas system studied are resources, current conditions, costs, and an outlet for biogas and residues. A sewer is in addition an infrastructure investment that has very long life - more than 50 years. Although future conditions must be examined.

Biogas potential in today's sludge production and the amount of collected food waste is at least 1500 MWh annually. This is equivalent to the annual energy consumption of 75 houses (20 000 kWh), or 150 apartments (10 000 kWh). If the sludge from septic tanks is collected or more households are connected to Ängholmens WWTP, and more food waste from households and businesses are collect, it can instead be at least 2100 MWh of biogas produced.

The estimates are grossly understated. We have chosen to work with low efficiency, the potential above shows the amount which can be used directly, without any losses,. The energy content of the biogas is actually twice - 3000 MWh and 4200 MWh. With today's technology in the biogas industry, the biogas yield of the existing facilities could be expanded.

If about 400,000 Nm<sup>3</sup> upgraded biogas is used for truck traffic in the Municipality of Tjörn, a truck could drive over 1300 000 km / year. Truck has still the gas tank and as the gas tank is 60 Nm<sup>3</sup>, it gives a mileage of 200 km. A used garbage truck will cost no

more than 2 million and a conversion to biogas operation costs between 150,000 to 200,000 SEK.

Our studies on co-digestion of food waste and fish waste showed shared messages. While Stenfeldt (2011) have indicated some skepticism to the co-digestion in Tjörns municipality, based on economic viability, case studies, such as Svedjan in Boden, shows the successful implementation of the facilities of the same type that is in line for Tjörn. Furthermore Tjörn is in the situation that an investment in a new drainage solution still is needed, the money must therefore be used anyway.

We therefore recommend that the Municipality of Tjörn expand Ängholmens WWTP and simultaneously construct an anaerobic digestion plant for co-digestion of sewage sludge and food waste, which also will increase the estimated biogas yield. Biogas should initially be used for the wastewater treatment plant's own energy needs - which is calculated according to previous configuration to 1700 MWh per year.

Another strength of the wastewater treatment plant is the possibility of using the digestion residues as fertilizers and there is great potential to work for a closed loop in Tjörn Municipality. Our investigations have shown that the sewage sludge has higher quality compared to other places in Sweden, which is likely due to few heavy industries. If Tjörns residues are used within the municipality, it can also provide an incentive for households and businesses to use the sewage system properly. It can facilitate the public opinion on the west coast against the use of sludge.

Sewage sludge and food waste are the most favorable substrate for biogas production because they are free, closed looped and has no competition with other uses. Tjörn has also great potential in the future to expand its biogas production from energy crops or biomass. This is also an opportunity for the disposal of residues from production, the skepticism regarding sewage sludge usually only applies to the cultivation of food. Digestion residues could also be used for own production of pellets and other biofuels, which can replace imported fuel to local district heating or for domestic boilers.

The above is a shining example of how local businesses benefit. Tjörns farmers can set aside a portion of the land, growing energy crops or biomass, to receive free fertilizer and acquire increased revenues. Depending on the extent requested by the municipality, there may also be applicable for the establishment of new businesses. If the pipeline to the mainland is built Tjörns disclaims thus local resources which in all likelihood will have great economic value, and to generate revenue, associated with increased energy and commodity prices.

### **Why should Tjörn take the plunge and invest?**

- A pipeline may contribute to fewer jobs in the municipality (which leads to reduced tax revenues if move out occurs) because of the smaller sewer operations in Tjörn. An expanded sewage treatment plant may in the future generate more jobs, businesses, and increased immigration.

- Tjörns municipality has to invest in a new drainage solution and a sewer and the expansion of Ängholmens WWTP is budgeted at equal cost during the construction

phase. Because of the grants which can be obtained, the cost of Ängholmens WWTP will probably be less than the cost of the pipeline.

- Operating costs for the two solutions are more difficult to study. Energy requirement for an expansion of Ängholmens WWTP is very small in relation to management of the pipeline. Depending on how energy prices develop, this could have a decisive impact on costs. What remains is if the operation of an own sewage treatment plant is less than water and sewage fee to the municipality of Kungälv in current and future periods. Will Tjörn be able to affect water and wastewater charges? What happens if the sewage and water fee is increased due to higher energy costs or other investment requirements prevailing at the Rya plant?

- An expansion of Ängholmens WWTP contributes to a situation where Tjörn benefit in the long run, given the revenue generated and retained within the municipal boundaries. Tjörns municipality pays today for the collection and processing of food waste without taking part of the revenue that the waste generates, revenues which in the future will increase.

- Regardless of the collection of food waste, and if it is run by the municipality or procured, sewage sludge and food waste are treated at Ängholmens WWTP, which means reduced treatment costs by 500 000 SEK / year. If the municipality conducts its own collection, it can be at least two million earmarked annually for the collection system without requiring a larger budget than at present. Any savings opportunities should be explored for sewage sludge in municipal WWTP and sewage systems.

- As in the rest of Sweden, there is a great need for energy security in Tjörn Municipality. Households in Tjörn Municipality is worse equipped to cope with higher energy prices than in urban areas because of the extensive commuting. Maintaining resources for biogas production is an important early move to ensure energy security and create important conditions for increased biogas production. It secures the future of the island's commuters and businesses that depend on cheap transport.

- Tjörn is well placed to obtain a very good quality of sewage sludge and residues, which may benefit local businesses by receiving free fertilizer. It can also increase the biogas production and boost investment in biofuels to local district heating or renewable fuels.

- The construction of a pipeline would bring big lock-in effects for Tjörn Municipality. It deprives the municipality of all the flexibility to adapt to future changes and Tjörn will be dependent on the mainland, with a decreased ability to influence their situation. Conditions will probably be changed, such as more or fewer residents in the municipality. What if the Rya plant in Gothenburg, cannot accommodate more water? What happens if the rainfall increases so the Rya plant requires less water being pumped into the sewage treatment plant?

- Energy prices will increase, within any application. A pipeline require extensive pumping stations that require large amounts of electricity to operate. Costs for the collection of food waste, other waste and sewage sludge will increase - when the prices of fossil fuels increases. Without own biogas production or filling stations the municipality may not be able to set demands on contractors, Västtrafik or other actors

within transport to run on biogas.

- Increased prices of fertilizers will lead to increased importance for society's waste and increased revenues for all types of resources that contain phosphorus and other nutrients. In addition, Tjörn has an enormous potential to obtain a very pure sludge.

As mentioned the two main options require approximately the same budget during the construction phase. If Tjörn base the choice of a pipeline that there is "longer amortization period" - it must be related to all the possibilities, arguments, and changes outlined above.

These investments are of strategic importance mainly to avoid lock-in effects and a dependency on the mainland which a pipeline means, but also to promote local businesses and local development. The investment in a pipeline to the Rya plant is a solution for a very long period that reduces Tjörns flexibility, something which could be essential given the circumstances facing the world and the prevailing society.

**Finally, we wish to highlight three other key areas not addressed in larger scale in this study. Try going for a strategy for private sewers that could benefit the municipality in the future. The best of all solutions is undoubtedly the source separating sewage. The problem is to build on already existing buildings and sewage systems. The municipality has now a unique opportunity to contribute to a positive development - in conjunction with new construction and inventory of private sewers which will still require that action be taken. Contact with "Avloppsguiden" who has great experience and knowledge in the field is an option. We also recommend introducing a differentiated waste tariff that favors those who throw away less waste, in connection with household waste collection. Household recycling is not considered necessary in the smaller islands within the municipality but the municipality must urgently protect the islands' interests towards the producers and arrange for recycling on the islands, it is unreasonable that they should on their own carry waste to Tjörn.**

### 3. CONTINUE ENERGY EFFICIENCY MEASURES

**The most environmentally sustainable energy is the energy that is never produced. Tjörn Municipality has invested heavily in energy efficiency of municipal buildings, and should continue to do so. Energy efficiency is usually the most cost effective solution to future energy problems, and there are almost always easy steps of reducing electricity consumption and heating or cooling needs.**

Tougher requirements should be initiated on energy efficiency and energy advice in connection with the building permit process, especially in connection with the municipality's own new buildings. An eco-building program for environmentally friendly construction should be prepared, for example it may apply to purchase agreements and land allocations. The program should be harder than the applicable legal requirements, such as in buildings energy use, because energy efficient buildings not only save electricity and heating costs for the municipality and its residents, but causes a resistance to higher energy prices - which as a bonus also increases the value of buildings and homes.

Municipalities can also promote household energy efficiency efforts by getting in touch, instead of waiting for households contacting advisors. Repayment periods are usually shorter than people think, with reduced operating costs as a result.

In cooperation with the energy and climate advisors, more awareness campaigns, meetings and lectures should be held. The municipality can offer free advice on the spot, perhaps in the form of a contest. Successful examples from other parts of the country should in all aspects be studied, and if possible implemented. One example is the Miljö Var Dag- campaign in Karlstad, where about 100 families during a year had intense support from energy and climate advisors, with a serial in the media (Karlstad kommun 2010).

The program will be an important part of the municipality's profile as a sustainable island - and energy efficiency measures are probably the most important component of this work.

#### 4. INVEST IN WIND POWER

**Wind power in Tjörn has great potential. Wind turbines could produce all the electricity to Tjörn, relatively simple. Given public opinion against wind turbines and the uneven flow of energy that wind turbines generate, Tjörn should also complement the wind turbines with wave power. With this solution, there are good opportunities for Tjörn to become completely self-sufficient in renewable energy. Recommendation number four is to invest big in wind power.**

The five wind turbines that are available on Tjörn currently produces about 4 GWh / year and planning permission has been granted for another four turbines. Besides these, testing of twelve major wind farms has been initialized, which together can produce 85 GWh / year and also for two additional wind turbines. We recommend Tjörn to approve all these wind turbines, unless they are in breach of environmental legislation. If all is approved, they can together produce about 95 GWh / year.

Although there is some opposition to wind farms, we stick by our recommendation to build twelve large and two small wind turbines on Tjörn. If the municipality is to fulfill its vision of becoming self-sufficient in renewable energy it requires the construction of wind power. The example of Samsø shows that it is possible to achieve such a vision and they are now getting all its electricity from wind turbines on the island. Part of the resistance to wind turbines are based on misconceptions about how different types of energy are subsidized and about the impact the turbines actually have on the local environment. These misconceptions can be clarified by means of information campaigns on wind turbines. We recommend Tjörn to review the forms of ownership for the wind to thereby avoid energy taxes.

The residents can buy shares in wind turbines and thus feel that they are involved in Tjörns energy while getting ready to buy cheaper electricity. This can lead to a greater acceptance of wind power because the population probably look better on the wind on the partially own them and have economic advantages of doing so.



## 5. INVEST IN WAVE POWER

**The project in Sotenäs will serve as a good reference as for how wave energy can be implemented on the West Coast. There is currently great interest in the energy team and the potential is great. If Tjörn would choose to install wave power, the municipality profile themselves as new thinking while they are in the forefront of renewable energy.**

If a wave power plant like the one in Sotenäs is built, it could produce 25 GWh / year (17% of total electricity consumption of 150 GWh) in Tjörn. In addition, a wave power park is easily adapted to the current needs, by changing the number of buoys that produce electricity. However, the size of the possible sea areas appropriate to wave power is a limiting factor. It was originally planned for 2000 generators in Sotenäs but it was decided to only start with 420 pieces, because of an undersized identified suitable surface to build upon (Karlsson, M. 2011).

It is recommended that Tjörn is there from the beginning when the wave power initiative starts on the west coast. It is a step on the road to energy self-sufficiency and has great potential to create jobs in the municipality. There is potential to create a world-leading region with commercial wave power which can bring Tjörn on the map by being a good role model in the world.

According to the costs of Sotenäs an investment of at least about 260 million would be required. It is quite possible that several major energy companies would be interested and bear some of the cost. To hand in an application of financial aid to the Swedish Energy Ministry and applications for EU grants are also recommended. A public owned portion of the wave power station is also to be proposed. It probably leads to increased commitment and acceptance of the wave power station. A similar model successfully used in wind energy could be used, which allows the investor in buying shares and then gaining a low energy cost. It is something that is worth discussing with the current energy companies. The construction of such a work could in principle get started within two-three years provided that all permits are going through (Waters 2011).

The wave power could produce electricity at a cost of 40-80 cents / kWh in the beginning which would require some tax subsidies for green electricity. As technology evolves, one could come down to 50 cents / kWh, which makes wave power fully competitive with wind power without the need for assistance or tax subsidies (Waters 2011).



## 6. INVEST IN FLEXIBLE AND SMALL SCALE HEATING SYSTEMS

**Regarding the heating of Tjörns property there is no grand solution, but it consists of several different components that together can provide a very high proportion of heating without direct electricity or fossil fuels. The foundation is already mentioned as good energy efficiency efforts by the municipality.**

Given that Tjörn can be considered as "Sweden's most densely populated rural areas" because of its scattered settlements, an extension of a big district heating network is not recommended. However, in some parts it may be justified with a smaller heating systems, especially in areas where buildings are planned but not built yet. It is more economical to have such a system from scratch. The boiler could be run by pellets or other renewable energy sources, preferably locally produced. Smaller heating systems could share geothermal heat.

A continued and increased investment in solar collectors should also proceed. The technology is developing rapidly, and during the summer, a solar heating system could account for more than 90% of a home's total heating and hot water needs (Energimyndigheten 2009b). Hot water heating accounts for a large part of the energy consumption of a house, and is therefore worth investing in even if it is fully operational during the summer months. Given the increase in population during this period, solar is an even more attractive solution. In addition to investing in the municipal buildings, an increased consultation to citizens are important to get results. Tjörn is already well advanced on this front but has the capacity to be even greater.

Households that cannot benefit from a heating system is recommended to obtain some form of heat pump. Geothermal heat is recommended because they are the most efficient of heat pumps as they can account for up to 90% of the heat. However, they are expensive to install, they cost usually in class from 120,000 to 170,000 SEK (Energy Advice Centre 2011). Even earth and ocean heat is to be recommended, but they have lower efficiency than the geothermal heat, and can be cumbersome in terms of conditions (notably sea heat and shoreline exemptions). They are usually a little cheaper than geothermal, around 10,000 kronor cheaper (EnerEnergirådgivningen 2011).

Heat pumps can be recommended as a last resort. They are relatively cheap in the investment cost but have lower efficiency than the above (Energy Advice Centre 2011). The municipality could provide greater consultation and information campaigns to convert to any of these systems.

Replacing oil as pellets in a boiler is also a possibility, but we do not recommend in the first place. To continue to burn for heating would probably just make many habitants continue under the old habit and not actually reduce their energy consumption which is important. Moreover, the pellets are imported, and given the ever increasing competition for wood raw material, it will probably not be a viable solution in the longer term, especially economically. With a well insulated house, energy efficiency measures, solar collectors and some type of heat pump you can get far. If the remaining electricity also comes from renewable sources, Tjörn would be able to profile itself as a very good example of a sustainable island

# 6.

## ACTION PLAN

### **1. DEVELOP THE VISION OF “THE ISLAND OF OPPORTUNITY”**

A common vision in which the goal of a sustainable island becomes a new and unique concept in the West Coast and Sweden. Investments in long-term sustainable energy production and local resources (steps 2-6 in the Action Plan) are the first steps towards a sustainable island, which creates favorable conditions for developing more sustainable ideas for the future.

### **2. EXPAND ÄNGHOLMENS SEWAGE TREATMENT PLANT**

Waste is a resource! Uncertainties in energy prices and other external changes are too big for a construction of a pipeline to the mainland. Priority number two is therefore that Tjörns municipality immediately decide on an extension of Ängholmens sewage treatment plant.

### **3. CONTINUE ENERGY EFFICIENCY MEASURES**

The most environmentally sustainable energy is the energy that is never produced. Work on energy efficiency should continue. Documents on the municipality's policies and guidelines on energy conservation should be up to date.

### **4. INVEST IN WIND POWER**

There are incredible opportunities for wind power in Tjörn Municipality. Wind turbines can cover the entire municipality's electricity requirements, prerequisites that are missing in many other places in Sweden. Accepting the existing wind power plan and create awareness about the benefits of wind power, are good initial steps.

### **5. INVEST IN WAVE POWER**

There are also good prospects for wave power in Tjörns municipality, which may serve as a complement to wind power. Initially, cooperation with interested utilities and companies in the wave power industry initiated.

### **6. INVEST IN FLEXIBLE AND SMALL SCALE HEATING SYSTEMS**

With investment in renewable energy and energy efficiency measures Tjörn are already well on its way towards a long term sustainable energy. Expanded counseling and possibly contributions to the installation of solar panels and heat pumps should be considered. Local district heating in conjunction with new construction (but also old) should always be investigated. When Ängholmens WWTP is developed it should also be a discussion initiated by Tjörns farmers about the use of sewage sludge to energy crops, which can be used by the island's local district heating and private units.

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# Appendix 1

## ENERGY RESOURCES AND CONDITIONS

1. SEWAGE	4
2. WASTE	9
3. WIND	13
4. WATER	15
5. SUN AND EARTH	19

**After mapping Tjörns many resources we have found that sewage and waste, solar, wind and water can be potential energy resources. In addition, we have identified that further energy efficiency measures are important in Tjörn Municipality.**

Energy use in Sweden in terms of surface area for residential and commercial buildings has fallen by 15% between 1995 and 2008 (Boverket 2011). Reasons for this include more energy-efficient heating types and the buildings are better insulated (ibid.). According to the Swedish environmental objective of "A Good Built Environment", a further 5% reduction is due in order to reach 20% reduction by 2020 (ibid.). A 50% reduction by 2050 is the next step (Boverket 2011). In 2008 Tjörn consumed 150 GWh of electricity / year (Ström 2011).

Energy efficiency is considered to be among the most cost effective solutions to reduce energy consumption. There are many different ways to proceed in order to reduce the energy consumption. Approximately 60% of the household energy goes to heating (Eon 2011c). Therefore, measures aimed at reducing the need for heating are essential.

A few years ago Tjörn Municipality began to invest heavily in energy efficiency measures for their own properties with the purpose of replacing fossil fuels (Grönlund 2011). They have so far managed to replace 80% of the oil with the help of overseeing the ventilation, insulation and installing geothermal heating (Grönlund 2011). Another strategy the municipality has is to sell off older, energy-intensive buildings such as old school buildings, which are too expensive to renovate. The idea is partly that those who buy these properties, which are often sold for high sums because out of their location, mostly will renovate the property by themselves anyway. This makes the houses renovated, without the municipality needing to bear the cost (Grönlund 2011). Whether this works in practice is not something we have looked further in.

Local residents can get help like advice on energy efficiency of the municipal energy advisors. Tjörn together with Orust and Stenungsund have an energy and climate advisor who inform and guide the households, organizations and small businesses in energy and transport issues and its impact on climate (Tjörns kommun 2011c).

Energy efficiency will be an essential part of the transition to a long-term sustainable energy production for Tjörn Municipality. Energy is needed in any case, and in the following sub-chapter we have investigated various renewable energy resources.

# 1.Sewage

**By rotting sewage sludge at wastewater treatment plants, biogas is produced, which can be used for energy production. For larger sewage treatment plants an anaerobic digestion plant with biogas production is rather a norm than an exception. The aim has been to stabilize and reduce the amount of sewage sludge for practical reasons (Avfall Sverige 2008). For small wastewater treatment plants are usually more financially advantageous to send the produced sewage sludge to a larger facility for further digestion and biogas production (ibid.). What is true for the Tjörns case? What resources are available?**

Tjörn Municipality has four municipal wastewater treatment plants (WWTP) with about 10 000 members of a total of about 15 000 inhabitants (Tjörns kommun 2006). The four sewage treatment plants in the municipality are: Sunna WWTP in Kyrkesund, Skärhamns WWTP, Ängholmens WWTP in Rönnäng and Höviksnäs WWTP. During the summer months, an average of nearly 23 000 people are staying in Tjörn Municipality, of which about 17,000 people are expected to be connected to municipal WWTP. The higher load during the summer months occasionally exceeds the capacity of the four municipal sewage treatment plants (ibid.). There is also new construction of housing in the municipality, which is planned to be connected to municipal water- and sewage system. (Dahllöf 2011).

The number of properties with individual sewage is estimated to be between 3000-5500, but an investigation is in progress in the Municipality of Tjörn (Wik 2011; Andersson 2011b). Some properties have reportedly formed larger systems together with neighboring properties, with a common smaller sewage plant (ibid.). In the current situation there are no guidelines for emissions levels from private sewers, but areas around Stigfjorden Nature Reserve are planned to get high protection levels in the near future (Wik, 2011).

Tjörn Municipality is of the above reasons, in the decision phase of how the future municipal sewer system on the islands is going to be planned and built out (Dahllöf 2011, Carlsson 2011). At the moment the municipality chooses between two options, to expand Ängholmens WWTP or to build a sewage pipe to the mainland. Both solutions will be able to connect more people to the municipal WWTP (ibid.).

In the current situation in Tjörns municipality, biogas is produced only at Skärhamns WWTP in and used to heat the digester (Tjörns kommun 2006). The prevailing view in the municipal is that there is a lack of resources to invest in biogas production (including Wik 2011, Carlsson 2011).

## THE OPTIONS

An expansion of Ängholmens WWTP is the possibility that the project has been most extensively discussed (Dahllöf 2011; Carlsson, 2011). The idea is that Sunna WWTP and Skärhamns WWTP simultaneously close down and the waste water is diverted to the new Ängholmens WWTP (Norconsult 2009). The current load of the three sewage treatment plants is around 10 000 pe and the expansion of Ängholmens WWTP should be dimensioned for 20,000 pe<sup>1</sup> (ibid.).

For some time now the planning of the expansion of Ängholmens WWTP has been halted (Carlsson 2011). The municipality is instead planning to build a sewage pipe under the sea to pump wastewater to the mainland, a collaboration with Kungälv municipality and the city of Gothenburg (ibid.). Tjörns municipality is responsible for the building of the pipeline from Tjörn to the mainland, while Kungälv municipality is responsible for the increase in capacity of existing sewage systems on the mainland, and for the sewage pipelines and pump stations needed to pump wastewater to the Rya plant in Gothenburg (Dahllöf 2011).

Before the wastewater is pumped to the mainland it needs to go through a simpler form of treatment to reduce the amount of easily degradable organic matter (Dahllöf 2011). In addition to a water pipeline to the mainland, is therefore required that a simple sewage treatment plant with a flotation plant is built. Even a storm water treatment plant must be built to handle wastewater flows exceeding the capacity of the sewage system (ibid.). This type of sewage system also requires a number of major pumping stations to pump wastewater from the Sunna and Skärhamns WWTP to the simpler sewage treatment plant, and from there pumped it to the mainland (ibid.).

If the pipeline to the mainland is being built, the wastewater is to be treated at the Rya plant, which is located in the city of Gothenburg and operated by Gryaab AB<sup>2</sup>. Rya has both biogas production and a REVAQ certified<sup>3</sup> sludge production (Davidsson 2010). Biogas produced at the Rya plant is sold to Göteborg Energi, which are upgrading biogas to vehicle fuel which is then used within the region (ibid.).

The design of an expansion of Ängholmens WWTP has a digester with gas production in connection to the sewage treatment plant (Dahllöf 2011). The biogas produced will be used to cover the heating and electricity needs of the digester and plant. In the drawings there is also room to build another digester, for the digestion of food waste (ibid.). If it is economically advantageous to rot and produce own biogas at small wastewater treatment plants largely depends on the local and cost effective resources available, along with the amount of sewage sludge (Energimyndigheten 2010a).

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<sup>1</sup> Pe corresponds to a BOD<sub>7</sub>-load of 70 grams / day. BOD stands for Biochemical Oxygen Demand and indirectly indicates the amount of organic material.

<sup>2</sup> The company is owned jointly by the municipalities of Ale, Göteborg, Härryda, Kungälv, Lerum, Mölndal and Partille.

<sup>3</sup> REVAQ-certification is a quality assured sludge production, where upstream work is an important component.

## RESOURCES

The four municipal sewage treatment plants on the island produces around 300 tons DS (dry solids) of sludge<sup>4</sup> (Tjörns kommun, 2010a, 2010b). On three of the sewage treatment plants (Ängholmen, Sunna and Höviksnäs WWTP), there is no gas production instead the biogas produced by anaerobic digestion of sewage sludge is released into the air (Tjörn kommun 2006, 2010b)<sup>5</sup>. At Skärhamns WWTP about 40 000 Nm<sup>3</sup> (normal cubic meters) of biogas are produced annually from about 100 tons of sewage sludge DS (Tjörns kommun 2010a). The gas is used to heat the digester (ibid.).

If all sewage sludge produced is used for biogas production, the amount could be tripled, to about 120,000 Nm<sup>3</sup>/year (compare Avfall Sweden 2008), which corresponds to the energy content of 800 MWh (6.5 kWh/Nm<sup>3</sup> biogas) (compare Avfall Sverige 2011). To be realistic in the calculations it is assumed that 400 MWh / year of a total of 800 MWh / year can be used because of low efficiency during combustion. In previous design, the biogas is used for the wastewater treatment plant's own energy needs, which should be around 1700 MWh / year (Norconsult 2009). Together with additional substrates, biogas production could be increased.

According to the previously completed design work is approximately 4000 kWh of biogas could be produced daily at a load of 15 000, which would mean that 1500 MWh of biogas can be produced annually (Norconsult 2009). The design also highlights that biogas can be used to heat the digester. In this case, use 1000 kWh a day to heat the digester (ibid.), which would mean that about 1100 MWh produced biogas remains each year.

Additional sewage sludge collected from septic tanks in the community, is estimated to approximately 5000 m<sup>3</sup> annually<sup>6</sup> (Wik 2011), which even if underestimating should be equivalent to an additional 100 tons of sewage sludge DS. Tjörns municipality also plans so more households can be connected to the expansion of the Ängholmens WWTP. Whether sludge from septic tanks is collected or not, 400 tons DS sewage sludge could be calculated as the amount that can be digested in an expanded Ängholmens WWTP. The total potential of biogas production from 400 tonnes TS sewage sludge should be 160 000 Nm<sup>3</sup>, which represents about 1,000 MWh annually.

## COSTS

Costs for the election of sewage system has been divided into two parts, the cost during construction phase and during the operating phase. Tjörn Municipality has focused on costs during the construction phase. We have only been able to take advantage of cost estimates for the expansion of Ängholmens WWTP and not for a pipeline to the mainland. Cost estimates shall according to the municipality show that the drain to the mainland and an expansion of Ängholmens WWTP are in need of about the same budget during the construction phase (Carlsson 2011). The pipeline will require a total budget

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<sup>4</sup> Höviksnäs WWTP: 93 ton DS (DS-content 18 %); Sunna WWTP: 10 ton DS (DS-content 3,5 %); Skärhamns WWTP: 85 ton DS (DS-content 24 %); Ängholmens WWTP 125 ton DS (DS-content 26 %).

<sup>5</sup> At the Sunna WWTP there is no digestion, the sludge is transported to Skärhamns WWTP.

<sup>6</sup> Emptying of 2 m<sup>3</sup> of sludge per year for approximately 2,000 properties, and emptying of the 2 m<sup>3</sup> every other year for 1000 properties.

of around 130 million SEK<sup>7</sup> and the expansion of Ängholmens WWTP approximately 125 million (ibid.). Tjörn Municipality believes that primarily cost and economies of scale are in favor of building a sewage water pipe to the mainland (Carlsson 2011).

The cost advantage that particularly is highlighted is the amortization period for the investment cost, which should be longer for the pipeline (Carlsson 2011). The municipality mean that the amortization period for the pipeline is 50 years against 33 years for the expansion of Ängholmens WWTP (ibid.). The municipality will, therefore have more time to pay back before new investments are needed. A cost advantage during construction of the expansion of Ängholmens WWTP, could be contributions from various environmental and rural development projects. Money for the project C2CI might be used.

During the operation phase the pipeline will generate three types of costs that differ from an expanded Ängholmens WWTP: A water and sewage-charge to the municipality of Kungälv (who are members of Gryaab AB), the operation of the flotation plant and stormwater unit and energy costs for pumping stations. Operating costs for an expanded Ängholmens WWTP consists primarily of the operation of the sewage treatment plant.

Kungälv municipality will request water and sewage charges for the reception of sewage and further transport to the Rya plant. The fee is likely to consist of a fixed and a variable part (Dahllöf 2011). The fixed fee will cover investments in a capacity increase of the sewage network in the municipality of Kungälv. The variable fee is instead based on the number of cubic meters Tjörns municipality is pumping out the sewer (ibid.). The municipality of Kungälv will use the variable portion of the fee to cover the needs that exist. If Kungälv municipality or Gryaab AB needs to implement initiatives and new investments, the fee will therefore be raised for Tjörns municipality, with limited ability to affect pricing. Depressed operating costs through economies of scale as a sewer to the mainland may cause, should be able to control water and sewage fees from the municipality of Kungälv, but future fees will be difficult to predict.

Another expense that is likely to differ between the pipeline to the mainland and an expansion of Ängholmens WWTP, is the cost of the current energy needs. If energy prices increase, the expansion of WWTP Ängholmens is to have significantly lower operating costs because the plant will have self-produced heat and electricity, and also have less need for energy-consuming pumping stations. And because the sewage treatment is funded by the water and sewage tariff, the municipality will have more control over the pricing of water and wastewater tariff against local residents, if they choose to expand Ängholmens WWTPs.

The treatment of sewage sludge currently costs about 500 per ton of sludge, a total of at least 150 000 per year. There is also a cost for the collection of sewage sludge. These two costs will disappear if a pipeline is being built to the mainland, and instead be included in the sewage fee to the municipality of Kungälv. In addition the local residents who have private septic tanks will have to pay an collection fee.

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<sup>7</sup> Drainage pipes will cost about 80 million, a flotation unit and a stormwater treatment unit another 40 million and the projecting about 10 million SEK.

## OTHER POSSIBILITIES

Produced sewage sludge is today used as plant soil (Andersson 2011b). The sewage sludge is collected from municipal sewage treatment plants by a contractor. Sewage sludge is shipped to a waste facility in Stenungsund for processing and manufacturing of plant soil (Tjörn Municipality 2010b). As for private sewers Tjörn Municipality is one of the few municipalities in Sweden that let homeowners with individual sewage be responsible of emptying their own septic tanks (Wik, 2011). The sludge is probably proceeding the same treatment process as sewage sludge at municipal WWTPs.

Sewage sludge in Tjörn has in analysing heavy metal concentrations levels well below the statutory limits (compare Naturvårdsverket 2010, Tjörns kommun 2006, 2010a, 2010b). For some heavy metals the sludge also have concentrations far below the more stringent limits that may be introduced into Swedish law in 2012 (ibid.). Organic pollutants are in the current situation considered not to affect nature or mankind in a negative way, since most pollutants are dissolved into less dangerous compounds relatively quickly (Naturvårdsverket 2010). The organic pollutants which there is greater uncertainty about, are the persistent organic pollutants (ibid.).

If wastewater treatment operations are retained in Tjörn Municipality through the expansion of Ängholmens WWTP, there would be easy to handle the sewage sludge. Current disposal system can be used, where sewage sludge is collected by a contractor. The municipality may otherwise deal with sewage sludge on their own by entering into agreements with the company Veolia Vatten AB which is located on Tjörn. There are also agricultural activities in Tjörns municipality which can use sewage sludge as fertilizer. If sewage sludge is used as fertilizer it is however probably a lot of work required to increase the acceptance in the community, because out of fear of heavy metals and other hazardous substances in sewage sludge. An upstream work in connection with the enforcement work within the municipality can increase control of the persistent organic pollutants and thus an increased acceptance.<sup>8</sup>

If the sewage pipeline is built instead, the sewage sludge will end up at the Rya plant in Gothenburg. From 2010 the sludge management is divided between contractors Veolia Vatten AB and Kuskatorpet Lantbruk & Entreprenad AB (Davidsson 2010). Since Veolia Vatten AB Company is located in the Municipality of Tjörn (ibid.), is likely that a part of the produced sewage sludge is to return to Tjörns municipality. According to Gryaab AB's environmental report Veolia Vatten AB should be the manufacturer of plant soil of the sludge and Kuskatorpet Lantbruk & Entreprenad Ltd be composing sludge (Davidsson 2010). According to Veolia Vatten AB (2011) the REVAQ certified sludge from the Rya plant will be used to manufacture fertilizer. Of the non-certified sludge different types of soil products including plant soil and soil conditioners will be produced. Only 1% of the REVAQ certified sewage sludge from the Rya plant was used in 2010 in agricultural activities (Davidsson 2010), which is probably due to the resistance against the spreading of sewage sludge in agriculture in the Gothenburg region.

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<sup>8</sup> An extended upstream work will also be required if the wastewater is sent to the Rya plant, as the Rya sludge production is REVAQ certified.



## 2.WASTE

Biogas is produced through anaerobic digestion, which is an anaerobic (oxygen free) digestion of various organic substrates. The substrate that can be used is in addition to sewage sludge includes food waste, agricultural residues and energy crops (Energimyndigheten 2010). Forestry residues may be necessary in the future when the second generation biofuel develops (thermal gasification) (ibid.). The most favorable substrate to use for biogas production is in addition to sewage sludge especially food waste from household and restaurant and food industry (Energimyndigheten 2010). The reason is that the substrate provides the greatest environmental and societal value by closing cycles (ibid.). These substrates normally have no price tag and no competition for other uses, which is rare. Therefore the mapping of the substrates in Tjörn Municipality has been focused on food waste.

In Tjörn Municipality collected food waste (primarily fish offal) and forwarded to Borås and Trollhättan for treatment and biogas production (Johansson 2011). The biogas is upgraded to vehicle fuel and used as fuel in each municipality. The collection system runs by an entrepreneur who daily collects food waste in the municipality with the help of three trucks. The trucks have two separate compartments, one for food waste and one for the household waste (ibid.). The municipality is currently planning to change the collection system of household waste possibly to offer separation of more waste fractions more than just food and household waste (Palm 2011).

### THE OPTIONS

Biogas can be used to produce both heat, electricity and vehicle fuel. When biogas is used for heating (local or district heating) it requires only that water vapor is separated before combustion takes place in a boiler (Biogasportalen 2011). Biogas can also be used to produce both electricity and heat simultaneously, CHP, by using a gas engine. With such a process about 30 - 40% of the energy is extracted as electricity while the rest becomes heat (ibid.). In order to produce vehicle fuel from biogas, the biogas energy content needs to be raised through an upgrading process where carbon dioxide is removed and the methane concentration reaches 97%. This requires an upgrading facility adjacent to the digestion plant (ibid.).

Exploiting biogas may require investment in infrastructure. To effectively utilize warming potential, it is advantageous with an existing district heating network. For the biofuel filling stations and a vehicle fleet that can use biogas are required. These can be used in small-scale solutions in a beneficial way by focusing on local investments, such as pipelines to nearby buildings and filling stations in connection with the biogas plant. It is also advantageous to build a biogas plant for food waste in connection to the sewage treatment plant to take advantage of existing infrastructure and facilities, since digestion is already active here.

## RESOURCES

Today around 620 tons of food waste is collected and processed annually from households in the Municipality of Tjörn. It is mandatory for residents to sort food waste. Random testing has shown that much food waste still ends up in household waste (Johansson 2011). It is also common to households in the municipality to compost their food waste in the garden.

Within Tjörns municipality companies and other businesses may also get food waste picked up at an additional cost. Today, about 10 percent of businesses requests the service, which generates 300-400 kg of food waste a week (15-20 tons / year) (Andersson 2011a). The fishing industry in Tjörn generates about 400 tons of organic waste in the form of fish waste annually (Ström 2011). Within Tjörn Municipality, there are currently plans to include service for companies and businesses in the basic offer, at no extra charge, in order to collect more food waste (Johansson 2011).

The total amount of collected food and food waste (including fish waste) is 1040 tons. Today's collection amounts to provide about 345,000 Nm<sup>3</sup> of biogas and thus generate approximately 2200 MWh / year<sup>9</sup>. With a low efficiency in gasengines for heat and electricity generation, about 50% is utilized - giving 1100 MWh. Along with sewage sludge annually around 1,500 MWh of heat and electricity can be produced.

Tjörns municipality has a total of 15 000 inhabitants spread over approximately 6300 households. According to Avfall Sverige (2008) a person generates annually about 100 kg of food waste in Sweden, of which 70 kg is reasonable for practical reasons to collect. It should therefore be possible to collect about 1,000 tons of food waste from households in the municipality. During the summer months, additional 200 tons of food waste is collected because of the extensive tourism and the large number of interim housing<sup>10</sup>.

There are a total of some twenty restaurant and hotel businesses, eleven local schools, three grocery stores and five other businesses that generates food waste in the Municipality of Tjörn (Tjörns kommun 2011b). If all companies and businesses collect food waste to the same extent as the companies and businesses mentioned, 150 -200 tons of food waste could be collected annually instead.

If food waste from households, companies and businesses are on a larger scale (with the above specified limits), the potential collection amount is 1800 tons of food waste. Fish waste will probably stay at the same amount as before (400 tons). This should provide about 500 000 m<sup>3</sup> of biogas, providing further 1 000 MWh per year.

The smallest possible amount of biogas that can be produced in the municipality is therefore 3 200 MWh. With the constant evolution of technology in the production of biogas, the biogas yield in the near future could be even higher.

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<sup>9</sup> Biogas yield of food waste and fish offal are 204 and 537 m<sup>3</sup> per ton of wet weight and the concentration of methane is 63% respectively. 65% of the total amount of biogas (Svenskt Gastekniskt Center, 2011) and the energy yield of the pure methane (100%) is 10 kWh per m<sup>3</sup> (Avfall Sverige 2011).

<sup>10</sup> Usually a person generates 70 kg food waste in 12 months, equivalent to approximately 6 kg / month. A further 15 000 people over two months, thus generates 180 tons of food waste.

## **COSTS**

The current state of organic source separated food waste generated in Tjörn revolves mostly around different forms of costs for the municipality. In the last year the Municipality of Tjörn paid 2.2 million for management and disposal of food waste (Johansson 2011). In the same year 620 tons of food waste were collected from households (ibid.). Tjörns municipality pays 595 SEK / ton, approximately 370 000 SEK for the treatment of food waste each year (Carlsson 2011).

Opinions about the economic viability of biogasplants is shuttered. Jonas Stenfeldt (2011), project manager for Swedish Biogas International, believes that it would need a flow of approximately 10 000 tons of organic material per year, for a biogas plant to be economically justified (ibid.). Tjörn Municipality has the potential to collect at least 1800 tons of food and food waste in the current situation. Difficulties on profitability is also based on the different types of substrates to be treated in Tjörns municipality, which requires a certain type of equipment to co-digest (Stenfeldt 2011).

By looking at case studies in Sweden one encounter however a completely different picture. The following describes an example of the economy on a co-digestion plants which handle both sewage sludge and food waste.

## **CASE STUDY – SVEDJAN IN BODEN**

Boden Municipality has over the past 20 years been actively working with environmental and resource management issues (Held et al. 2008). In 2003 they built a biogas plant which is only used to warm up Svedjan sewage treatment plant. After continued investment and upgrades sewage sludge and food waste are now being co-digested.

In 2007 the plant received 1 200 tons of food waste and 960 tons DS sewage sludge and produced 5500 MWh of energy for heating, district heating and vehicle fuel. Digestion residues produced is used as soil fertilizer. The facility makes use of thermophilic anaerobic digestion, where the substrate is digested in 14-16 days. It is equipped with both a garbage disposer, sanitation chamber, raw sludge layer, gas boiler and upgrading plant for biogas, all that is required for an anaerobic digestion facility able to process the substrates in the Municipality of Tjörn (ibid.).

The overall investment costs amounted to 46.3 million, were 18.7 million were financed through various grants (Held et al. 2008). There are several economic benefits of investments, including cost reduction in food waste management, income from the vehicle fuel and the reduced amount of sludge that must be handled.

Overall it is estimated that investment has led to savings of about 3 million / year, giving a payback period of 10 years (ibid.). In connection with the construction and operation of the facility it has also created jobs and Boden has reduced its carbon emissions by over 1 400 tons per year. Even the transport of sewage sludge has been reduced by 700 annually. Biogas from Svedjan Boden supplies in the near future six buses, three heavy

vehicles and 150 municipal and private cars with biofuel every year (ibid.).

## OTHER POSSIBILITIES

Also substrates from the agricultural sector can be used for biogas production. Substrate from the agricultural sector is usually less attractive than food waste, because the substrates are often scattered over large areas, which complicates the collection to a large-scale biogas production (Energimyndigheten 2010a). However, this should not be the case in Tjörn, a municipality with a small distance between the sewage treatment plant, agriculture and livestock keeping. Although agricultural residues and energy crops are not treated in this study, there may be significant future opportunities for Tjörn to increase biogas production.

The most advantageous agricultural substrate that can be used for biogas production is manure (Energimyndigheten 2010a). The reason is that manure is disposed of and contained in the digestion process, which simultaneously gives a reduction in greenhouse gas emissions into the air. It is usually recommended that farms produce biogas for their own use, as manure is not profitable to be collected and transported. The digestion process can be used on the farm to close the cycle (ibid.). Within Tjörns municipality, there should be two to three farms engaged in livestock keeping to the extent necessary to invest in a biogas plant (Karlsson, MT. 2011).

When biogas is produced digestion residues are obtained, which contains water, organic matter and nutrients (Biogasportalen 2011). Residues from biogas plants that digest food waste, fish waste, manure, agricultural residues and energy crops can be used as fertilizer. Manure of the above origin can be classified and certified as bio-fertilizer if the biogas plant has gone through a certification process where concentrations of metals and pathogenic bacteria are being controlled. These residues are suitable as a fertilizer in agriculture (ibid.). The residues are of the same content as sludge from biogas production at wastewater treatment plants.

All types of residues contain phosphorus and are adequate for plant nutrition, which suggests the use of sludge as a fertilizer in agriculture (Biogasportalen 2011). There is a greater risk of high levels of heavy metals in the sludge than in the bio-fertilizer, as water and wastewater network is also used by heavy industry.

Instead of using sludge in agriculture, the sludge is often used for the production of various types of agricultural products (ibid.). It should be noted that the Swedish Environmental Protection Agency estimates that it is "very important" (Naturvårdsverket 2002) to recycle phosphorus from sewage and from other potential sources of phosphorus (ibid.). The subject is the environmental and resource problems associated with the mining of phosphate minerals and that it is a finite natural resource. There are also problems with fertilizer production, and eutrophication (ibid.). The Environmental Protection Agency also supports the recycling of phosphorus because of the so-called waste hierarchy<sup>11</sup>, and because of the economizing and recycling principles in the Swedish Environmental Code (ibid.).

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<sup>11</sup> According to the Environmental Protection Agency (Naturvårdsverket 2002 p. 69) Sweden's national waste hierarchy indicates that "of different methods of disposal re-use of materials must have top priority. This is

### 3. WIND

Wind turbines have a relatively simple technique. The wind speeds up a rotor using the rotor blades and a generator that is connected to the rotor converts kinetic energy into electricity (Svensk Energi 2011). The technology is constantly improving which leads to the construction of wind turbines that can produce more and more energy. The most common size today has an installed capacity of 2 MW, but there are also wind turbines with capacity of 6 MW and on the drawing boards between 10-20 MW (ibid.). A wind turbine is running about 80% of the time, and offshore wind turbines could generate roughly 50% more energy than those on land (ibid.). Wind energy works as a complement to hydro power in Sweden. When the wind blows a lot of, the water in reservoirs are being stored. In 2010, wind turbines produced about 3.5 TWh. The government's goal is that wind power will produce 30 TWh by 2020 (ibid.).

Wind turbines are classified as environmentally hazardous activities and are thus treated at a trial. The municipality has a right of veto regarding the construction of wind turbines, but if the government believes it is extremely important to build the power plant they can decide in the matter over the municipality (Iveroth 2011). There is some resistance against wind turbines in Tjörn today and the governing parties, with the exception of the Centre Party, are against the development of more wind farms (Persson 2011). The reasoning is that wind power is considered disturbing to the landscape, and that they are subsidized (ibid.).

Tjörns municipality has good potential for wind energy thanks to good wind conditions and today there are five small turbines in Tjörn. There are plans to build four wind turbines with a capacity of 2 MW (Grönlund 2011). The municipality's wind power plan, which is not adopted, but will go to consultation, mention plans for twelve large wind turbines with a capacity of 2-3 MW (Iveroth et al. 2011). A wind turbine with 2 MW of power can produce 6000 MWh / year, and a turbine of 3 MW up to 8000 MWh annually (Ström 2011). If the twelve wind turbines in the wind power plan are built, they can together generate 84 000 MWh annually.

Investment costs for wind turbines is normally between 14,000 to 16,000 SEK per kW and operating costs between 15-20 cents per kWh (O2 2011).

#### OWNER STRUCTURES

Private individuals can buy shares in wind power through a company, which helps lower energy costs and new construction of renewable energy (Paulsson 2011). By buying a share, for example for 6700 SEK, the shareholder is guaranteed to purchase 1000 kWh for the same price, for example, 24.5 Swedish cents / kWh. (example from wind power company O2) (O2 2011). Including energy, electricity certificates and VAT the price will be about 70 cents / kWh. The cost of the share is refundable when you decide to

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followed by recycling and energy recovery. Recycling is a priority in energy when environmentally motivated. Landfilling is the last resort for waste which cannot be handled by other means. "

withdraw from the system (ibid.). For a private person, the electricity price in the market is currently around 115 cents / kWh, incl. energy tax and VAT.

A homeowner who uses 25,000 kWh / year, buys 25 units à 6700 which will cost approximately 170 000 SEK, which is refunded when one chooses to withdraw from the entry system. With shares in wind power the homeowner pays approximately 17 500 SEK / year for his electricity consumption, while the homeowner to the usual price of electricity are paying 29,000 SEK each year - a cost saving of more than 10 000 SEK / year. Even companies and housing associations can buy shares in order to make cost savings or to stand against price increases for electricity (O2 2011). Many companies and housing associations have made cost savings of between 20% to 40% (ibid.).

If the bank loans is necessary for the purchase of shares, it is reducing the cost savings due to interest expense for the purchase of shares. Individuals, companies and housing associations that have capital therefore makes the greatest cost savings per year. If Tjörns municipality buy shares to cover the electricity consumption of the public sector (13 000 MWh) it would cost the municipality about 90 million SEK (O2 2011, Ström 2011). Because of the expense it is probably not realistic for Tjörns municipality to buy shares in wind power. Buying shares in wind power as a municipality can also be viewed as a non cost-effective investment if the company that you buy shares from have a profit interest, and therefore charge a higher cost (Paulsson 2011).

When a municipality has an energy consumption greater than 7000 MWh, as Tjörn, it serves the municipality to invest in self-owned wind power (Paulsson 2011, Forsberg 2011). The benefits with municipally wind include that it can be exempted from the current energy tax of 28.3 cents / kWh (O2 2011). The municipality pays for the investment cost of 90 million or less, and the operating expenses.

As an example the Municipality of Rättvik has chosen to own wind turbines because it leads to an opportunity to use tax exemption (O2 2011). The three wind turbines cover 70% of the municipality's electricity consumption and the municipality is expecting savings of 3 million SEK per year (O2 2011). The exemption is only possible to exploit for their own consumption in municipal operations and cannot for the population (Forsberg 2011).

To cover Tjörns total electricity consumption with renewable electricity, the municipality may choose to produce their own electricity. It is then connected to the Nordic electricity network Nordpool (Svensk Energi 2011) and the electricity supplier has the right to determine the price for the competitive part (ibid.). The price however, tend to be under the market price on Nord Pool. It is also advisable from an environmental point not to put a lower price than that prevailing in the Nordic electricity market, because a lower price reduces incentives for energy efficiency (Paulsson 2011).

It is quite possible that the municipality owns the wind turbine (or other renewable energy) in other parts of the country (Forsberg 2011). A property outside the municipality may have both advantages and disadvantages. Competition for land within the municipality decreases, however, the energy loss through the transport on the grid means to less cost- and energy efficiency (Paulsson 2011). Tjörn has good conditions for

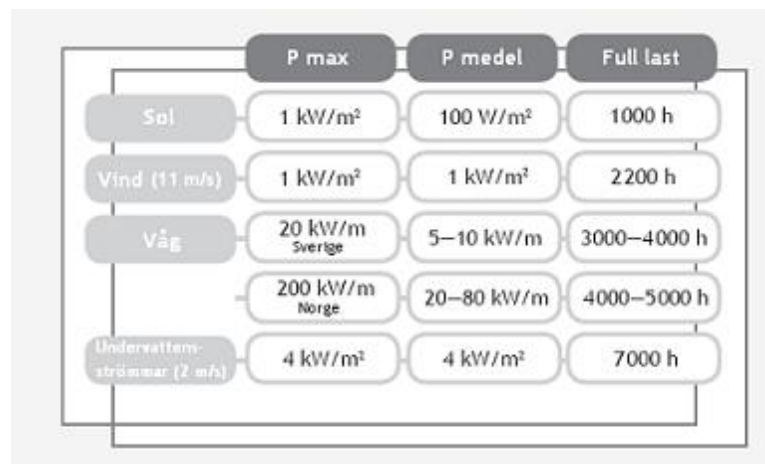
local electricity production and thus minimal energy loss when they use electricity. By local production it would also benefits jobs both in the construction and operation.



## 4. WATER

Water can be utilized in many different ways to produce energy. On Tjörn the most interesting way is through the ocean waves. Wave power is an endless but currently relatively untapped source of energy. There are currently three different technologies in the world to convert wave motion into electricity: wave activated, oscillating water columns, and the over-washing of waves (Energimyndigheten 2011d). These in turn can be divided into coastal placed, inshore and offshore wave power plant (ibid.). The potential for wave energy is believed to be large (Seabased AB, 2011a). It is estimated the annual potential in the world to 10-15 000 TWh per year. Only the Baltic Sea has the potential to cover 18% of Sweden's energy consumption (24 TWh in 2007). In Sweden, the estimated potential is 10 TWh per year (ibid.). But what about in the Tjörn case?

Compared to wind power the expected energy density per wavemeter is about 10 times greater than the wind per square meter and the utilization rate is also much higher, about 50% of the installed potential annually (see Figure 1) (Seabased AB, 2011a).

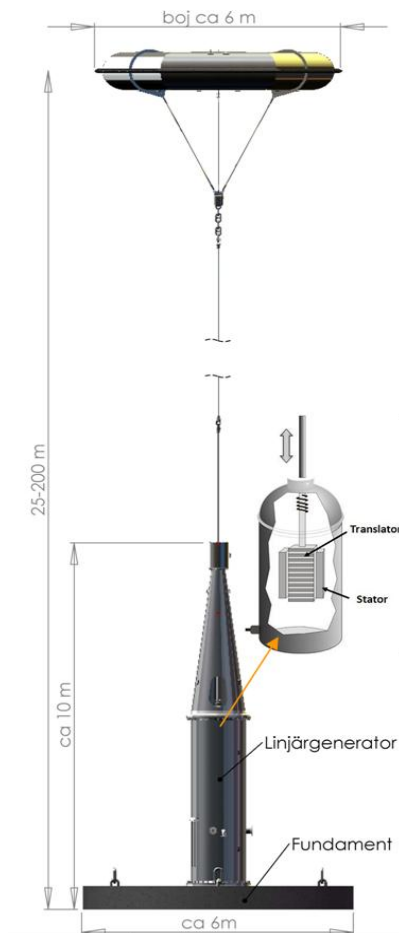


**Figure 1: Basic physical comparison of renewable energy, sun[sol], wind [vind], wave [våg] under-water currents [undervattensströmmar]. (P max = maximum effect, P medel = mean power over time, Full last = hours / year of operation for maximum production held constant. 1 year = 8760 h)**

Since the wave power plant has a high average power relative to its maximum power there are excellent prerequisites for good profitability. However, technology is too new to be able to give exact figures. The closest analogue is the wave power plant which will be completed in late 2011 in Sotenäs municipality in the county of Bohuslän. It will be a wave activated power plant located offshore (20-40 km from shore). The technology is optimized for Swedish conditions with relatively small wave heights. The company Seabased Ltd based in Lysekil will account for the construction and the plant will be operated by Fortum. The building cost is half paid by the energy authority and is in total about 260 million SEK (Karlsson, M. 2011). It expects to produce electricity at a cost of 40-80 cents per kWh, but that as technology advances come down to 50 cents per kWh, which makes wave power fully competitive with wind power without the need for assistance or tax credits (Waters 2011).



Sotenäs municipality has 9200 inhabitants. This is where the wave power park is located (Figure 2) with 420 generators and an installed capacity of 10 MW (25 kW per unit) (Seabased 2011b). It will provide an electricity generation of approximately 25 GWh per year, equivalent to a 1000 houses annual electricity consumption. The plant will occupy an ocean surface of 0.5 km<sup>2</sup> and has an estimated life of 20 years. Recommended depth is 20-100 m, but according to the manufacturer Seabased AB depths up to 200 meters are possible (ibid.).



**Figur 1: Sketch of Seabased AB's wave power generator (Seabased AB 2011d).**

## CONDITIONS ON TJÖRN

The prospects for wave power in Tjörn is more or less identical to those in Sotenäs (Waters 2011). The problem is to find an area outside the shipping lanes and military fields that exist around Tjörn, and to avoid sensitive marine habitats (Waters 2011). Optimal for Seabaseds wave systems are muddy flat bottoms that are not too deep (Waters 2011). In a master's thesis at Uppsala University, the potential location for wave energy along the west coast were examined using GIS. After taking into account all the technical possibilities and interests remained three optimal areas of a total of 26 km<sup>2</sup>. Of these, one is located 17-20 km from Rönnäng (5 km<sup>2</sup>). If you fill this field with wave power unit, one could get a power of 75 MW. However, it may not be economically feasible right now but the potential is great. Tjörns municipality is considered one of the most suitable places on the west coast of wave power (Andersen 2006).

There are many benefits of wave energy. First and foremost, it is a clean and infinite energy source (Waters 2011). The landscape is disturbed very little since the buoys to the generators are low, and often located several miles from land. The wave energy is also a much more stable source of energy compared to wind, because there are still waves even when the wind stops temporarily. Seabased who are producing wave power systems are located in Lysekil and a commercial wave energy park will be completed in late 2011 in Sotenäs (Waters 2011). This means that the company has a strong foothold in the region and opportunities for expansion along the west coast are big. In doing so, jobs are created in the region and a new factory will soon be established.

What may be problematic with wave energy is that it is a new and relatively untested technology (Seabased AB 2011c). There is still uncertainty about operating costs and requires large initial investments. Wave power is also an obstacle to trawling. Another potential problem could be the possible environmental effects even if the research available today suggests that wave energy does not contribute to any significant impact on the environment (Waters 2011). They have rather seen the formation of artificial reefs on the foundations placed in the water and it benefits many species of molluscs and crustaceans, birds and marine mammals as well as provide shelter and new spawning-places for fish.

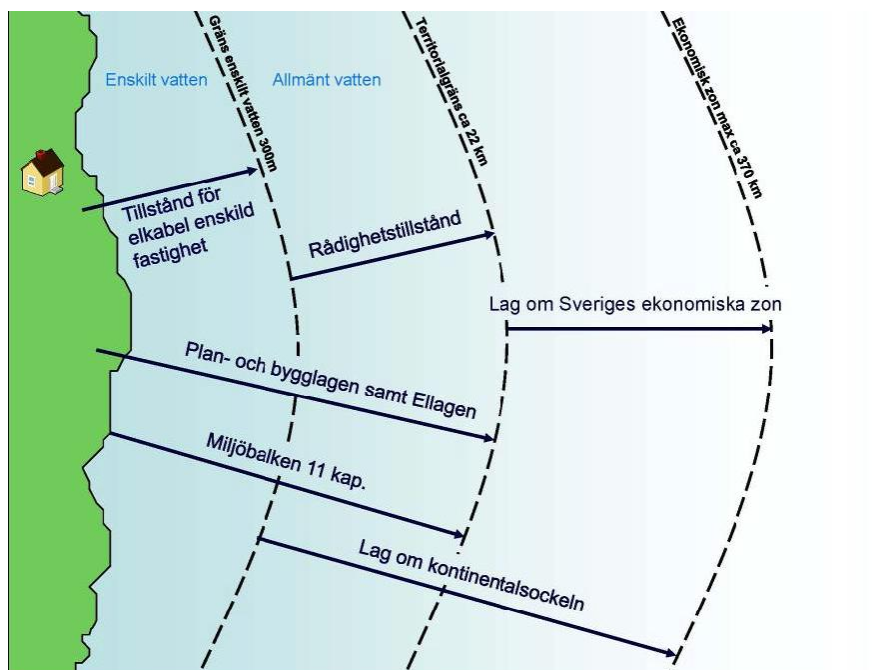
Opposition to the wave power is small. Those who had objected to the construction of Sotenäs are trawlers. However, they have been too few to create a strong opinion. During Stockholm Love 2010 Fortum showed up their wave venture. When they showed wave buoys, they also presented an opinion poll carried out by United Minds where 1000 people, 230 of which from the Stockholm area, gave their views on wave power (Fortum 2010). In the survey, 40% favored investment in wave power. These respondents were mainly from Stockholm (70%) and were positive for production of wave energy within their home municipality. Wave power is now seen widely as a great alternative to both solar and wind energy when it comes to environmental friendliness. There was widespread dissatisfaction with the expansion of renewable energy. 70% in the Stockholm area thought that the pace of expansion is too slow. Almost 40% were very positive about the wind or wave power being built in their home municipality. Regardless of where one lived in Sweden, it was thought that wave power production should be located on the west coast. Most believed that the state should invest in the development of wave energy and promote research in the area, because 20% would choose renewable energy as electricity and for the whole 60% it would to some extent be able to influence their decisions (Fortum 2011).

## **LAW REGARDING WAVE POWER**

The regulations relating to marine areas in Sweden's economic zone inside the territorial boundaries are regulated primarily in the Environmental Code (MB). Wave power has not got any practice in Swedish legislation but are to some extent equivalent to the laws regarding planning of offshore wind power as well as a whole in the 11th chapter of the MB on water activity. In order for a wave energy park to get permission to operate, it needs to meet certain basic environmental requirements of Chapter 2-5 of the MB, and include an environmental impact assessment (EIA) in accordance with Chapter

6. A number of different permissions will be required to construct a wave power park and associated wiring and pipes. The limit of private water is at 300 m from the mainland, so a wave energy park will in most cases be located in public waters. For connection and expenses of an undersea cable from a wave power park requires network concession for the line as the second chapter of the Electricity Act. In addition to these conditions is required rights for an electric cable on private waters, and on the continental shelf ground surveys may need permit and permission for water constructions (see Figure 3) (Seabased Industry AB 2009).

Under Chapter 6 of the MB, a permit application for water activities include an EIA. An EIA should be designed by the operator and shall identify and describe an overall assessment of the project's impact on man and the environment. Before the EIA is made the responsible operator has to have all necessary information and communicate it to the authorities, the public and those considered relevant and sought their views on the planned activity. They will by consulting information be given an opportunity to influence the project and the location which is an important quality assurance in the licensing process. The extent of consultation and the EIA is decided with respect to the project size and estimated impact on the environment (Seabased Industry AB 2009).



**Figur 2: Schematic diagram of the relevant legislation for establishment of wave energy, including submarine cable [only in Swedish] (Seabased Industry AB 2009).**

## 5.SUN AND EARTH

**There are many ways to take advantage of solar energy. The most obvious possibility is solar panels that provide electricity and heat. Other options are to use the stored solar energy in biomass through combustion and district heating systems or to use the stored energy from the sun and earth in rock, soil, lakes, sea or air.**

### SUN CELLS

With the help of solar cells sunlight can be converted directly into electricity in the form of direct current (Energimyndigheten 2010e). The conversion of solar energy into electrical energy requires no supply of fuel which means that the technology gives zero emissions. A solar cell consists of a disc in a thin semiconductor material which by exposure to sunlight frees electrons and creates an electrical current (ibid.).

In Sweden, the effective production of solar cells is 600-900 kWh per installed kW per year, depending on where and how the systems are installed. Such a system corresponds to a saving of 600-1100 SEK per year and installed kW, calculated with today's electricity prices (Energy Agency 2011e). The cost of PV systems in Sweden is in the range of 40,000 to 150,000 SEK per kW. A standard calculation commonly used for PV systems is about 50 000 SEK (excluding VAT) per kW. The cost of building integrated solar cells is somewhat higher (ibid.). Anyone who installs any type of grid connected PV system is able to apply for a grant of 60% (55% for large companies) of the solar installation, both materials and labor included (ibid.). The maximum contribution per building amounts to EUR 2 million (ibid.).

On a clear day a square meter of solar cells provide about 130 watts (ibid.). Currently, about 90% of all Swedish solar cells are in small systems not connected to the grid, for example in lighthouses, boats and homes. Both in Sweden and globally, however, the share of grid-connected building integrated photovoltaic is increasing (ibid.).

### SOLAR COLLECTORS

Solar collectors take advantage of solar energy by converting it into heat. The sunlight shine on a matte black finish which capture the heat and transport it further by liquid or gas. Through the circulation it can be used to heat surfaces and produce hot water (Energimyndigheten 2011e). According to the Energy Advice Centre solar collectors saves about 50% of the energy needed to heat hot water. In an average house, this means a saving of approximately 2500 kWh per year per dwelling. During 4-6 months in summer, a solar heating systems account for more than 90% of a home's total heating and hot water needs (Energimyndigheten 2009b).

A solar thermal system has a relatively high installation cost, but the energy source is free, and special support for the installation of solar energy can be applied so there is great potential to achieve a good economy through investment (Energimyndigheten 2011e). Solar heating aid is dependent upon the annual solar heat exchange and made the principle of SEK 2.50 per annual kWh (Planning 2011). The aid is limited to a maximum of 7500 SEK per apartment houses and a maximum of 3 million per project

(ibid.). The Agency uses the example of cost-benefit analysis on the 20-year amortization period and an interest rate of 5% and provide a solar heat cost of 60-100 cents per kWh, depending on conditions. In a 20-year perspective with rising energy prices can this example be competitive (Energimyndigheten 2009b).

Tjörn Municipality is currently already one of Sweden's solar densest areas, where most of the solar investments are made in small houses in addition to heating (HVAC Forum 2004). Between the years 2000-2007 as much as five grants per 1000 inhabitants were handed out in the municipality, which puts Tjörn the 6th place in the number of grants per capita in the country (Svensk Solenergi 2008).

To install solar panels in the ceiling area within the municipality's recreational areas, it does not require a building permit. At the other solutions a building permit can be required.

## **DISTRICT HEATING SYSTEMS**

District heating is an effective, relatively climate friendly and environmentally friendly form of heating. It starts from a heating central station which produces hot water that heats the entire community. So-called local heating is the same principle but with a smaller system, only a few households connected. District heating is currently the most common form of heating in Sweden, more than half of all residential and commercial buildings are heated by district heating (Svensk Fjärrvärme 2010). It is climate- and environmentally efficient because it is relatively efficient, one heating can heat several hundred or a thousand households. It is especially resource-efficient when the waste heat is used, for example from power generation or industry.

Getting the heat turned on is usually an expensive process (Svensk Fjärrvärme, 2010). It requires that the property since before has a hydronic heating system, otherwise it must also be changed (ibid.). The costs of connecting to district heating network varies considerably over Sweden, but can range from about 35,000 to 70,000 kronor for a villa (ibid.). The price of district heating will also vary, in Stenungsund, which is next door to Tjörn, the price in 2010 for a smaller apartment buildings were at 63.12 Swedish cents per kWh, while in Kungälv municipality it was at 78.39 cents per kWh (ibid.). The deployment of a district heating system is a costly process. It is impossible to say what the expansion of the network exactly would cost for Tjörn, it obviously depends on the size of the network and the choice of heating. The country was, for example, in Hässleholm 116 million, while in Mjällby it was estimated to 40 million SEK (Nilsson 2006, Petersson and Klint Hage 2010).

Tjörn has not the right conditions for a large district heating system because the buildings are very scattered. Furthermore, there is no major industry or other major source of waste heat which could make heating more economically viable. Smaller, local heating systems could, however, be developed. Ström (2011) suggest in the report primarily the development of local heating from geothermal heating or combined heat and power from the combustion of the pellets.

An example of a small scale district heating system is Vimmerby Energy. They have currently about 550 clients connected to a combustion boiler that runs on biofuel. It

delivers heating at a price of 76 cents per kWh (Vimmerby Energy & Environment AB 2011).

## **GEOTHERMAL HEATING**

Geothermal heat is a safe, renewable and environmentally friendly method of heating where the heat source is free (Ström 2011). A geothermal heat pump takes heat from one or more approximately 80-200 m deep holes drilled into the bedrock (Energirådgivningen 2011). The heat which can be extracted is about 145 kWh per meter and years. A geothermal heat pump is normally designed for about 90% energy coverage, while the remaining so-called "peak effect", is produced by an electric heater, electric boiler or similar (ibid.). This will therefore also demand some electricity. Heating costs are reduced, however, with up to about 60% compared to direct electricity. The biggest problem is during the winter months when colder than - 6 ° C, this brings difficulties for geothermal heating (Ström 2011).

Another drawback of geothermal heating is the high installation costs (about 120,000 to 170,000 SEK is common for a house) (Energirådgivningen 2011). A prerequisite for geothermal heating is a hydronic heating system in the building, otherwise it costs even more to switch to one. The heat pump must be replaced after 15-20 years, while the borehole is operational for up to 60 years (Ström 2011).

Permits are also required from the municipality to drill for geothermal heating. Tjörns has already invested actively in geothermal energy through their energycounseling (Palm 2011). During the rebuilding of the town hall they have also installed geothermal heating.

## **EARTH / SEA / OCEAN HEAT**

Soil or ground heat is taken from a 500 m long hose that is buried about 1 m thick, which can provide heat equivalent to about 30 kWh per meter of hose and year (Energirådgivningen 2011). A geothermal system is about 10-15 000 SEK cheaper than a geothermal heating system, ie it is in the price range around 110 000 SEK (ibid.). Maritime and ocean heat pumps substracts in the same way heat from the surrounding water.

Coastal properties in Tjörn could possibly benefit from ocean thermal, but this requires permission from the municipality and an exemption from the shore protection law which can be problematic. Another problem is the anchoring of boats risking to tear up the hoses from the bottom.

## **HEAT PUMPS**

There are different types of heat pumps. They have in common that they like all heat pumps also need electricity to operate, the amount varies, however.

Exhaust air heat pumps recovers heat from the air that leaves the house and requires for optimal functioning that the building has a mechanical ventilation system (Energirådgivningen 2011). Exhaust air heat pumps can be used to heat both buildings

and hot water. Depending on the type of exhaust air heat pump installed it reduces energy use by 2500 to over 9000 kWh per year. In recent years combined exhaust air heat pumps have been developed which also take heat from a short ground loop or a borehole with a further reduction in energy consumption as a result (ibid.).

Air / air heat pumps are normally installed in houses with direct electric heating and can reduce heating needs are around 20%. They often cost around SEK 25 000 (ibid.). In the winter at temperatures below - 10 ° C to - 15 ° C, they must usually be turned off.

The so-called air / water heat pumps are designed for Nordic conditions and needs just as geothermal heating system properties with a hydronic heating system (Energirådgivningen 2011). Cost is around 80,000 to 110,000 SEK. An air / water heat pump can cover about 75% of heating and hot water need but just like all the heat pumps it requires an electric heating element or process to regulate the tip effect. This means a final reduced heating costs by about 50%. A disadvantage of this system is that the noise from the outdoor unit is often higher compared with air / air heat pumps.









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