Energy solutions for Namibian fishing industry

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Summary

Fishing industry is one of the most important sectors for the Namibian economy and also a significant energy consumer. Energy issues such as security of supply and energy efficiency are becoming increasingly important for the Namibian fishing industry due to the rising costs of energy in the country. This report discusses the energy issues related to the land based operations of the fishing industry.

Energy consumption in a fish processing plant is very dependent on the type of activities. The main sources of energy are electricity and liquid fuels, i.e. oil products. Shares of these two can vary between different types of operations, e.g. focused either on freezing or canning. The role of energy measurements, monitoring and planning in the fish processing plants is emphasised. The measurement data helps in recognising where efficiency improvements are needed the most and supports the assessment for new investments by providing baseline data for quantifying and confirming the expected benefits.

This report presents an overview on the renewable energy technology options, which could potentially be used by the Namibian fishing sector. These include solar photovoltaic (PV) panels, wind power, biogas and biodiesel from fish waste. Also the energy storage technologies are discussed. A simple MS Excel based tool for evaluating the profitability of the investments in renewable energy has been developed and is presented in the report. The tool has been distributed to the Namibian fishing companies involved in the project. The report also lists energy efficiency measures, which can be studied and put into action in the fish processing plants. In addition, the possibilities for local co-operation between the fishing companies in energy production are briefly discussed.

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Preface

This report is one of the outcomes of the project "Energy Solutions for Namibian Fishing Industry" by VTT Technical Research Centre Ltd, funded by the Ministry of Foreign Affairs of Finland under the Energy and Environment Partnership Programme (EEP) in Southern and East Africa (project code NAM7019). The project ran from 2/2015 to 9/2016. The initial objective for the project was to study the possibilities for biodiesel production in Namibian fishing sector under project name: Fish based biodiesel for Namibia (FIBINA), but the project scope was extended to better correspond to the needs of the stakeholders and to cover other renewable energy and energy efficiency options. This report focuses on the energy issues related to the land-based operations of the fishing industry. The results could also be applied for other sectors than fishing.

The project results consist of this report, a seminar organised in Swakopmund, Namibia in 19th May 2016, an MS Excel tool with training material provided for the Namibian fishing companies involved in the project enabling the evaluation of profitability for investments for renewable energy. Also several training sessions on using the tool were organised for the companies in Walvis Bay in May 2016. In overall, the project set out to promote awareness on energy related issues within the industry.

The authors want to kindly acknowledge the funders, as well as several co-operation partners in Namibia; the Ministry of Fisheries and Marine Resources, the local fishing companies involved, ErongoRED, Embassy of Finland in Windhoek, and the Namibia Energy Institute.

The views presented in this report are those of the authors only.

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Contents

1. Introduction

Fishing industry is one of the most important sectors for the economy of Namibia in terms of contribution to gross domestic product (GDP) and employment along with mining, agriculture and tourism. It is also a significant energy consumer. Energy issues, such as security of supply and energy efficiency, are becoming increasingly important for the Namibian fishing industry due to the rising energy costs in the country. Furthermore, the Namibian energy system as a whole would benefit from new investments especially in electricity production.

This report introduces suitable renewable energy and energy efficiency solutions for the Namibian fishing sector, focusing on the land based facilities. It aims to provide a clear and compact description of the issues to be considered when planning on investing in renewable energy technologies such as solar or wind power or when improving the energy efficiency of a fish processing plant. The results and approach presented can be useful also within other industrial sectors in Namibia and beyond.

The report is structured as follows: First, short general descriptions of the Namibian energy sector and fishing industry are given. Second, the role and importance of energy planning related to industrial processes and future energy developments is discussed. Third, several renewable energy options and an MS Excel based tool for the evaluation of their economic feasibility are presented. Finally, energy efficiency measures for the fishing industry are listed and opportunities for local co-operation on energy solutions sought.

The key beneficiaries of the project are the Namibian fishing companies, which can utilise the proposed solutions to improve their energy planning and energy efficiency in their facilities, and to reduce the energy costs. The solutions can also help to increase the energy self-sufficiency and security. The energy efficiency measures can benefit the Namibian society and the local community as a whole by improving the profitability of the fishing business by creating energy savings and by presenting potential investment opportunities for local energy production.

1.1   Development of the Namibian energy sector

The energy consumption in Namibia has been steadily increasing during the last decade. The total energy consumption has almost doubled since 2000, from around 34 000 TJ to 61 000 TJ in 2013 (Figure 1). The same is true for the electricity consumption, which has increased from 2 000 GWh to almost 4 000 GWh over the same period (Figure 2). However, when evaluated per capita, electricity consumption in Namibia has been around 1.5 MWh/capita for past ten years. As a comparison, the figures for 2013 are 0.57 MWh/capita for whole Africa, 1.97 MWh/capita for non-OECD countries and 8.03 MWh/capita for OECD countries. (IEA 2016)
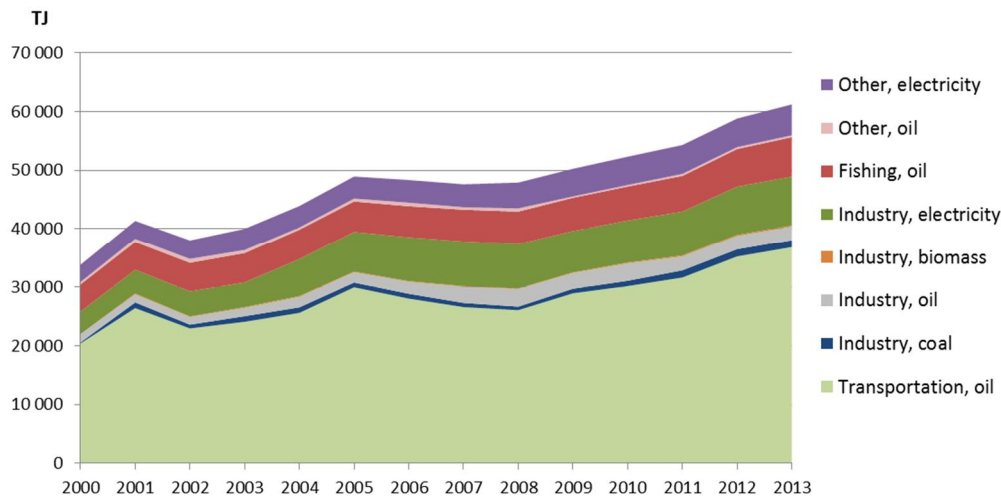
Figure 1. Total energy consumption per sector in Namibia 2000-2013 (Namibian energy statistics).
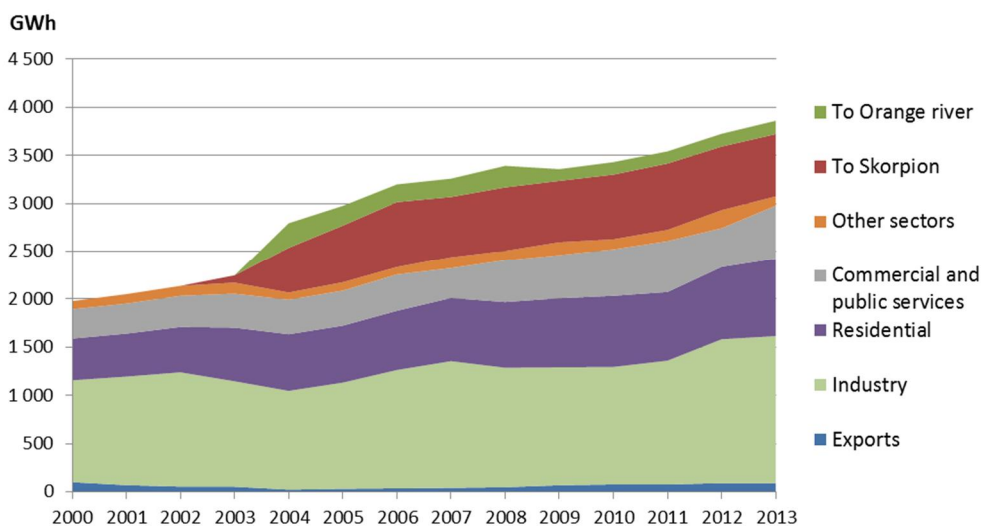

Figure 2. Electricity consumption per sector in Namibia 2000-2013 (Namibian energy statistics).

Even though the electricity consumption has grown during the recent years, the electricity production capacity in Namibia has not increased substantially and there is a strong dependency on imported electricity. E.g. on March 2015 the recorded peak demand was 524 MW (excluding Skorpion Zinc Mine) and domestic electricity production capacity was 300 MW (NamPower 2015). The share of imports in electricity supply has been over 60% during the last years. Electricity is mainly imported from South Africa, Zimbabwe and Zambia. At the same time, the electricity prices have increased from around 0.50 N$/kWh in 2007 to 1.5-2.5 N$/kWh in 2015[1] for industrial customers, depending on the region (ECB 2015). Time-of-use tariffs are commonly in use for large consumers of electricity such as businesses and industry. Electricity generation and transmission is carried out by national utility, Nampower. Distribution of electricity is done by Regional Electricity Distributors (REDs) or by local authorities if a RED is not present.

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[1] Note the currency fluctuation; in 2007 1N$≈0.1€ whereas in 2015 1N$≈0.06-0.07€

Electricity supply situation will remain critical in Namibia for the coming years and similar challenges also exist in neighbouring countries. Thus investments on new electricity production capacity have become crucial in order to secure the electricity supply and to avoid power shortages (Rämä et al. 2013). Both technical and economic development of renewable energy technologies, especially photovoltaic (PV) based solar electricity production, enables local energy solutions that can be utilised by e.g. private companies in order to secure their energy supply. This type of an arrangement is becoming increasingly common in Namibia (see Table 1 for examples). Regional Electricity Distributors such as ErongoRED are also offering a possibility of connecting distributed generation of electricity into their grid.

Namibia has a framework for Independent Power Producer (IPP) licencing in place, administrated by Electricity Control Board (ECB). Power producers of less than 500 kW in capacity are exempted from the licensing process. In addition, an interim Renewable Energy Feed-In Tariff (REFIT) programme for maximum number of 27 eligible IPPs was currently active[2] creating a framework for negotiating required Power Purchase Agreements (PPAs) with NamPower for projects between 500 kW and 5 MW in capacity. The 5 MW Omburu Solar Power plant is the first local Independent Power Producer (IPP) with whom NamPower has signed a PPA (NamPower 2015).

All renewable on-site electricity production technologies of equal or less than 500 kW are also eligible for net metering, although the technical limitations of the local distribution network are taken into consideration. Rules for net metering including principles for tariffs, compensation and billing are described in the Net Metering Rules[3] established by ECB.

Table 1. Examples of solar power installations.

Examples of solar power installations in Namibia
Solar power plants
• Omburu, 4.5MW by Innosun Energy Holdings[4], Omaruru
• Otjiwarongo, 5 MW under construction by HopSol AG[5], Otjiwarongo
Coastal installations
• Kuiseb Fishing, 120 kW Walvis Bay
• The Salt Company, 190 kW by HopSol, Swakopmund
• Roof-top installations in Spar Supermarkets, 230kW and 260kW, Swakopmund
Few other examples
• Roof-top installation in Maerua Lifestyle Shopping Centre, 500kW by HopSol AG, Windhoek
• Roof-top installation in Mega Centre mall, 500 kW by Mettle Solar[6], Windhoek
• Roof-top installation in Gwashamba Mall, 430 kW by Mettle Solar, Ondangwa
• Roof-top installation in NamPower, by Solar Age Namibia[7], Windhoek

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[2] The deadline for the programme was in 15th June 2016.
[3] http://www.ecb.org.na/images/docs/Economic_Regulation/NET_METERING-Final%20Rules.pdf
[4] http://innovent.fr/innosun/
[5] http://www.hopsol.com/
[6] http://www.mettlesolar.net/#!solar-projects/c15sf
[7] http://www.solarage.com/company-info/project-gallery/

1.2   Namibian fishing industry

Namibian fishing industry is concentrated in two locations, the coastal cities of Walvis Bay and Lüderitz. The total landings of all species have varied from around 336 000 to 475 000 tons per year. The fishing sector significantly contributes to the country's GDP, e.g. by 3.45% in 2013, with total value of 4 181 million N$ (MFMR 2013). The various fish products such as hake, horse mackarel, canned pilchard and rock lobsters as well as seal products are mostly exported to the neighbouring South Africa, European Union and other international markets. The export activity makes the fishing industry a very important source of foreign currency for Namibia. Namibian fishing sector is also an important employer.

Due to unregulated fishing activities before the Namibian independence in 1990, fish stocks were exploited by foreign vessels. However, since independence, the Namibian government has developed and established a 200 mile Exclusive Economic Zone, marine research, an appropriate legislation and a control and surveillance system to secure sustainable utilization of marine resources (Mukumangeni 2006). The total allowable catches (TACs) are distributed among the fishing companies and only licensed fishing vessels are operating in the Namibian waters. Biggest TACs are defined for horse mackerel and hake, 350 000 t and 170 000 t in 2013, respectively (MFMR 2013).

The Namibian fishing industry is one of the most significant energy consumers in Namibia. For example, the fuel consumption in fishing vessels represented 11% of the total energy consumption in Namibia in 2013 (Figure 1). The electricity consumption of the fishing sector has more than doubled between 2000 and 2013, from around 30 GWh to 70 GWh per year (Figure 3). This increase in electricity consumption is partly due to the efforts to produce more value-added fish products in Namibia in order to create new business and employment for local people. This makes energy efficiency and securing a reliable supply of electricity crucial for the fishing sector.
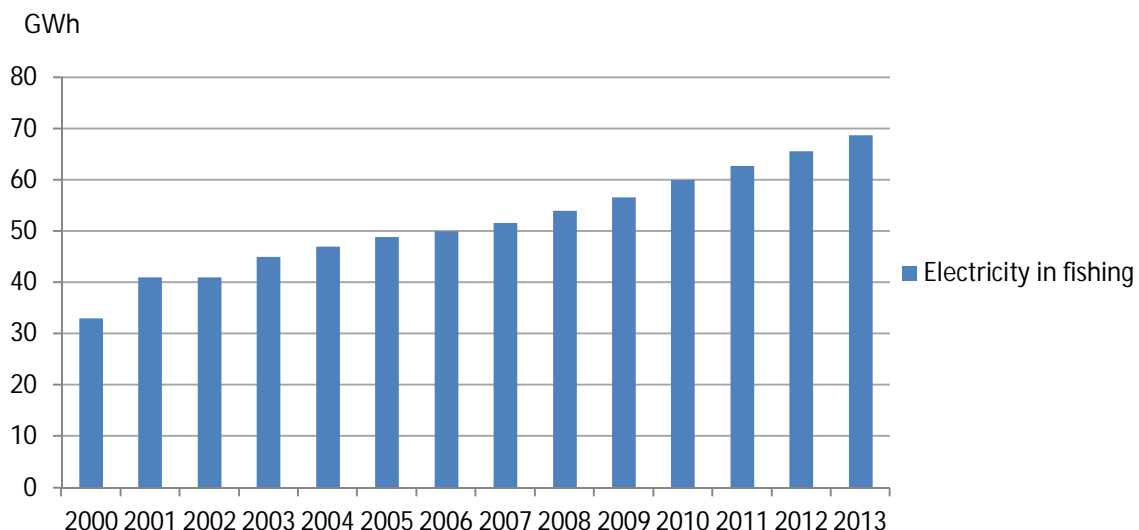
Figure 3. Electricity consumption in Namibian fishing sector 2000-2013 (Namibian energy statistics).

While this report deals with energy consumption of land-based operations of the fishing industry is it well worth pointing out that majority of the consumption within the industry consists of oil. Although there is notable oil consumption in desalination and heat and steam generation on land, the fishing vessels themselves are the largest consumers of oil products. In 2013, oil consumption within the industry was estimated to be 1705 GWh (6138 TJ).

1.3 Fishing industry as an important regional energy consumer

ECB (Electricity Control Board) is the responsible national authority on electricity tariffs and monitors and enforces existing technical and economic regulation including tariffs set by individual Regional Electricity Distribution (REDs) companies. The different REDs have varying practices concerning tariff specification, but it is common to have specific tariffs for different consumer groups and to utilise time-of-use tariffs. The tariffs for all distribution systems are available on ECB web pages. The tariff structure of ErongoRED[8] for Walvis Bay and system operated by the municipality of Lüderitz[9] presented in Table 2 are the most relevant for the fishing companies.

Consumer group definition usually applied for fishing companies in ErongoRED region is "business (bulk connections)" and in Lüderitz "large power users". Both systems have time-of-use tariffs for peak, standard and off-peak times. Furthermore, demand charges and ECB and National Energy Fund (NEF) levys are applied. Time-of-use hours for different weekdays as well as high and low season definition is identical for both systems. ErongoRED also has also specified a yearly Network Access Charge and a monthly Network & Service Fee.

Tariffs, charges, fees and levies confirmed for 2015/2016 are presented in Table 2 below for both systems.

Table 2. Time-of-use electricity tariffs, charges and fees for Walvis Bay and Lüderitz.

	Peak time (N$/kWh)		Standard time (N$/kWh)		Off-peak time (N$/kWh)		Network & Service fee (N$/month)		Charges (N$/kVA/month)	
Location	Erongo	Lüderitz	Erongo	Lüderitz	Erongo	Lüderitz	Erongo	Lüderitz	Erongo	Lüderitz
High season	2.47	3.34	1.65	1.74	1.24	1.12	1670	0	-	
Low season	1.66	1.76	1.41	1.58	1.04	1.08	1670	0	-	
Network access charge	-		-		-		-		125	0
Demand charge	-		-		-		-		131	128
ECB levy	0.016		0.016		0.016		-		-	
NEF levy	0.0108		0.0108		0.0108		-		-	

In addition to the tariffs and charges presented above, if a consumer exceeds its predefined maximum demand for more than 30 minutes a penalty charge will be applied. The amount of this charge is a sum of demand and access charges, i.e. consumer will pay 256 N$/kVA for the demand exceeding the declared value for the month in question. Shorter peaks than 30 minutes do not affect the pricing, giving the consumer time to respond and adjust if needed.

For example a business or a company within ErongoRED system consuming 10 000 MWh of electricity, demand fluctuating between about 1 000 kW and 1 300 kW each day of the year, and with a peak at midday, would have total electricity costs of 18.3 MN$. The share of each cost component is illustrated in Figure 4 below.

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[8] ErongoRED, http://www.ecb.org.na/images/docs/Tariffs/2015/Erongo_RED_2015.pdf
[9] Lüderitz Municipality, http://www.ecb.org.na/images/docs/Tariffs/2015/Luderitz_2015.pdf
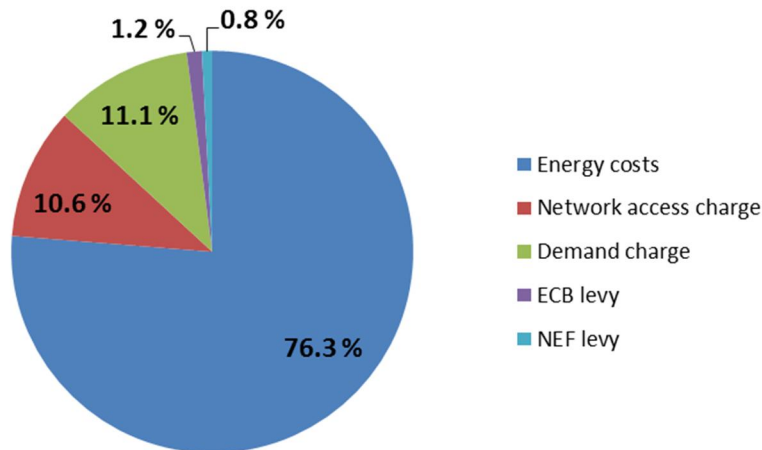
Figure 4. Share of each cost component for an example business in Walvis Bay.

The illustration shows the relatively large share of demand based charges; access charge and demand charge. Investing on local electricity production or storage solutions will change this balance as the share of access and demand charges increases when the energy cost decreases due to on-site production of electricity. These changes are discussed in more detail in Chapter 4 concerning the calculation tool for evaluating feasibility of such systems.

1.4 Energy consumption in a fish processing plant

Energy consumption in a fish processing plant is very dependent on the type of activities. The main sources of energy are electricity and liquid fuels, i.e. oil products. Shares of these two can be very different for operations specialising on processing fresh fish into frozen or canned products.

Fuels are used for heat and steam generation for the processes as well as in evaporation based desalination. Electricity is used for powering processing equipment, lighting and most notably in cooling and freezing. It is also used in reverse osmosis based desalination where such plants exist.

Cooling and freezing can be identified as the single most interesting targets for energy efficiency improvements as they typically represent a major source of electricity consumption in operations including these processes. Savings in fuel consumption can be accomplished by improving the efficiency of the heat usage within the processes by identifying and utilising waste heat flows e.g. preheating purposes or for separate processes with lower temperatures requirements. The energy efficiency measures are discussed further in Chapter 5.

Figure 5 below presents the most typical processes in fish processing plants with energy input per type (fuel, electricity or heat) illustrated with coloured arrows. Managing, monitoring and recording energy consumption divided into these or more representative division of processes for a specific type of operations is recommended.
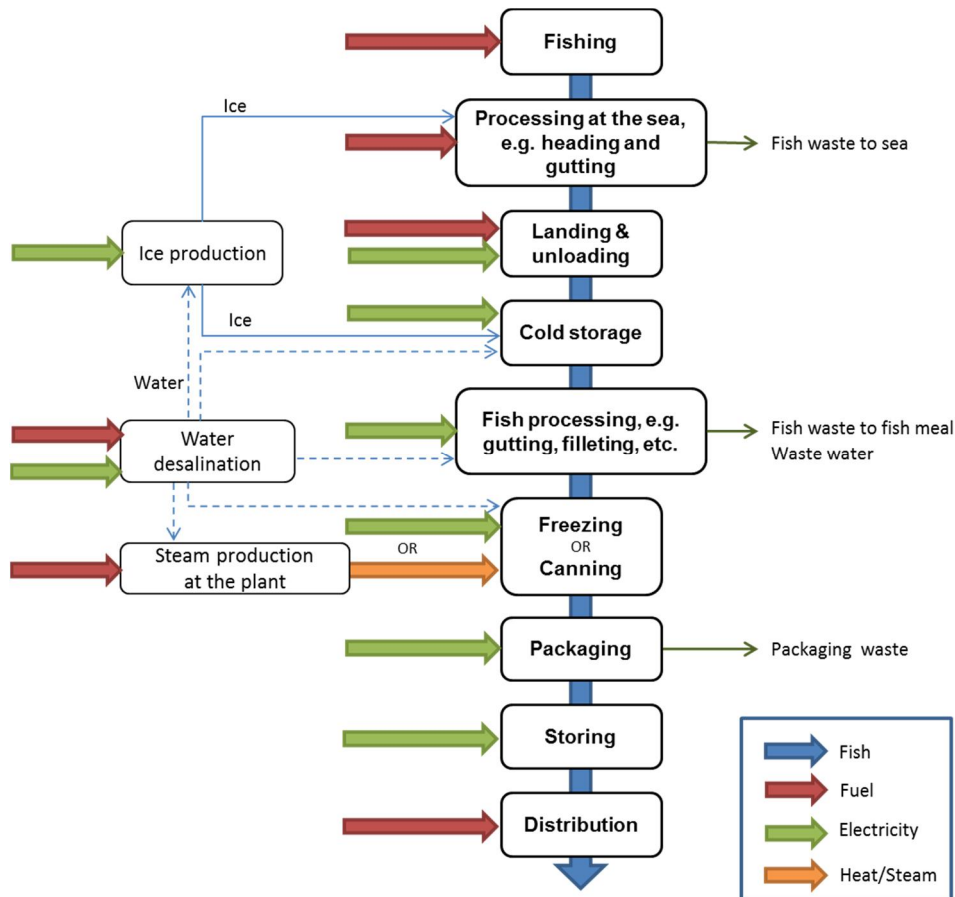
Figure 5. Simplified example of the energy flows and some material flows in a processing plant.

Studying an illustration such as presented above can reveal several possibilities for material and energy efficiency improvements. For example, using waste heat from canning process for preheating water in desalination or steam production plant could provide energy savings. The waste heat could also simply be used as a source of heat for providing warm water for showers and cleaning. In addition, the packaging waste could be used for local heat production. Heat recovery and use is elaborated further in Chapter 5.2. Co-operation between companies for example in steam generation could potentially be both cost and energy efficient. The same is true for desalination and ice production (see Chapter 6).

2. Energy planning

The definition of energy planning in the context of this report is a systematic approach for planning and developing energy related activities within the industry. This process can be further divided into four main parts;

(1) *monitoring* energy consumption,

(2) *identifying* the most significant targets for improvement,

(3) *evaluating* suitable solutions and

(4) *implementing* the required changes.

These four phases can also be considered as a continuous, iterative process for improving the energy performance of a facility. This circular nature of the concept is visualised in Figure 6 below.
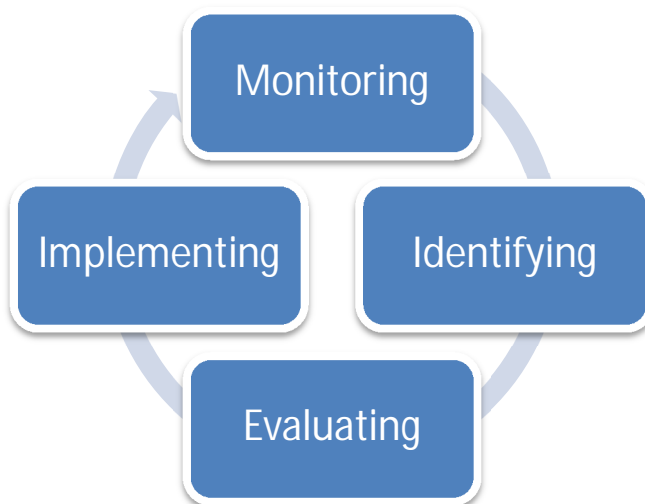

Figure 6. Basic structure and continuous nature of an energy planning process.

Monitoring will reveal where energy is consumed and help in identifying the potential targets for energy efficiency improvement. The most logical starting point is to concentrate on the processes or functions with the highest energy consumption or the highest costs due to consumption. The overall energy consumption profile is also needed in pointing out possible opportunities for local energy production.

Monitoring energy consumption is accomplished by energy metering, which is essential for providing the necessary information for the whole process. It is often overlooked or not realised to its full potential due to lack of direct economic benefits. However, it is a vital part of energy planning process as it establishes a baseline for energy consumption. If no such information is available, evaluating and confirming the benefit of any improvement is uncertain or impossible.

Planning for metering requires information concerning the operation of a facility, i.e. where and for what purpose is electricity, heat or other forms of energy used. Electricity consumption of cooling and freezing, machinery and other equipment in separate stages of production and lighting for different spaces are concrete examples of this. The setup for the monitoring system depends on the type of activities and studying the energy and material flows of an individual facility in e.g. similar way represented in Figure 5 can be helpful in the task.

Energy consumption is not the only relevant value worth monitoring. Measuring the power factor (see Chapter 5.1) for electricity as well as temperatures (see Chapter 5.2) experienced in heat related energy consumption can be very relevant. Both can also reveal opportunities for energy efficiency improvement.

Monitoring is also an important tool for operation and maintenance of any facility as it helps in detecting changes in energy consumption either with set limits for alarms or by active monitoring. While monthly compilations of monitoring data are adequate for rough economic evaluation and reporting purposes, maintenance requires more accurate data in at least intervals of one hour. This information is also relevant for investigating temporal variations of e.g. electricity demand and is often crucial for identifying and planning the actual measures and solutions for improving the system. Monitoring instantaneous demand helps in managing maximum demand and is thus important for minimising demand related charges for electricity.

Data storage solution for storing historical information collected by monitoring system is also a necessity as it enables comparison between similar periods of activity, quantifying changes made in the process in terms of energy. Key performance indicators (KPIs) such as energy consumed per tonne or kilogram of fish product can be calculated providing information on the role of energy as a factor of production.

The development needs identified from the monitoring data should be further studied and the technical solutions for energy efficiency or energy production sought. Studying available technologies based on the identified targets and evaluating their performance in terms of energy and economics will help in singling out the actions with most impact.

After the implementation of the chosen improvements, confirming their performance by monitoring is both reasonable and necessary. This information can also be helpful in improving the operation of the implemented action, e.g. by adjusting the control parameters of a new cooling system for maximising its operational efficiency.

Need for good quality data and in-depth information on the system is clear. A well planned and implemented energy monitoring will provide the needed data. Information is necessary for energy audits, evaluation of energy efficiency improvements, and for any decision or investment concerning energy. The best decisions are based on the best available information.

3. Renewable energy solutions

Renewable energy solutions discussed within this chapter include solar energy, wind power, related energy storages, biogas and fish oil based biodiesel. Discussion is linked to Namibian operational environment where appropriate.

3.1   Solar energy

The energy from solar radiation can be used to produce heat or electricity. In Namibia, the solar heating is already widely utilised and could also be used in industrial applications, e.g. in water heating. However, this report focuses on use of solar energy in electricity production.

Solar power can be produced with two different technologies: 1) by solar photovoltaic (PV), 2) by solar thermal electricity power plants, also known as concentrating solar power (CSP) systems. From the Namibian fishing industry point of view, the solar PV is the most interesting option, as solar panels can be installed within the existing production sites. The solar PV works with the photovoltaic effect, which leads to positive and negative charges creating a voltage and therefore producing electricity. (JRC 2014)

The most significant part of the newly installed solar PV systems is based on crystalline Si technology which is highly mature for a wide range of applications. This technology is expected to remain the dominant PV technology in the short-to-medium term. The technical life time of PV modules guaranteed by manufacturers goes normally up to 25 years. However, with proper maintenance, the actual life time of the panels can be significantly longer. (JRC 2014)

Degradation rate of solar panels is another issue linked to the aging of solar panels. However for established technology it is not a major issue as the degradation is estimated to be less than 1% per year, crystalline Si panels having a degradation rate (median value) of 0.5% per year. (NREL 2012)

The coastal region of Namibia presents a challenging environment for solar panel installations in terms of maintenance. The two main problems are corrosion due to a humid, marine environment and dirt in form of fine sand from surrounding desert.

The marine environment with humid air and chlorides will expose metal structures to galvanic corrosion. Special care needs to be taken to protect e.g. aluminium frame of solar panels by separating them from more noble metals in galvanic series e.g. in supporting structures and bolts. This can be done by physical insulation. One of the examples for PV installations within the coastal region listed in Chapter 1.1, the Salt Company in Swakopmund, used wooden support structures with the panels as a solution to the corrosion problem.

Dirt in the form on sand requires regular basic cleaning and maintenance in order to maximise the electricity production. The optimal tilt angles are low in Namibia. Fortunately in roof-top installations they usually are more than 5°, which is considered as a limit for serious dust issues (Sarver et al 2013). However, the problem in desert regions and also in the Walvis Bay area is the amount of rainfall that might not be sufficient to provide natural cleaning for the panels. Thus periodic, manual cleaning may be required for installations in the area. Also other pollution, e.g. fine particles from local activities such as grid blasting, may impact the output of solar panels. General experiences and measurements from local installations, e.g. roof-top system implemented by Kuiseb Fishing indicate that the issues are manageable.

The costs of solar PV have radically decreased during recent years. E.g. in South Africa the Renewable Energy IPP Procurement Programme the tariffs for PV in three bid windows have

decreased[10] from 3.3 ZAR/kWh in 2011 to 0.82 ZAR/kWh in 2014 (DOE SA 2014). However, the final cost of the solar PV installations may be very site dependent and vary from country to country, even though the price of PV system hardware would be more or less the same. This is because the costs of financing, permitting and labour are different. In case of Namibia, the exchange rate plays a significant role for imported products. In addition, installer or system integrator margins may vary significantly. Also issues such as market size, competition between different installers and regulatory framework in place may have an impact. The share of the non-technology related costs of the total costs in PV projects is expected to rise and thus the future cost reductions may be less significant than the experienced, historical development (see Figure 7). (JRC 2014)

For rooftop installations, possible need for renovation of supporting structures should be investigated and their costs evaluated. In the case of a new building, these additional costs might be marginal compared to a normal roof structure and enable more cost efficient installation of solar panels.

When planning for a renewable energy investment one must bear in mind that the true costs may differ from the early estimates, for example due to local operating conditions. For example, the investment cost announced for the Omburu solar station was around 10.8 million US$[11], and the cost per kW calculated based on that is 2 400 $/kW; higher than the estimates found in the literature. Thus, when planning for renewable energy investments the risk of rising costs should be taken into account.
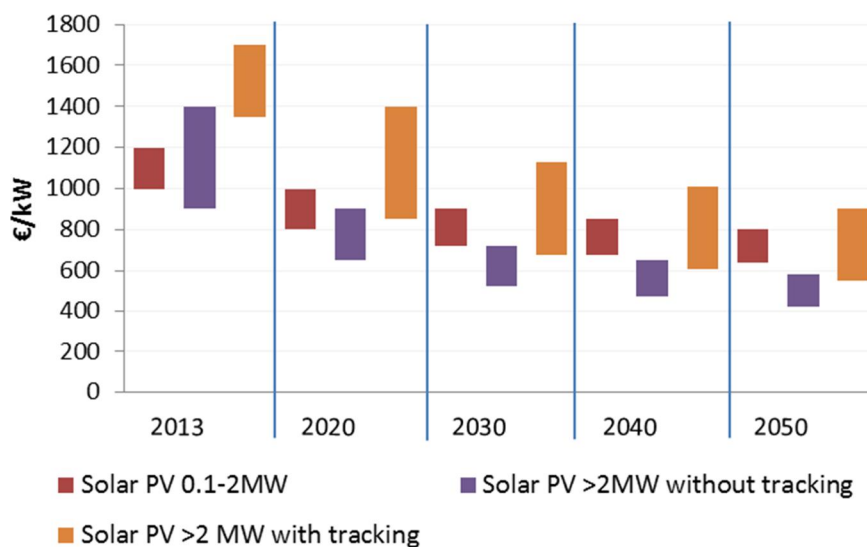

Figure 7. Estimated cost development for solar power (JRC 2014)

Solar PV installations with tracking systems following the path of sun across the sky, in order to maximise the production during a day, are very interesting in Namibia, but not well suited for roof-top installations. Their investment costs are on average 30% higher than for normal PV installations, although energy production is higher. Omburu PV plant (Table 1) is equipped with a tracking system.

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[10] In terms of April 2014 Rand value
[11] http://renewables.seenews.com/news/innosun-breaks-ground-on-4-5-mw-solar-plant-in-namibia-449352

3.2   Wind power

Wind can be utilised to mechanically power generators in the wind turbines to produce electricity. Wind power can be constructed on-shore or off-shore. The technology for on-shore installations is already mature, whereas the technology for off-shore installations is still developing. The technical life time of wind turbines is estimated to be around 20 years. The size of wind turbines has been increasing and currently the new on-shore wind turbines typically have capacities of around 2 MW. By 2050 the expected average size for wind turbines is 4.5 MW. Wind turbines are often installed as wind farms, i.e. a group of wind turbine units, sharing civil works, a substation and grid connection point. The typical capacity factors for onshore wind are 20-25%, corresponding to 1800–2200 full-load hours. (JRC 2014)

In planning phase of a wind power installation, the local wind conditions need to be carefully studied. A project on measuring the wind resources in Namibia in order to provide more accurate data for the potential investors has been ongoing by the Namibian Energy Institute (NEI), but the results are not yet publicly available. A recent study on the wind resources in Southern Africa (Fant et al. 2016) using MERRA (Modern-Era Retrospective for Research and Analysis) dataset estimates that the Namibian coastal line offers favourable conditions for wind power (Figure 8). A study by IRENA (2015) on planning renewable energy for Eastern and Southern Africa indicates significant wind resources in central Namibia as well.
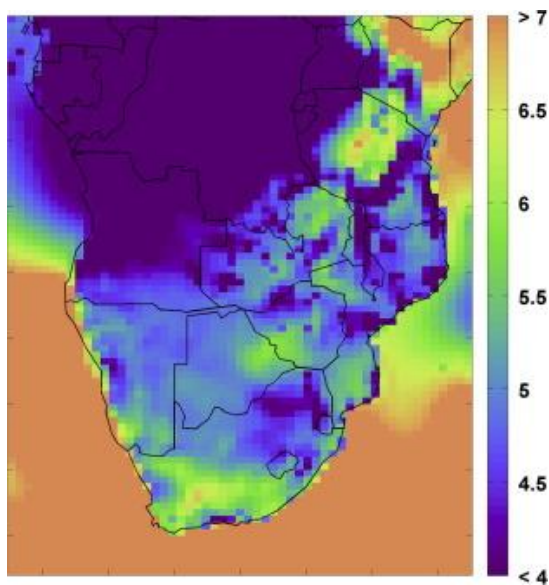

Figure 8. Mean wind speed (m/s) at 50 m for southern Africa (Fant et al. 2016).

The investment costs of wind power are highly site-related, being higher for off-shore installations. The investment cost is influenced by factors such as turbine transport distance and conditions, soil or sea bed characteristics, and distance to the grid connection point. The most significant cost component is the turbine responsible for around half of the total costs. The other factors such as the site preparation and foundation, electricity related infrastructure, financial costs and operating expenses form the other half (NREL 2015). Since on-shore wind power is already quite mature technology it is expected that capital costs will drop at a moderate rate, whereas offshore wind is a less mature technology with greater technological improvements and cost reductions expected until 2050. For example, technical lifetime and maximum capacity factors are expected to increase (JRC 2014).

The estimated development of the costs for on-shore and off-shore wind power is presented in Figure 9.
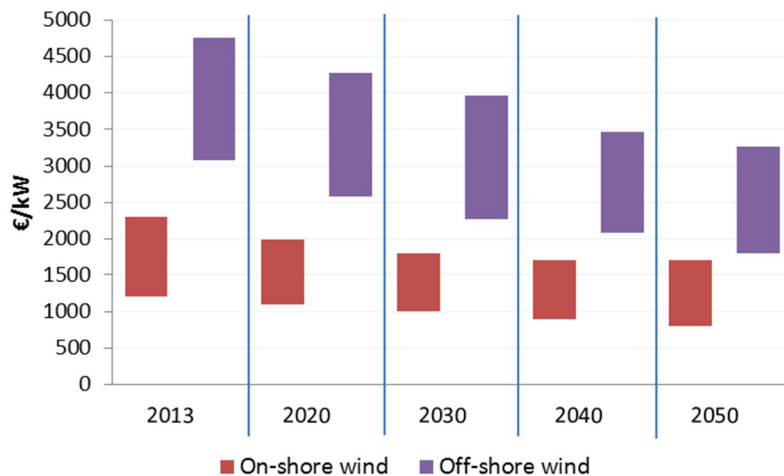
Figure 9. Estimated cost development for wind power (JRC 2014).

Currently in Namibia, there is one wind turbine (220 kW) installed in Walvis Bay. Also several stand-alone 1 kW turbines are installed around the country and used for water pumping and electricity generation for farms (WEC 2007). A 300 MW wind farm is planned to be built in Ludëritz by InnoSun - the builder of Omburu solar power station. A PPA with NamPower has already been secured for the investment.[12]

For Namibian fishing industry, the wind power could be utilised e.g. as a concept where the electricity production is outsourced to a separate company owned by several companies. Installing big wind turbines on-site next to the actual fish processing plant site may not be possible or feasible in many cases. The established wind power producer should then acquire an IPP and a PPA to be able to sell the energy to the grid. The benefits would be shared between the fishing companies who have invested to the power plant (see Chapter 0 on local energy co-operation).

3.3   Energy storage

Energy can be stored by several methods, such as mechanical (flywheel, pumped-storage hydroelectricity), thermal (ice, water, molten salt), electro-chemical (batteries, supercapacitors), and chemical (bio-fuels, hydrogen, power to gas) media. The energy storage technologies discussed here concern mostly electricity storages. Heat energy (thermal) storages are a much more mature, commercially available technology implemented most often as insulated hot water or steam tanks. The general principle of their utilisation on managing varying production and consumption is identical to electricity storages.

The electricity production by renewable energy sources such as solar and wind power fluctuates by the hour of day due to e.g. wind and cloud conditions. This creates a natural need and a market for storage technologies, enabling energy to be stored during times when production exceeds consumption and used when production falls below consumption.

The energy storage solutions can also be utilised for adding flexibility to the power system and for optimising the energy consumption of a production facility. They can be used e.g. to cut off the peak demand of the plant in order to avoid exceeding the maximum demand level fixed with the local distributor. They can also be used to store electricity generated during the low tariff periods to be used during the high tariff periods. The different scenarios for electricity storage utilisation are studied with the calculation tool developed in this project

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[12] https://www.esi-africa.com/news/wind-power-innosun-secures-first-ppa-for-namibia-farm/

(see Chapter 4). Distributed electricity storages can be installed at grid level (1-20MW storage), community level (100kW-1MW) or at micro-grid level (up to 100kW).

The electricity storage technologies have an ability to store energy over time (several hours) or an ability to deliver power with high capacities. Short-term application for storage technologies could be e.g. frequency control, whereas load shifting is an example of a long-term application. If the energy system is tailored for short-term applications, the storage technologies need to be rated at a higher power capacity (MW) over energy storage capacity (MWh) (ratio of the power output to energy storage capacity ≥1). If the need is for long-term application, the storage technology has a higher energy storage capacity over the output capacity (output to capacity ratio <1) (JRC 2014).

In the context of Namibian fishing industry, the development of the electricity storage technology potentially combined with solar or wind power seems like an interesting option to be studied. The price development needs to be followed, as at the moment the technologies are still expensive. Figure 10 illustrates a simplified example of using electricity storages with solar PV.
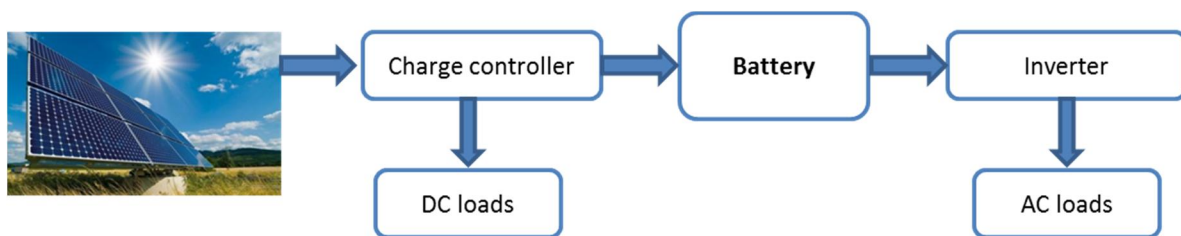

Figure 10. A simple illustration of using batteries as electricity storage with solar PV.

The electricity storage systems are based on different technologies such as lithium-ion, advanced lead-acid, and sodium sulphur batteries. The different battery types and their main features are described in Table 3.

Table 3. Battery types (JRC 2014, Pasonen et al. 2012)

Technology	Description
Lithium ion battery	Lithium-ion battery (Li-ion) is relatively new as a technology. Compared to other electrical batteries, Li-ion batteries offer better performance for efficiency, energy density and durability, along with the lowest self-discharge rates. Li-ion batteries are widely used for portable devices and seen as the primary solution for electric vehicles and residential renewable system applications.
	Li-ion batteries are still at demonstration stage for power grid applications such as frequency control and voltage support. They cannot simply be scaled-up. Safety and reliability remain as issues. Current research efforts indicate a rapid overall development and reduction in costs.
	The technical life time of Li-ion batteries is currently estimated to be 10 years. Installations can vary in size according to their application. Systems can range between 5 kW to 2 MW in capacity. Storage capacity in large systems can be up to 4 MWh.
	Strengths: Fast developing technology, high energy and power density (120–160 Wh/kg), low self-discharge rate, long cyclic lifetime[13] ; from 3 000 cycles to 16 000 full cycles and even 250 000 partial cycles, long service life. Li-oxides and salts can also be recycled.

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[13] Charge and discharge cycles

	Weaknesses: Need for heat control, high investment cost, needs battery cell balancing and protection.
Sodium–sulphur battery	Sodium-sulphur (NaS) batteries are a commercial energy storage technology generally installed in large size of the orders of MW and with long energy storage duration. Most common NaS storage batteries are provided in multiple of 1 MW / 7 MWh. NaS technology is used in frequency control and load shifting. The technical life time of NaS batteries in energy system applications is currently estimated to be 10 years. **Strengths**: High efficiency (89–92%), high cyclic life (~2500 cycles), high energy density (150–200Wh/kg), no self-discharge, suitable for MW size systems. **Weaknesses**: High working temperature (300–350 °C), only few manufacturers, safety issues (fire accidents).
Lead acid battery	Lead-acid batteries (Pb-acid) are one of the oldest battery technologies, invented already in the mid-1800. They are widely used as power engine starters in the automobile, naval and aeronautical applications. They are also deployed in uninterruptable power supply systems to reduce energy losses and in grid installations to provide stability, voltage regulation, and frequency control. Due to low cyclic life time these batteries may be less suitable to be used in combination with solar PV. Pb-acid batteries can be used for both short-term applications (seconds of electricity storage) and long-term applications (up to 8 hours of storage capacity). The technical life time of Pb-acid batteries for bulk storage applications is currently estimated to be 5-10 years, depending on the number of charge-discharge cycles per year and depth of discharge. **Strengths**: Mature, widely used, cost efficient, low self-discharge, small service cost, recharge ability (90%). **Weaknesses:** Low energy density (25–50 Wh/kg), environmental hazard (Pb), narrow temperature area, low cyclic lifetime of around 2000 cycles.
Interesting links:	Educational website providing up to date information on battery technologies e.g. for engineers and battery users. http://batteryuniversity.com/ Scalable Powerpack-technology based on lithium-ion batteries from Tesla Motors. https://www.teslamotors.com/powerpack Zinc hybrid cathode battery technology uses widely available materials with a robust, scalable design to achieve long-life and low-cost. http://www.eosenergystorage.com/technology-and-products/

The costs of electricity storages consist of several components: the electricity storage technology used, the inverter and related installing costs. The costs of electricity storages are still high, but significant developments can be expected in near future as the use of energy storages is expanding rapidly (Figure 11). For example the Department of Energy in United States (DOE 2013) has estimated that the development of the energy storage systems involving redox flow batteries, sodium-based batteries, lead-carbon batteries, lithium-ion batteries and other technologies will advance in short to medium term in capital costs of under 250$/kWh, system efficiency of over 75%, and cyclic life of over 4000 cycles. In long term, the development is expected to allow capital costs of under 150$/kWh, system efficiency of over 80%, and cyclic life of over 5000 cycles.
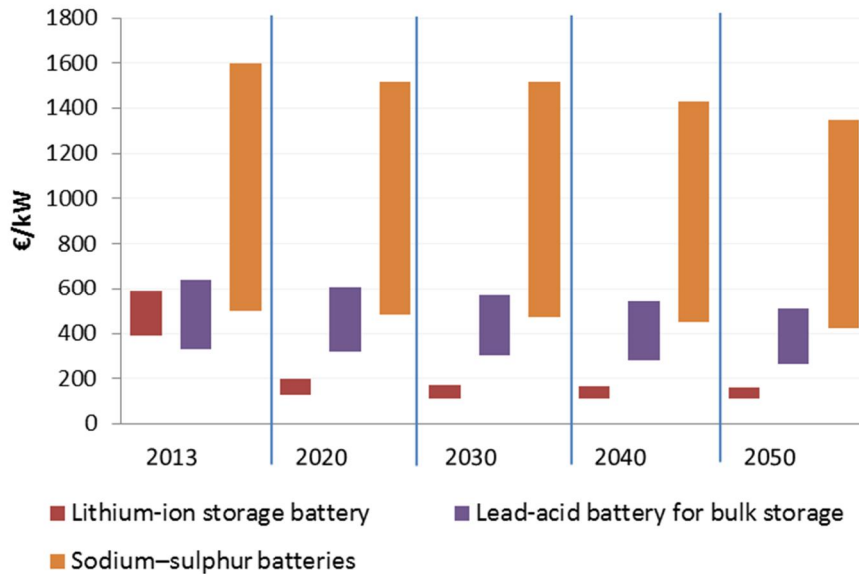
Figure 11. Estimated cost development of lithium-ion, lead-acid and sodium-sulphur batteries (JRC 2014).

3.4   Biogas

Renewable energy could also be produced from renewable biomass resources or biogenic waste. One form of bioenergy is biogas, which is produced in decomposition of organic matter in anaerobic conditions. Biogas is mainly composed of methane (CH_4) and carbon dioxide (CO_2), methane content being around 50-70%. Biogas is often produced from organic waste so that the substrate for biogas production (organic waste) is mixed with an inoculum (e.g. a sludge or manure) in the biogas reactor (Figure 12). Biogas can be used to produce electricity and heat with average efficiencies of 25-30% and 50-60%, respectively.
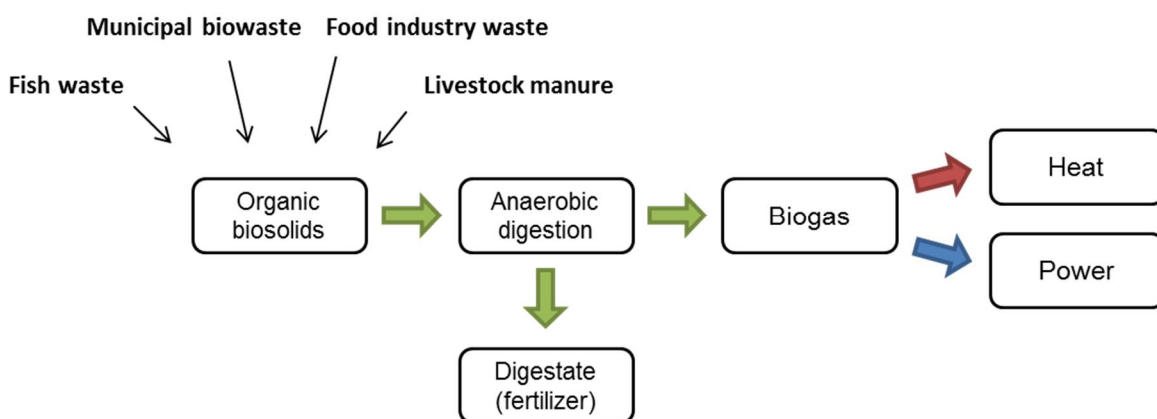

Figure 12. Simplified illustration of biogas process.

The fish processing plants produce some amounts of unused organic waste, found e.g. in the effluent waters. This waste stream could potentially be used in biogas production. However, results from the literature show that the fish waste should be mixed with other organic waste in order to enable efficient biogas production. The problem of using only fish waste for biogas production can be the high lipid content in the waste as the long chain fatty acids can inhibit the process (Gumisiriza et al. 2009). This problem could be solved by pre-treatment of the fish waste with chemicals or enzymes, but co-digestion with other biomass substrate has

been found to be the best option. In laboratory scale tests fish waste has been mixed e.g. with brewery waste water and sisal pulp (Mshandete et al. 2004, Gumisiriza et al. 2009). Fish waste is already used in bigger biogas plants e.g. in Denmark as one the substrates among other bio-degradable materials.

In order to consider biogas as a renewable energy option for fishing sector, the composition of the specific fish waste and its suitability for biogas process should be investigated. In Walvis Bay, regional co-operation with other actors producing organic waste could also be sought. Other organic waste streams could include e.g. waste from other food industry sources, breweries or municipal bio-waste. If transportation of fish waste is needed, the acidification of waste prevents its deterioration.

3.5   Fish oil biodiesel

A concept of using fish cleaning waste as a feedstock to produce renewable energy in form of biodiesel has been demonstrated in the Enerfish[14] project in Vietnam where biodiesel production was combined with a large aquaculture facility processing 120 t of raw fish daily.

In the biodiesel process, the fish cleaning waste first goes through a thermo-mechanical treatment in order to produce fish oil which is further refined into biodiesel in a series of reaction vessels by adding chemicals, water and heat. The process also produces by-products such as feed and glycerine. Biodiesel can be used as a fuel for a local combined heat and power (CHP) production unit producing process heat for the biodiesel reactors and electricity for the facility or simply as fuel for e.g. fishing vessels. The electricity could also be sold to the grid (Figure 13).
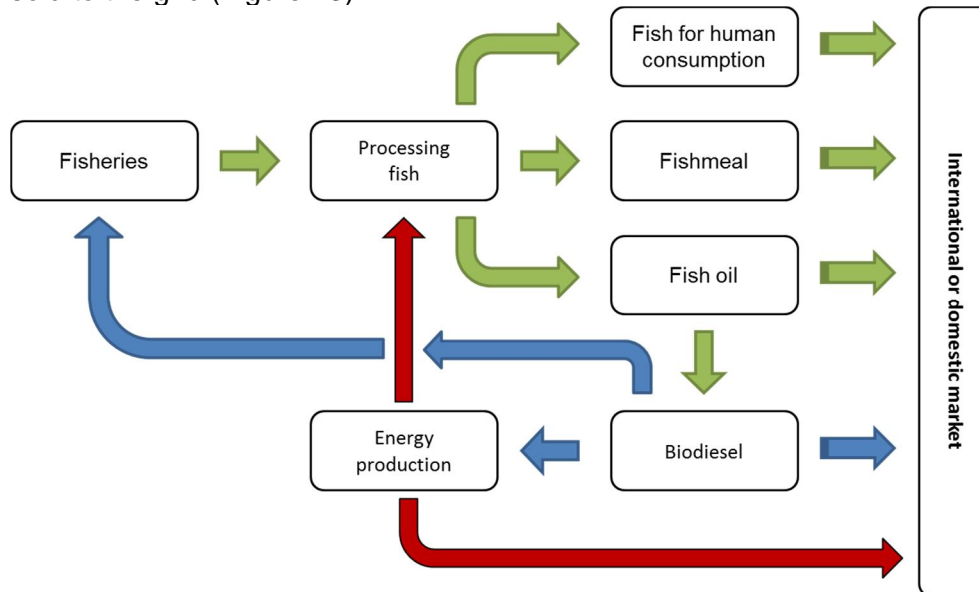

Figure 13. Simplified illustration of the fish oil biodiesel concept

In the Namibian conditions, several challenges related to the fish biodiesel production were recognised. First, the fish species caught in large quantities in the Namibian waters, such as hake and horse mackerel, are not very oily and thus not the best raw material for biodiesel production. Species potentially more suitable for biodiesel production, such as pilchard, are caught only seasonally (3-4 months) and in relatively low quantities. Second, the local industry already has a well-functioning concept of using fish waste for fish meal production, and no large unutilised waste streams are available. Third, the market prices of the fish oil as

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[14] Enerfish web pages, http://www.enerfish.eu/

such are currently high. Thus, the biodiesel production does not seem to provide enough value added to be feasible.

The current pilchard TAC is 14 000 t per year. If all the waste[15] from the total pilchard catch would be utilised for biodiesel production and yield assumptions for fish oil from the Enerfish project are used, approximately 1 500 t of biodiesel could be produced out of 2 000 t of fish oil. This amount of biodiesel corresponds to an energy content of 65 TJ (18 GWh). This is roughly the same figure in scale of activities as studied in the Enerfish –project.

The seasonal nature of pilchard fishing results in a challenge in designing a possible power plant. If targeting a steady supply, a substantial storage solution of 1 200 to 1 400 m^3 in volume is needed. Alternative option is to design a plant with limited utilisation rate operated only when fuel is available.

Using the produced biodiesel for CHP production could generate 6.3 GWh of electricity and 9.0 GWh of heat. Using biodiesel solely on electricity production could generate 8.1 GWh of electricity.

Assuming an average electricity tariff of 1.38 N\$/kWh and a heat price 0.75 N\$/kWh, based on diesel price evaluation of 9 N\$/kWh and an average efficiency for a heat boiler (80%), the yearly energy production would have a value of 8.7 MN\$ for CHP based electricity production, 6.8 MN\$ for CHP based heat production, and 11.2 MN\$ for separate production of electricity. Market value of fish oil is currently high and fluctuates quite a lot. Still, using an average price of few recent years (1 500 USD/t) results in value of 30 MN\$ for fish oil itself. Even without considering related investment costs, the concept does not seem promising.

As a conclusion, the concept of local energy generation based on biodiesel production utilising fish waste does not seem feasible unless fish oil market prices are in region of 500 USD/t and energy prices increase significantly. Also, sustainability issues due to the role of fish waste as feed for fishmeal and linked food production mean that significant benefit would need to be gained in order to offset the possible negative effects of the operation.

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[15] Assuming 68% of fish goes to waste.

4. Calculation tool for planning renewable energy investments

A simple MS Excel based calculation tool for evaluating potential investments in renewable energy and energy storages was developed in the project. The tool has been provided to the companies who participated in the project.

The tool includes solar panels, wind energy and a generic, configurable combustion technology as production methods. Solar panels and combustion technology are considered as local/on-site power production while wind energy would be built off-site and its production sold to the grid. The user can define which technologies to include in the evaluation. Options for utilising electricity storages in different operational strategies are also studied.

Investigation of the feasibility is carried out by studying a set of scenarios and comparing them to business as usual (BAU) scenario where no investment is made. Later on in the text, the BAU electricity consumption profile is referred as "Original". Table 4 below describes the scenarios studied.

Table 4. Descriptions of the scenarios studied.

Scenario	Description
No storage	No electricity storage, evaluation includes only the selected electricity production methods.
Solar for peak tariff	Local/on-site solar panel based production is used only during peak tariff hours, electricity storage is utilised for off-peak production.
Constant load	Electricity storage is used to flatten demand during 24-hour periods taking into account any on-site production of electricity and demand variation.
Avoid peak tariff	Electricity storage is used for shifting consumption away from peak tariff hours while taking into account any on-site production of electricity.

Reasonable default values for various parameters have been set in the calculation tool, but the tool can easily be configured based on the needs of a specific user.

Main input for the calculation tool include

- Technologies included in the calculation, capacities and other technical parameters for each technology

- Various economic parameters, technology specific cost data and electricity price development

- Hourly electricity demand time series

Main results of the tool include

- Economic variables such as payback time, investment and annual costs, savings and return of investment (ROI) after a defined number of years

- Energy related results such as consumption, production and required storage size

The tool first carries out an energy analysis on production and consumption of electricity on-site based on user defined input and scenario definition for a representative year. This information is then used in profitability analysis in which the operation of the facility is studied during a 25-year period. Both profitability and energy analysis results are presented. The basic concept of the calculation tool is illustrated in Figure 14 below.
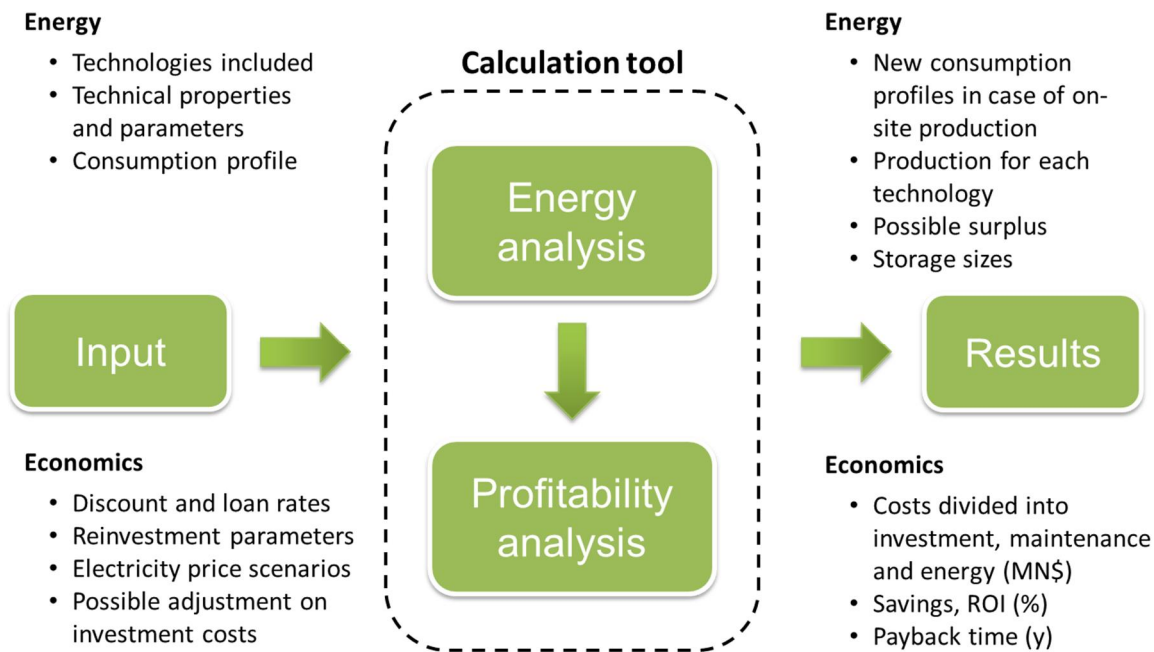

Figure 14. Calculation tool concept.

Solar irradiation data used within the calculation tool is a NASA reanalysis of satellite based observations, MERRA[16]. The grid size of the available data is ½ degrees latitude and ⅔ degrees longitude, i.e. approximately 56 km times 68 km in Walvis Bay region. To validate the use of MERRA based data, a comparison was made with local measurements of energy and peak production during January 2016 from an existing PV array in Walvis Bay. A grid located just outside the coast proved to be the best match. A comparison between different years from 2010 to 2014 showed no significant changes in yearly production. The calculation tool uses year 2014 as a representative time series for the solar resource. The calculation results were further adjusted based on another set of measurement data (monthly production values for year 2015) from Swakopmund. This enabled more accurate modelling of effects due to weather conditions especially during the winter months.

4.1 Results examples

A fictional facility with a roof-top solar panel installation and a yearly electricity consumption of 7 850 MWh is studied as an example in this chapter. The consumption profile was generated using a randomised constant and a sine function with 24-hour period. A week-long example of the electricity consumption time series generated with this approach is presented in Figure 15 below.

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[16] MERRA: Modern-era retrospective analysis for research and applications (http://gmao.gsfc.nasa.gov/research/merra/)
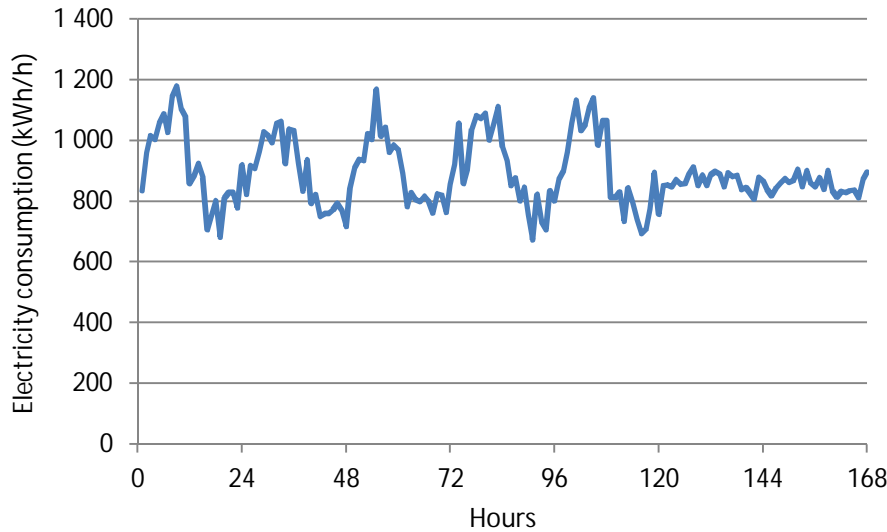
Figure 15. Week-long electricity consumption profile for a fictional example facility.

The energy planning tool includes reasonable estimations for variety of parameters, but some such as the investment and electricity price development are natural targets for the analysis. Figure 16 below presents the electricity price development scenarios used for this example as well as estimation from a recent study (Konrad Adenauer Stiftung 2012).
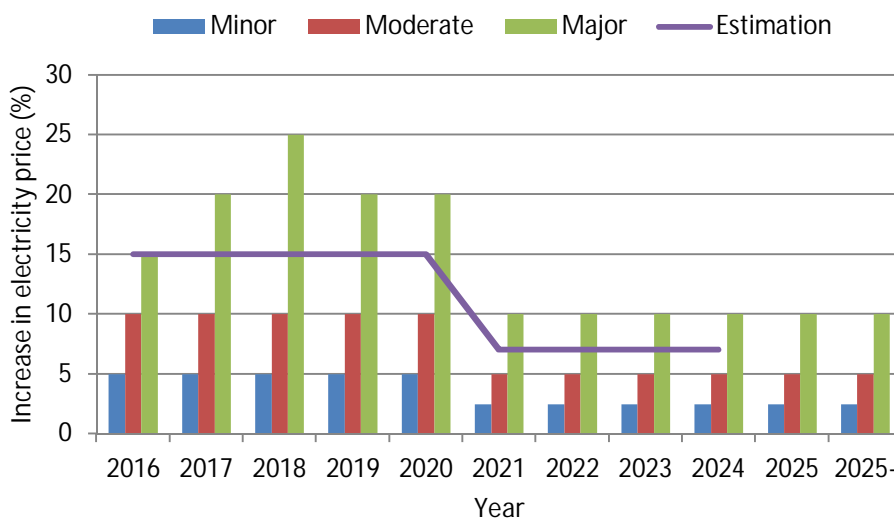

Figure 16. Three electricity price development scenarios used in the calculation tool compared to the estimated price development by Konrad Adenauer Stiftung (2012).

A 500 kW solar panel installed on the roof-top and located on Walvis Bay area has a yearly electricity production of 982 MWh. The system of this size does not require an independent electricity producer license and simply cuts into the electricity consumption of the example facility. The effect of the local production to the electricity consumption profile is illustrated in Figure 17, where the reduced electricity consumption from the grid due to solar electricity production can be noticed.
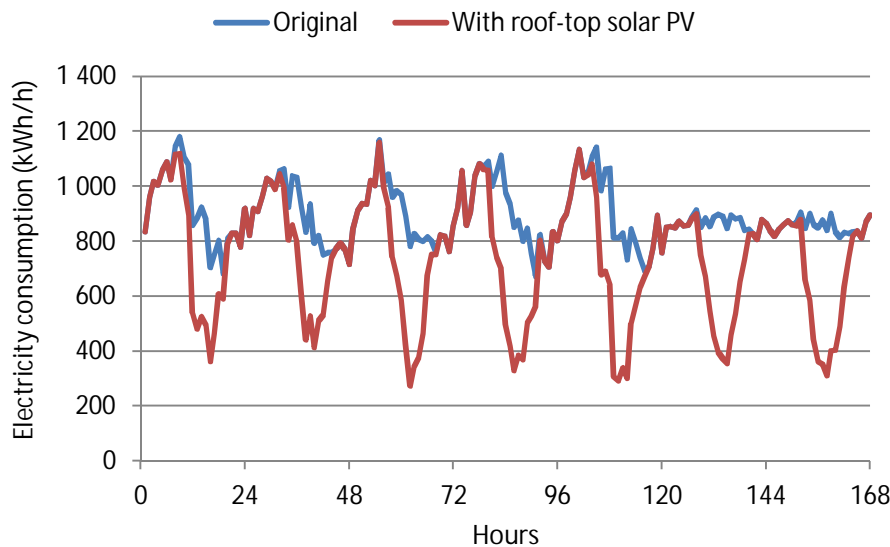
Figure 17. Electricity consumption profiles with and without roof-top solar PV.

The payback times of this system are presented in Figure 18 for three different levels of investment costs (16 500N\$/kW ±25%) and for the three electricity price development scenarios. For example, with investment cost decreasing by 25%, payback times of less than seven years are gained for all the electricity price scenarios (blue columns).
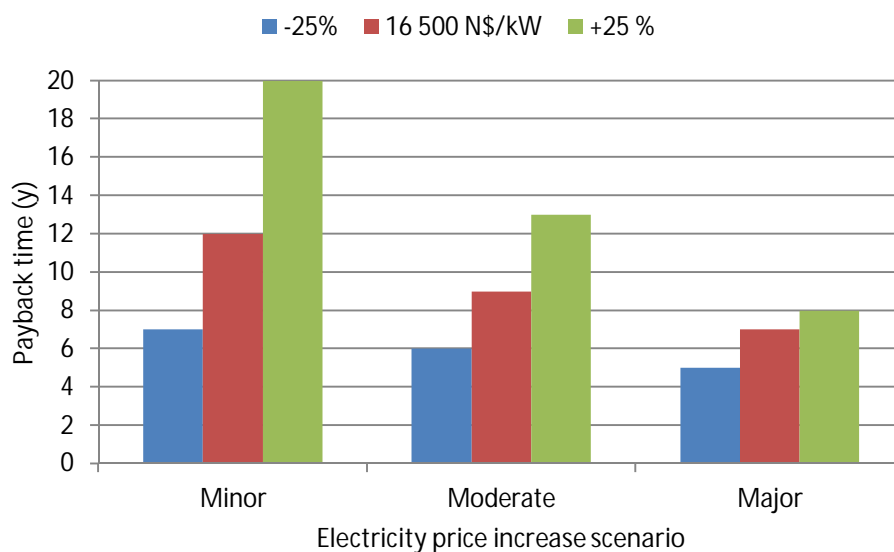

Figure 18. Payback times of a roof-top solar PV installation for the example facility.

The facility could also be equipped with electricity storage. These solutions remain costly, but foreseen development in required investment costs especially combined with the major increase in electricity prices can make storage options financially more attractive in future.

The effects of these storage solutions for the electricity consumption profile are presented in Figure 19. "Solar for peak" option stores electricity generated by solar panels and uses the stored electricity (if available) to cut consumption during peak tariff hours. In "Constant load" average electricity consumption and solar production is estimated for the next 24 hours and the storage is used to flatten the electricity demand from the grid. "Avoid peak" simply avoids using grid electricity during the peak load hours.
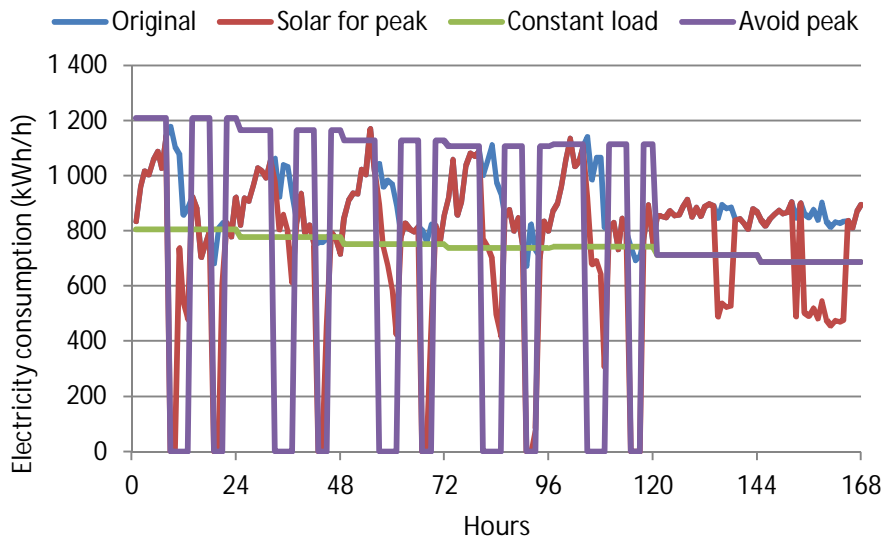
Figure 19. Electricity consumption profiles for storage options during an example week.

All the options with solar PV installed have the same electricity consumption (6 868 MWh), but hours of grid based consumption are different. The peak demand for the "original", "solar for peak" and "avoid peak" options almost the same. As a result, the demand based charges remain unchanged. The "constant load" option, however, significantly reduces the peak load demand. The "solar for peak" and "avoid peak" options have high charge and discharge capacities which are undesirable from the battery life time point of view. In the studied case, "constant load" option has around 50% lower (549 kW) charge/discharge capacity than the two aforementioned cases (1 158 kW). Storage sizes for the three cases are approximately 5.4 MWh for "solar for peak" and "avoid peak", and 3.5 MWh for the "constant load" option.

Following Figures 20 and 21 illustrate the electricity demand for the original and other studied scenarios as load duration curves[17]. The graphs show effects of solar PV system compared to original consumption. It can also be utilised in planning of peak cutting measures.
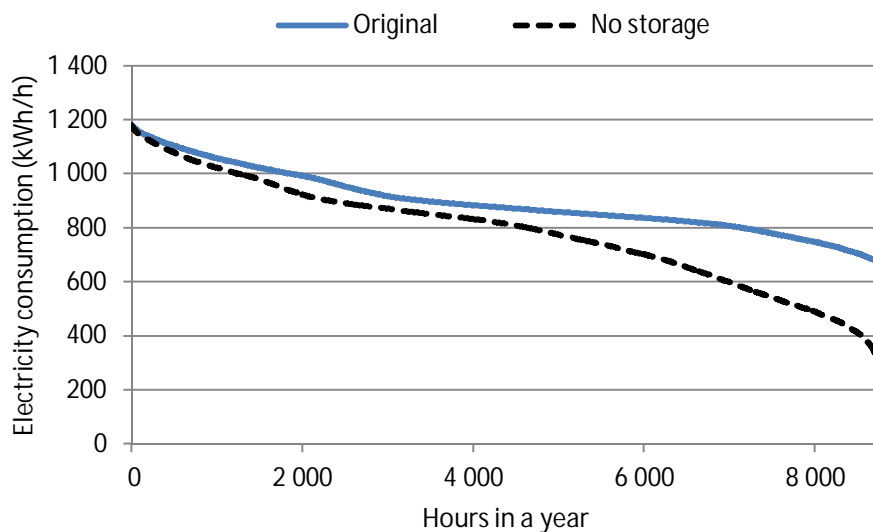

Figure 20. Load duration curves for original and no storage scenario for a full year.

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[17] Electricity consumption time series for a full year sorted from largest to smallest value.
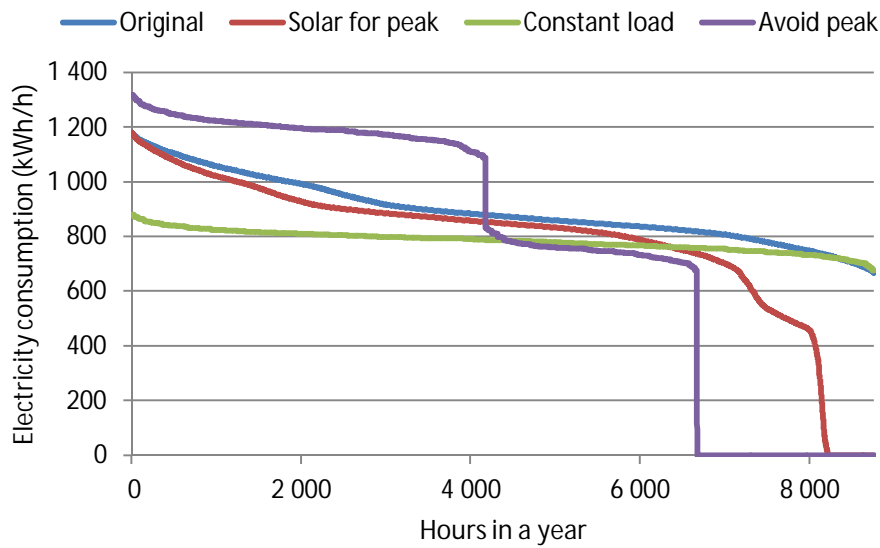
Figure 21. Load duration curves for storage options for a full year.

Table 5 lists the payback times for different storage options with the three electricity price development scenarios. Costs for the storage technology are varied. The current estimate (5 250 N$/kWh) for NaS –based (see Table 3 in Chapter 3.3) solution is used as a reference case with calculations made also with 25% and 50% reductions on this reference cost level.

Table 5. Payback for storage options, electricity price scenarios and investment costs.

	-50%			-25%			5 250 N$/kWh		
	Minor	Moderate	Major	Minor	Moderate	Major	Minor	Moderate	Major
Solar for peak	> 25	24	12	> 25	> 25	15	> 25	> 25	> 25
Constant load	> 25	19	12	> 25	> 25	16	> 25	> 25	> 25
Avoid peak	> 25	> 25	12	> 25	> 25	17	> 25	> 25	> 25

Results show that electricity storage technology is promising, but not currently interesting purely from the economic point of view. Only with a major increase in electricity prices and a significant decrease in storage investment costs these scenarios result in payback times in region of 10 years.

The calculations above are influenced by many parameters on different technologies and related economics. These include e.g. tilt angles (15°) and orientation of solar panels (north), discount rates (10%), re-investment year and amount compared to original investment (10 y, 30%), interest rate and loan length (5%, 10 y).

As demonstrated, when estimating the profitability of the investment in renewable energy and storages several parameters affect the end results. The future price development of the technologies used and electricity and capacity provided by the local grid operator have a major effect. The shape of the electricity consumption profile itself can have a meaningful impact on the outcome of the calculation, e.g. how consumption relates to electricity time-of-use tariffs and solar PV production. This is why energy analysis is useful when planning for new investments.

5. Energy efficiency measures

This chapter lists the most significant energy efficiency measures that could be considered in the fish processing plants. Energy efficiency measures are divided between solutions for electricity consumption, heating and cooling.

It is highly recommended to follow a systematic energy planning process described in Chapter 0 in order to identify reasonable energy efficiency measures for a specific plant. Accurate information on energy consumption and demand forms the baseline for evaluating investment on energy efficiency.

Having information on the best available technologies[18] (BAT) is generally recommended. The BAT technologies provide a useful reference in finding out what solutions could be commercially available. Learning more on these technologies from the actual technology providers will provide data needed to evaluate the actual benefits.

5.1   Electricity

Electricity costs consist of demand and consumption. Within the investigated operational environment of Walvis Bay these are both relevant cost factors. Energy savings are often a priority, but measures aimed at lowering the peak demand should also be considered. Very often these two are closely linked.

Electricity is consumed mainly by processing machinery and equipment, lighting and cooling. This subchapter mainly deals with electricity consumption in processes and lighting. Cooling is discussed separately within Chapter 5.3

The BAT concept can be useful in selecting machinery and equipment especially for new facilities and renovation of existing processes. However, two concepts should be kept in mind in operation of the equipment for possible energy efficiency improvement potential; power factor and potential for using variable-frequency drives.

Power factor correction

Power factor is defined as ratio of real power performing useful work to apparent power in the electricity circuit. The difference between these two is due to reactive power which in turn is caused by inductive (e.g. electric motors) or varying (e.g. fluorescent lamps) loads. E.g. a power factor of 0.8 would result in increase of 25% in demand. Higher demand also causes higher losses in electricity distribution, but this is negligible from the processing plant point of view due to short distances.

A low power factor results in higher demand (apparent power) from electricity grid than needed (real power). As noted above and in Chapter 1.3 demand and access charges for electricity are based on demand making this effect undesirable. However, solutions in form of power factor correction (PFC) equipment are available as sets of capacitors and/or inductors with a suitable control system.

The power factor correction equipment is usually very profitable as an investment. Therefore, measuring the power factor of different processes within the processing plant is highly recommended, e.g. as part of an energy audit in order to recognise the processes causing the low power factor.

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[18] Reference documents by Joint Research Centre (JRC) of European Commission can be considered as a source of information http://eippcb.jrc.ec.europa.eu/reference/ .

Variable-frequency drives

Other potential energy efficiency measure is the utilisation of variable-frequency drives in controlling a pump or a motor. Very often, the pumps or motors within a facility are not running at their design point, but well over what is actually required, e.g. pumps maintaining higher pressure level than needed. If the demand is not constant for this kind of equipment and it is not usually running close to a load it is designed for, installing variable-frequency drives can potentially result in significant energy savings. They can also help with the low power factor problem by avoiding sudden motor start-ups (variable load).

Variable-frequency drives are also widely commercially available and their potential can be identified in an energy audit, by going through the specifications of the existing machinery and by equipment specific energy consumption measurements.

As a summary, power factor correction can enable savings through reduction of demand and variable-frequency drives mainly through reduction in consumption, although they can also help in improving the power factor.

Lighting

Lighting can be a significant source of electricity consumption and also influence the power factor if fluorescent lamps are used. Identifying the method of lighting used and comparing against energy efficiency solutions such as light emitting diode (LED) based lighting, can potentially amount to a profitable investment. In addition to the actual technology used, it is useful to consider the reasonable operation of lighting within the processing plant. E.g. occupancy sensors can improve the efficiency of the lighting system considerably. Once again, measuring the lighting energy consumption can help in evaluating the potential and enable profitability calculations for different investment options.

5.2   Heating

Energy efficiency is often associated to electricity consumption only and heating is overlooked as a potential target for energy savings. However, depending on the type of operations in a processing plant, improving heating solutions can play a major role in overall improvement in energy and cost efficiency.

In addition to investigating heat consumption simply as energy, it is also useful to pay attention to the temperature of the heat utilised. Temperature can be considered to be an indicator of usefulness of heat available; the higher the temperature, the more options there usually is for using the heat. This is the reason why continuous monitoring and measurements during an energy audit on temperatures of the heat flows within the plant are important.

Main sources of heat energy in fish processing plants are boilers and electric heaters supplying hot water or steam into the processes. Ensuring an efficient production of heat is one of the main targets for energy efficiency improvements. Also efficient use of heat by minimising heat losses and combining existing heat flows in order to minimise heat discarded into the environment needs to be considered.

The efficiency in production of heat especially in boilers is often dependent plainly on the age of the boiler plant. Also, the technological solution used has a significant effect. The heat recovery from the flue gasses of the boiler and use of the recovered heat in separate processes can significantly improve the overall efficiency of the system. If heat demand is intermittent, a heat storage solution (steam or water tank) can also help in improving the

efficiency. These solutions help in designing a boiler plant for lower capacity than the peak demand, resulting in a more cost-efficient investment.

Steam may be used for cleaning, sterilisation and cooking in e.g. canning process. Generation of steam requires high temperatures provided by boilers or electric heaters, but if heat is needed e.g. in hot water production, other sources of heat can be utilised as well. One of the most significant sources of comparably low temperature heat (30-60 °C) is condensing heat from a cooling or freezing system. Other sources are heat flows from different phases of the project; steam ejection and water flows used for heat demand in separate processes or preheating. These flows of heat can also be used as a heat source for a heat pump process in order to raise the temperature level enabling more options to use the recovered heat.

Desalination by evaporation is another process utilised in fishing industry that requires similar heat levels as steam generation. It can be considered similar to a boiler plant as a process and as a target for utilising low temperature heat flows for e.g. preheating processed sea water.

Figure 22 below presents an example of how the heat consumption and heat flows within a processing plant might look like. It is useful to identify the activities within the plant and their energy consumption and temperature levels. Heat recovery from processes with higher temperature level requirement and use of the recovered heat in processes with lower temperature requirement will improve the efficiency of the plant. General aim is to minimise the waste heat. Heat pumps and condensing heat from freezing and cooling processes might not be available in every processing plant. Also, other heat generation technologies such as solar collectors and combined heat and power units are options to be considered.
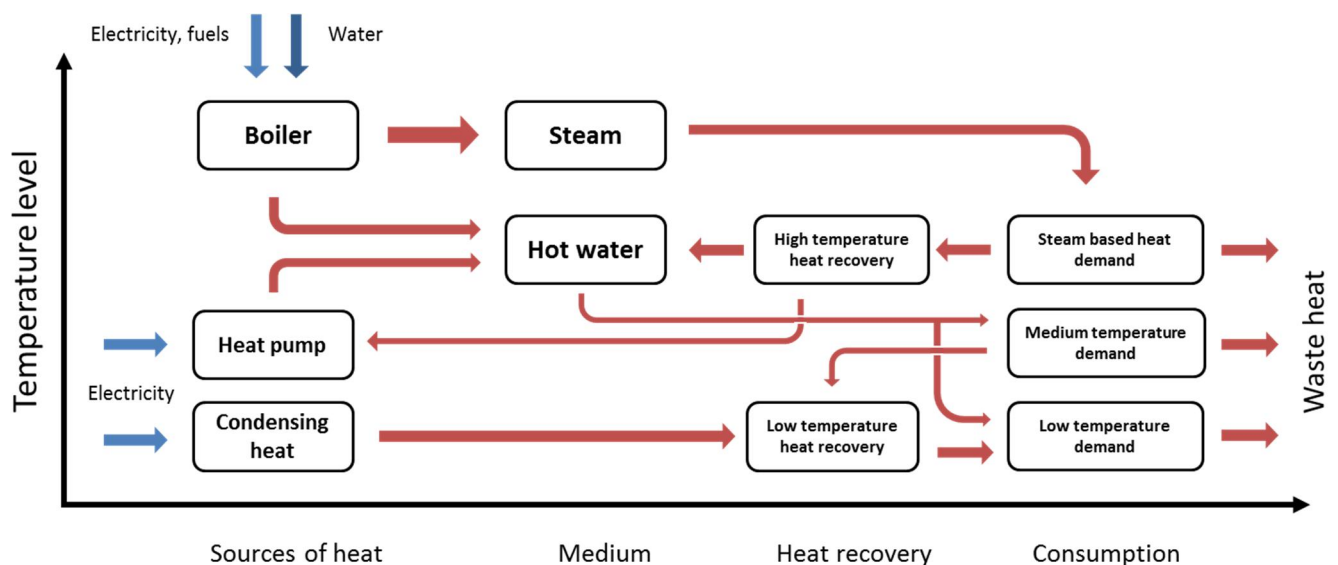

Figure 22. Example on heat flows within a processing plant.

One clear usage for a low temperature heat is the defrosting of evaporation heat exchangers in a processing plant with cooling and freezing systems, improving their operational efficiency. This is often implemented by heat recovery from condensers of the cooling system, but can be more economical with cheap waste heat recovered from processes with low temperature heat demand.

Sometimes a single processing plant has a surplus of available heat or the temperature of the unused heat is too low to be utilised within the plant. In this case, storage options and cooperation with e.g. neighbouring plants could be considered. An arrangement where surplus heat available from one plant is used by another nearby plant - which would

otherwise have to supply the heat with e.g. a separate boiler of its own - provides a simple, but effective example of industrial symbiosis described in Chapter 0. Providing waste heat can be a source of income for the company with the heat surplus while for the company utilising the heat, it could represent an affordable source of heat supply.

Decreasing heat losses in a processing plant is accomplished by minimising the transportation distance, i.e. pipe lengths, and by using insulated pipes. Heat losses can also be minimised by using reasonable temperature levels for each process; high temperatures result in high heat losses and should be avoided if possible.

5.3   Cooling and freezing

Cooling and freezing systems are responsible for considerable consumption of electricity in many fish processing plants. They also come with many possibilities for energy savings.

Improvement in energy efficiency concerning cooling and freezing system can be accomplished by using more efficient equipment, improving the operational efficiency of the current system or by decreasing the actual heat load for the system.

Equipment and operational efficiency

The cooling equipment consists of an evaporator, a condenser and any possible auxiliary heat exchangers, a compressor, an expansion valve, appropriate piping and a control system. The evaporators and condensers are often equipped with controlled fans. These fans can also be significant consumers of electricity and could be equipped with variable-frequency drives as an energy efficiency measure (see Chapter5.1).

The efficiency of a heat pump depends mainly on the evaporating and condensing temperatures, and on the working medium used. Lowering the condensing temperature or raising the evaporation temperature improves the efficiency of the cooling process. E.g. ice on the surface of the evaporator heat exchangers acts as insulation, meaning that lower evaporation temperatures are needed in order to deliver the same cooling effect. This is why periodic defrosting of the evaporators is needed. On the other hand, higher outdoor temperatures result in an increase in condensing temperature – and electricity consumption. Possibilities of using a natural or otherwise available source of cooling such as e.g. sea water can improve the efficiency. Moreover, replacing air/liquid heat exchanger equipped by fans with liquid/liquid heat exchanger supplied by a pump consumes less electricity.

The working medium, i.e. refrigerant used within the refrigeration process, has a significant effect on the efficiency of the process and sets constraints on suitable temperature levels. The most commonly used refrigerants in low temperatures are R-22 (chlorodifluoromethane, to be phased out due to its harmful effects to the ozone layer), R-404A (hydrochlorofluorocarbon, a possible substitute for R-22), natural refrigerants R-717 (ammonia) and R-744 (carbon dioxide).

Currently an interesting choice within the food industry is a combination of ammonia/carbon dioxide. This two stage system, i.e. two heat pump processes with different temperature levels, has higher investment costs, but also higher efficiencies. These kinds of systems are becoming common in industrial and supermarket size cooling and freezing systems. COPs[19] for different refrigeration systems are presented in Figure 23 below.

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[19] Coefficient of performance; defined here as ratio of cooling output to electricity input.
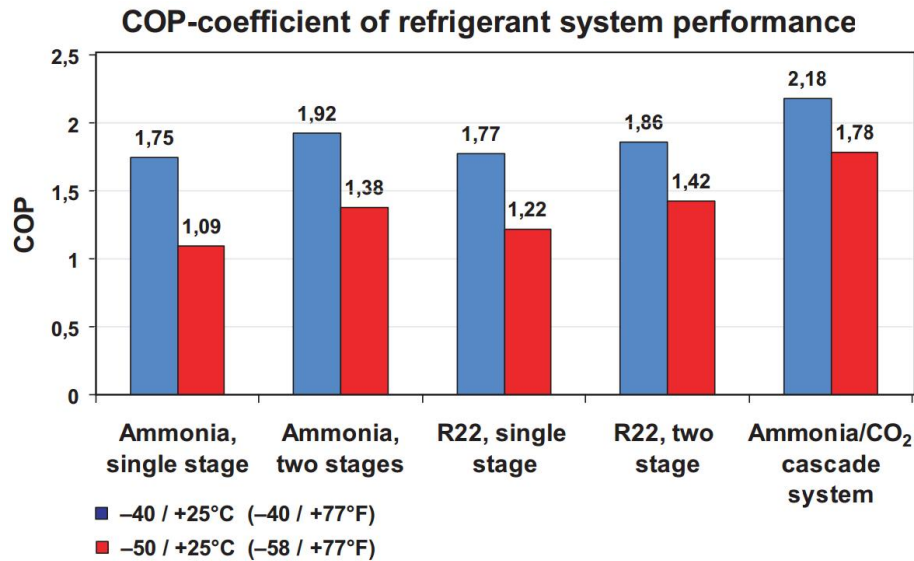
COP-coefficient of refrigerant system performance

Figure 23. COPs of several alternative refrigeration systems[20].

Decreasing heat load

Regardless of the technology used, managing heat losses and controlling air flow and air humidity is a very effective method of improving energy efficiency of a cooling and freezing system.

Heat losses result from temperature difference between the cooled space and surrounding environment. They can be reduced by installing insulation around the space.

Effect of air flow could also be classified as heat loss; it means the introduction of air of higher temperature into e.g. cold storage space. Its effect is greatly influenced by the humidity of air. This humidity first condenses and later freezes on the surfaces, releasing heat in the process. The significance of air humidity in terms of cooling demand is illustrated in Figure 24 below. The calculation of the relative cooling demand assumes a storage temperature of -20 °C and relative humidity of 68%. Humid air entering the storage is assumed to be 40 °C. These conditions can be considered as extreme, but the effect is nonetheless significant.

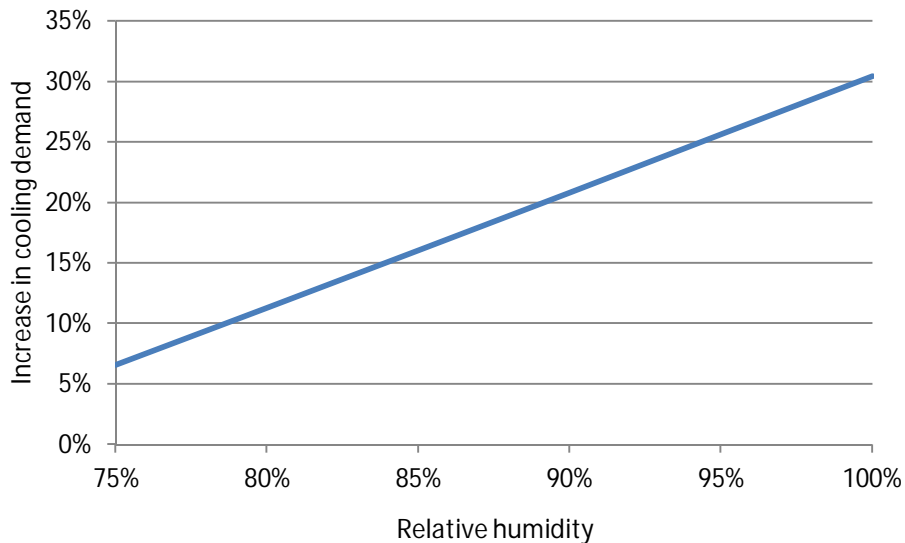[20] http://www.findri.fi/pdf/danfoss-r717_co2.pdf

Figure 24. Increase in cooling demand as a function of relative humidity.

Compared to differences e.g. between alternative refrigeration technologies, it is easy to notice that without taking care of indoor air conditions, the efficiency improvement by new state-of-art cooling equipment is negligible in comparison.

Air flow and humidity control can be improved by very practical, but effective methods. These include air seals in doors, minimising the time e.g. storage doors are open during loading or unloading. Working practices and instructions can play a major role in this. In addition, technical solutions include controlled ventilation and dehumidifiers.

5.4   Checklist of energy efficiency measures

Table 6 summarises a check-list on energy efficiency measures for fish processing plants. These measures are in a general level, and more specific energy efficiency measures can be found from each individual plant, e.g. in an energy audit.

Table 6. Check-list for energy efficiency measures.

Energy efficiency measure	Explanation
General	
BAT Technologies	When investing to new technology, information on best available technologies (BAT) can be used as reference. http://eippcb.jrc.ec.europa.eu/reference/
Energy consumption measurements, monitoring	Measurement data helps to recognise the need for improvements and to proof the energy savings achieved with new solutions.
Energy planning	Managing energy measurement data and making systematic plans on how to improve energy efficiency within the operations.
Training	Ensuring employees have sufficient knowledge on energy issues, how day-to-day actions effect on energy consumption (e.g. importance of controlling air flow by simply closing doors), and how to identify need for maintenance in different processes.

Electricity	
Power factor correction	Installing power factor correction (PFC) equipment to mitigate the effects of inductive and/or varying loads to reduce electricity demand.
Variable-frequency drives	Installing variable-frequency drives to control pumps, motors and fans.
Lightning	Installing more efficient lighting, e.g. LED (light emitting diode) lightning. Keeping lightning level optimal and turning lights off automatically when they are not needed.
Equipment and machinery	Monitoring and managing the energy consumption equipment in the facility, use of BAT solutions.
Heating	
Monitoring the heat flows	Monitoring the heat flows in order to recognise the usable excess heat flows and their temperature levels.
Heat recovery and utilisation	Use of heat recovered from the 1) flue gases of the boiler, 2) condensing heat from the cooling and freezing equipment, 3) heat flows from processes (steam, hot water) in processes with lower temperature requirement, e.g. pre-heating for hot water or steam production.
Heat storage	Use of heat storage (e.g. steam or water tank) can be useful to cut the peak demand by managing variable heat demand.
Decreasing heat losses	Controlling heat losses by minimising the transportation distance, i.e. pipe lengths, by using insulated pipes, and by using reasonable temperature levels for each process.
Co-operation on heat flows	Use of unutilised heat flows in co-operation with other plants or neighbouring consumers.
Use of waste for heat production	Possibility to use e.g. packaging waste in heat production can be studied.
Cooling and freezing	
Managing heat losses	E.g. installing insulation around the storage rooms.
Controlling air flow and air humidity	Including air seals in doors, minimising the time e.g. storage doors are open during loading or unloading, optimising working practices and instructions, installing controlled ventilation and dehumidifiers.
Controlling evaporators and condenser fans with variable-frequency drives	Installing variable-frequency drives to control fans.
Defrosting of evaporation heat exchangers	Keeping heat exchangers free of ice to enable use of design evaporation temperature.
Freezers	Minimising the freezing time.
Heat exchangers	Replacing air/liquid heat exchanger equipped by fans with liquid/liquid heat exchanger (see natural cooling).
Cooling technology	Use of efficient cooling technologies such as two-stage ammonia/carbon dioxide based systems.
Natural cooling	Using natural or otherwise available sources of cooling such as sea water can be investigated, e.g. to lower condensing temperature for the cooling system.
Water based cooling	Using closed cycles cooling where applicable.
Maintenance of equipment	Ensuring condenser and evaporator units have sufficient clearance for unrestricted air flow, keeping coils and heat exchangers clean and free of debris. Identifying and acting on possible leaks or damaged insulation.

6. Local energy cooperation

The concept of industrial symbiosis means sharing of services, utility, and by-product based resources among industries in order to add value, reduce costs and minimise the environmental impact. The companies and other economic actors situated near to each other can form networks of suppliers and consumers, which resemble natural ecosystems. Rather than looking the society from the traditional organizational, social or economic approach, the industrial ecology studies the economic systems through their material and energy flows (Sokka et al. 2011).

The Namibian fishing sector presents a substantial potential for local co-operation. E.g. in Walvis Bay, many of the fishing companies are situated very close to each other on a so-called "fishing mile", making the co-operation easy in principle. Co-operation possibilities could be found for example related to energy, water and waste streams. Possible excess heat supply could be used in the neighbouring facilities or the investments on new energy production could be made in co-operation between the companies (Figure 25).
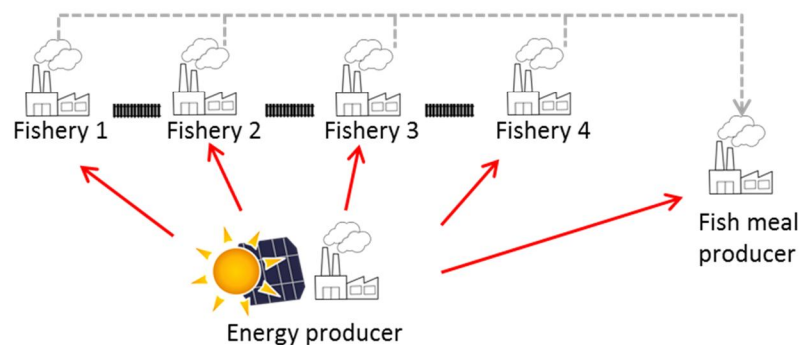

Figure 25. Possibilities for energy co-operation between the fishing companies.

In Walvis Bay fishing district, a well-functioning co-operation model has already been established between the fishing companies and a fish meal producer. The fish waste from fish processing plants goes to the fishmeal and fish oil producer, and the profits are divided between the partners based on their share of the provided raw material. Similar type of co-operation could be possible also related to the other resources. E.g. at the moment some of the operators have their own energy production, desalination and water treatment plants. In future, co-operation in these functions might provide cost benefits for the fishing companies, and improve the overall energy and material efficiency of the fishing sector (Figure 26). The good experiences from the co-operation with the fish waste utilisation can pave the way for further co-operation also in other sectors. The co-operation can provide savings in scale, e.g. the installation and maintenance costs of one bigger solar plant may be lower per MW than several smaller plants.
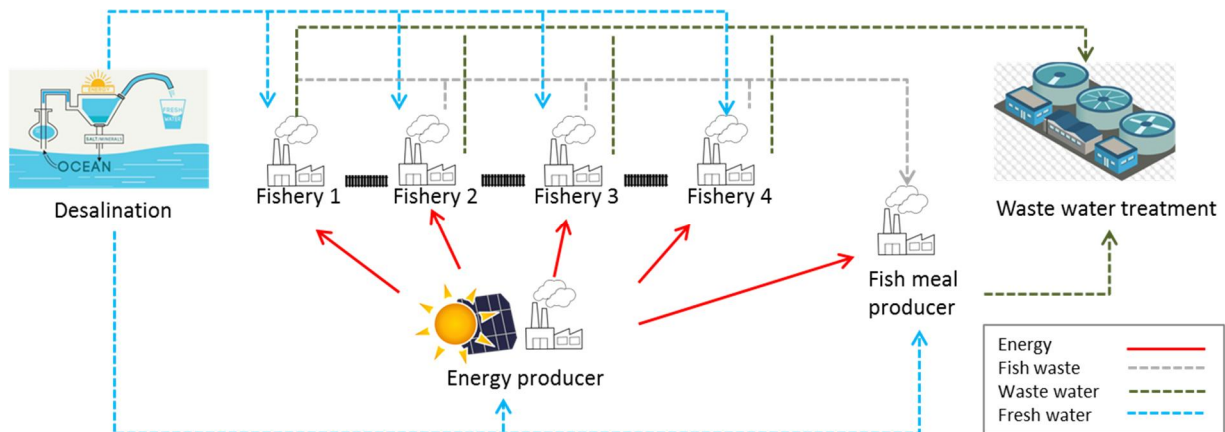
Figure 26. Possibilities for co-operation and synergies in the fishing district.

The local co-operation for efficient use of energy and material flows could benefit the environmental sustainability of the fishing sector by creating savings in resource use and reduce the emissions produced. It could also create economic and social benefits by possible improvements in the profitability of the sector. Thus, improvements in the overall environmental, social and economic sustainability of the fishing sector could be gained (Figure 27).
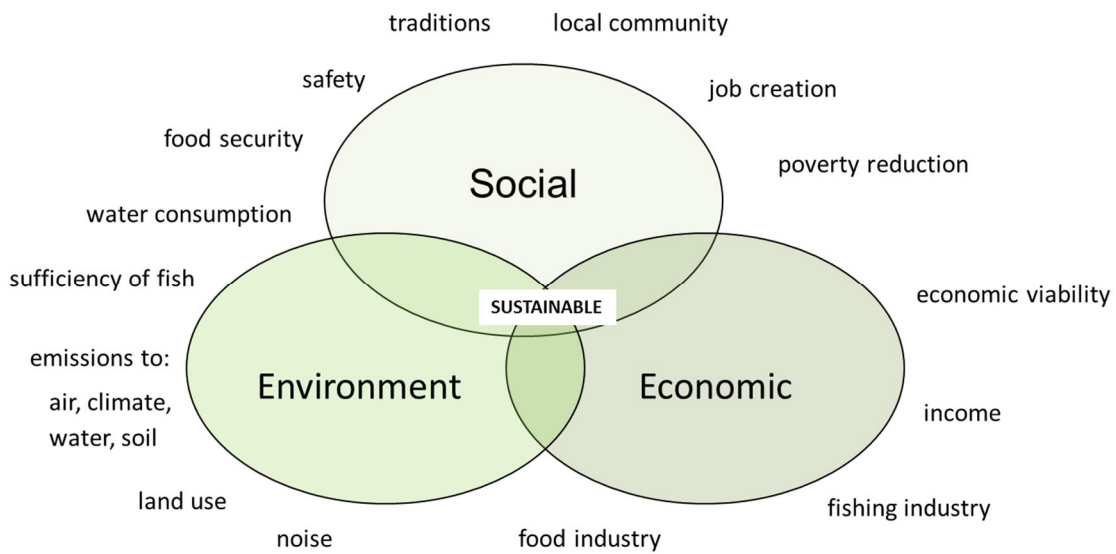

Figure 27. Three dimensions of sustainability.

7. Conclusions

Fishing industry is one of the most important sectors for the economy of Namibia and also a significant energy consumer. Energy issues, such as energy security and efficiency, are becoming increasingly important for the Namibian fishing industry due to the increasing energy costs in country. Furthermore, the Namibian energy system as a whole would profit from new investments on energy production. Namibia has also committed to Intended Nationally Determined Contributions (INDC) within United Nations Framework Convention on Climate Change with objectives of increasing the share of renewable electricity production in electricity supply from 33 % to 70 % in 2030 (Republic of Namibia 2015). This report studies the renewable energy and energy efficiency options for the Namibian fishing industry, concentrating on the land-based activities in fish processing plants. The findings can also be useful for other industries in Namibia and within the region in general.

Energy consumption in a fish processing plant is dependent on the type of activities. The main sources of energy are electricity and liquid fuels, i.e. oil products. Shares of these two can be different for operations specialising on processing fresh fish for freezing or for canning processes. Fuels are used for heat and steam generation for the processes as well as in evaporation based desalination. Electricity is used for processing equipment, lighting and most notably in cooling and freezing. The role of energy planning and energy measurement in the fish processing plans is emphasised. The measurement data is essential in recognising where improvements are needed and helps in assessing the benefits of the investments made by providing baseline data.

The report presents a short overview on the renewable energy technologies, which could be used in the Namibian fishing sector. These are solar PV, wind power, biogas and biodiesel from fish waste. Also the energy storage technologies are discussed. The electricity storages can be used to balance the fluctuating production of renewable energy technologies, but also for balancing the consumption and cutting the peak consumption of the plants. This could be an interesting option for the fish processing plants due to the electricity pricing, which consists of energy and capacity related cost components. From the options studied, the solar PV presents the most interesting one for the power production. The fast development of solar and electricity storage technologies can provide interesting future solutions also for the Namibian fishing industry.

A simple tool for estimating the profitability of the investments in renewable energy has been developed and is presented in this report. The tool has been handed to the Namibian fishing companies involved in the project. The tool enables studying various renewable energy options by adjusting the parameters needed in the evaluation. It can also be used to study e.g. the different scenarios for utilising electricity storage technologies.

The report also presents a list of energy efficiency measures, which can be studied and put into action in the fish processing plants. Cooling and freezing can be identified as the single most interesting targets for energy efficiency improvements as they typically represent a major source of electricity consumption in operations that include these processes. Savings in fuel consumption can be accomplished by improving efficiency of the heat consumption within the processes by identifying and utilising waste heat flows for preheating purposes or separate processes with lower temperatures requirements.

Namibian fishing industry is concentrated in two locations, coastal cities of Walvis Bay and Lüderitz. This creates potential for local co-operation, where some processes inputs (e.g. heat, power, water) could be supplied in co-operation. An example of the local co-operation is already found in form of fish waste treatment for fish meal and fish oil production. Similar type of co-operation e.g. in renewable energy production could benefit the industry and create environmentally and economically sustainable solutions.

References

DOE 2013. Grid Energy Storage. U.S. Department of Energy. December 2013.

DOE SA 2014. Renewable Energy IPP Procurement Programme (REIPPPP) for South Africa. [Accessed 29/8/2016] Available: http://sastela.org/wp-content/uploads/2015/10/DoE-REIPPPP-for-South-Africa.pdf

ECB 2015. Electricity Control Board. Electricity Supply Industry Statistical Bulletin 2014/15. ISSN: 2026-8033. Windhoek, Namibia. 39 p.

Fant C., Gunturu B., Schlosser A. Characterizing wind power resource reliability in southern Africa. Applied Energy 161 (2016) 565–573.

Gumisiriza R. et al. 2009. Enhancement of anaerobic digestion of Nile perch fish processing wastewater. African Journal of Biotechnology Vol. 8 (2), pp. 328-333, 19 January, 2009.

IEA 2016. International Energy Agency Statistics: Key Indicators. [Accessed 30/10/2016] Available: http://www.iea.org/statistics/

IRENA 2015. The Southern and Eastern Africa Renewable Energy Zones (SEAREZ). http://mapre.lbl.gov/rez/searez/

JRC 2014. JRC Science and Policy Reports. ETRI 2014 Energy Technology Reference Indicator projections for 2010-2050. ISBN 978-92-79-44403-6

Konrad Adenauer Stiftung 2012. Namibia's Energy Future – A Case for Renewables. VO Consulting. Dr Detlof von Oertzen. 111 p.'

MFMR 2013. Ministry of Fisheries and Marine Resources. Annual report 2012-2013. Windhoek, Namibia. 46 p.

Mshandete A., Kivaisi A., Rubindamayugi M., Mattiasson B. Anaerobic batch co-digestion of sisal pulp and fish wastes. Bioresource Technology 95 (2004) 19–24.

Mukumangeni 2006. The Namibian Horse Mackerel Fishery: Juveniles or Adults? Final project from the United Nations University. Ministry of Fisheries and Marine Resources. Windhoek.

Namibian energy statistics. Statistics booklet. ECB 2015 (Matias Moyo)

NamPower 2015. WattsOn. The Official Newsletter of NamPower Edition #1 2015.

NREL 2012. Photovoltaic Degradation Rates — An Analytical Review. Dirk C. Jordan, Sarah R. Kurtz. National Renewable Energy Laboratory. Journal Article NREL/JA-5200-51664. June 2012.

NREL 2015. 2014 Cost of Wind Energy Review. Christopher Moné, Tyler Stehly, Ben Maples, and Edward Settle. National Renewable Energy Laboratory. Technical Report NREL/TP-6A20-64281. October 2015.

Pasonen R., Mäki K., Alanen R., Sipilä K.Arctic solar energy solutions. Espoo 2012. VTT Technology 15.

Republic of Namibia 2015. Intended Nationally Determined Contributions (INDC) of The Republic of Namibia to the United Nations Framework Convention on Climate Change. [Accessed 30/10/2016] Available: http://www4.unfccc.int/submissions/INDC/Published%20Documents/Namibia/1/INDC %20of%20Namibia%20Final%20pdf.pdf

Rämä, Miika; Pursiheimo, Esa; Lindroos, Tomi; Koponen, Kati. Development of Namibian energy sector. Research report: VTT-R-07599-13 2013. VTT, Espoo, 68 p. http://www.vtt.fi/inf/julkaisut/muut/2013/VTT-R-07599-13.pdf

Sarver, T., Al-Qaraghuli, A. & Kazmerski, L.L., 2013. A comprehensive review of the impact of dust on the use of solar energy: History, investigations, results, literature, and mitigation approaches. Renewable and Sustainable Energy Reviews, 22, pp.698– 733. [Accessed April 19, 2016]. Available at: http://www.sciencedirect.com/science/article/pii/S136403211300021X

Sokka, L., Pakarinen, S. & Melanen, M. 2011. Industrial symbiosis contributing to more sustainable energy use – an example from the forest industry in Kymenlaakso, Finland. In: Journal of Cleaner Production 19(4):285–293.