Tasso A/S' possibilities to reduce the carbon footprint

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***Abstract*— This project analyses CO2-emissions for the iron casting company Tasso A/S and looks at different possibilities of reducing the emissions. There has been made data analysis of detailed electricity consumption and hourly CO2-emissions for the Danish public grid. Moreover, CO2-emissions of yearly data for fossil fuel consumption, electricity, heat and transportation is calculated. The reasoning behind looking at both hourly and yearly values is to take the fluctuating prices and emission from the electrical grid into consideration when matching these up against Tasso's consumption. The following scenarios have been investigated to see if it can reduce the CO2-emissions: timeshifted consumption, installation of solar power plant, installation of wind turbines and reduction or replacement of fossil fuels. Calculations has been made in excel and Matlab and simulations has been made in HOMER Pro. The results show that investing in wind turbines will give the highest reduction in CO2.**

I. Introduction

Many companies have published that they want to reduce the carbon footprint from their overall supply chain. The company Tasso A/S is a supplier to many of these companies and an iron foundry, which produces cast iron. This article will look into possibilities of reducing Tasso A/S' energy consumption and carbon footprint, and in that way let them remain an appealing collaborator. The solutions are based on received data, which is the total energy consumption on a yearly basis. The electrical energy consumption is given with a higher resolution as this is the primary energy source. Other energy sources that Tasso A/S uses are, diesel, natural gas and liquified petroleum gas.

The carbon footprint can be categorized by following the Greenhous Gas Protocol (GHG protocol) [1]. This investigation will only focus on scope 1 and 2, which are direct emissions from internal functions and emissions from external energy generation. This is to clarify Tasso A/S' emissions and thereby focusing on factors with the highest impact. It will be investigated how this is done the best way from an economic and engineering point of view. Tasso A/S is located in the middle of Odense, which complicates the implementation of most renewable energy sources in a scale that has a significant impact on their CO2-emissions. Alternative possible ways of reducing carbon footprint like rearranging the timeline of electricity consumption or constructing renewable energy sources away from the company's location compared to the investment will be discussed later in this article.

To indicate different investment's effect on emissions compared to the economics, a HOMER Pro model have been created. The base model illustrates the actual conditions at Tasso A/S, which therefore makes it easy to simulate different scenarios with different renewables.

II. Methods

Tools

The tool used for data analysis is mainly Matlab 2018b, which is good at handling large data sets and has many possibilities for calculating on and plotting data. Data analysis made in Matlab can be seen in appendix 4.

The tool used to simulate the cases is HOMER Pro. HOMER Pro is made to optimize the balance between electrical production and consumption based on costs or other constraints.

Data used in calculations and models

Data for the project is collected for analysis and for use in the simulation model.

The electricity consumption of Tasso A/S is given as power consumption with a datapoint every 2nd second for 2019. In Matlab the electricity data is aggregated to one-minute data to make it fit into HOMER Pro. This is done by taking the mean value of the data over one minute. Missing data is filled with the previous data value. Analysis of the data includes Fast Fourier Transformation (FFT), to see if there are any interesting patterns in the consumption.

Data for the fuel consumption is given as a value per year. As the emission per liter is time independent, the resolution does not matter, and there will be no data analysis of this.

Data for the price of electricity bought from and sold to the grid is based on hourly prices from Nordpool [2] for 2019 in DK1, as Tasso A/S is located in this area. Moreover, tariffs and fees are collected to get a good price estimate.
The electricity fee to the government is 0.892 DKK/kWh, but companies can typically get 0.888 DKK/kWh refunded, depending on what the electricity is used for. [3] In this project it is assumed, that Tasso A/S gets 0.888 DKK/kWh refunded for the entire electricity consumption. Transmission tariffs from Energinet [4] are also included in the electricity price. These include the following tariffs for consumption: transmission tariff (TSO fee), system tariff, balance tariff for consumption, and the following tariffs for electricity production: balance tariff for production and feeder tariff. Distribution tariffs are based on the local company "Vores elnet", where it is assumed that Tasso A/S is customer type "A-low", which means that they are connected to the 10-20 kV grid.

Data for CO2-emissions of electricity in Denmark is taken from Energinet [5], where the emissions are given per hour for 2018 and 2019. The hourly CO2-emissions are analyzed by looking at metrics as e.g. mean values, standard deviation and median. Moreover, there has been made plots aggregated per month to show yearly pattern and average hours to show the daily pattern.

Wind resources used in HOMER Pro is average wind speed data made over a ten-year period from 1983 to 1993 by NASA. The wind speed is measured at a height of 50 m in an open area, which seems reasonable for analysis of a wind turbine placed on the west coast of Denmark.

The solar resources are average values for global horizontal radiation made by NASA over a 22-year period from 1983 to 2005.

Yearly CO2-emissions

There has been made calculations of the CO2-emissions based on yearly data for consumption of fuels, electricity and heat.

Timeshifted consumption

The electricity consumption has been timeshifted to see if there are any advantages on CO2- emissions. It will not be practical to shift the consumption with more than one day, so this has not been evaluated. As CO2-emissions per kWh on hourly basis are used, it could potentially have an impact on the total CO2-emissions.

HOMER Pro simulations

Three cases are simulated in HOMER Pro, first a base case to validate the yearly results with actual values for cost and consumption from Tasso A/S.
The base case is their electric load schedule and the fluctuating electricity price. The other two cases are respectively one with solar energy and one with wind energy. The different cases report will be in appendix 2. The cases are set to run over one year and ten years. This is to find a possible breakeven point. At this point it is cheaper to have renewable sources than not having them. The cases are simulated with and without sellback to the grid. This is because the renewable energy penetration (REP) for Tasso A/S' consumption should only consider the renewable energy (RE) produced at the same time as they are consuming. The RE produced when they are not consuming is therefore not a part of their CO2-emission calculation. The LCOE is calculated when sellback is included, as its very reasonable that Tasso A/S will sell the excess energy.

III. Results

Data analysis results

The FFT of the electrical consumption shows that there is a clear weekly pattern in the consumption and every half year. This is as expected and validates the data to some extent.

The CO2-emissions are generally higher in 2018 than 2019. In the project the data for 2019 are still used as they match the price data for electricity. There is a clear yearly pattern of the emissions, with lower emissions during the summer both in 2018 and 2019, but most significant in 2019.
The emissions are almost constant during the day, see Figure 1.

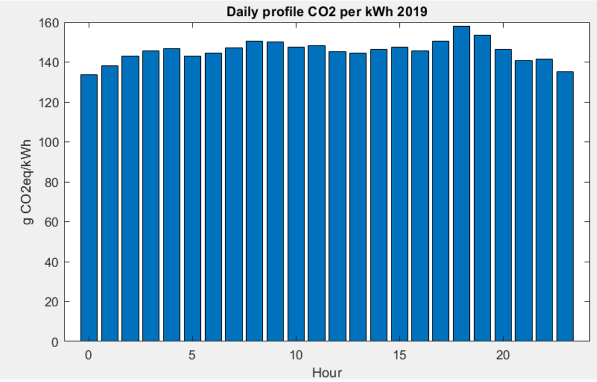

Figure 1, Daily profile of CO2 emissions per kWh electricity in Denmark

The standard deviation is calculated to 92 for the CO2-emissions for 2019, which is quite high compared to the mean value on 145. This means that the emissions vary a lot. The same is seen for 2018. The CO2-emissions used are based on Energinet's 125% method. The 125% method is a heat efficiency method, where it is assumed that the power plant also produces heat at a heat efficiency of 125%. This means that 1 TJ of fuel gives 1,25 TJ heat. The Danish Energy Agency recommends using 125% instead of 200%, therefore data based on 125% method is used in this project. 200% method will give higher CO2-emissions for the electricity, because a higher part of the fuels is used to produce electricity as the heat efficiency is higher. [6]

Timeshifted consumption

As both the CO2-emissions for electricity and Tasso's electricity consumption are generally constant over the day, timeshifting the consumption does not make a noticeable difference in the total CO2-emissions. The total CO2-emissions varies with maximum +/-4% depending on whether it is shifted forward or backwards and how many hours it is shifted, but there is no clear pattern.

Yearly CO2-emissions

Figure 2 shows the main consumption of fossil energy in scope 1 and how it is shared between the different fuels. The carbon emissions per MWh is found for each different fuel to calculate the total emissions of scope 1. Energy for transportation is not included in figure 2, but it is a part of scope 1 too.
All yearly calculated emissions can be studied in appendix 1.

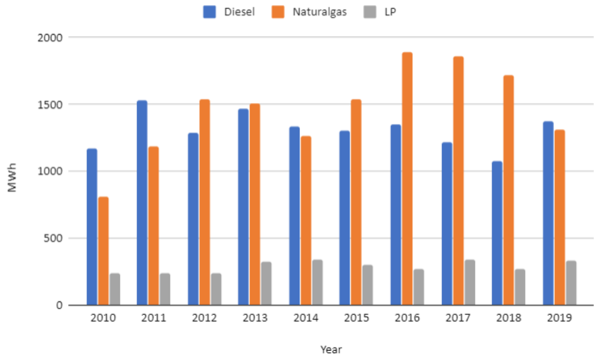

Figure 2, Tasso's consumption of fossil fuels in 2010 to 2019

Emissions for scope 2 are shared between three sections. As for scope 1 figure 3 shows the energy consumed. Clearly electrical energy is the most used energy type and is increasing. The graph also shows that from 2014 the surplus heat has been utilized. For electricity, emissions have been calculated using an average value from Energinet of the total CO2 emitted per produced kWh.

To determine emissions of district heating 190 kg CO2/MWh is used. This number is from 2013, and therefore probably a bit lower these days.

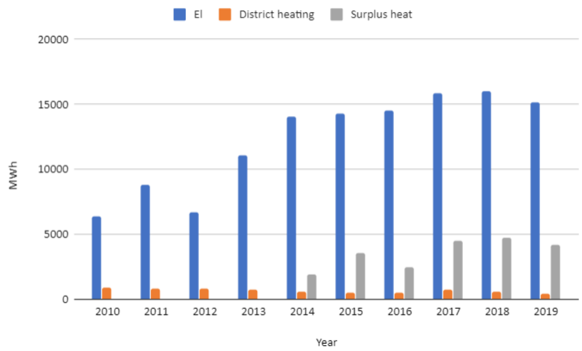

Figure 3, Tasso's electricity (blue) consumption and heat (orange) consumption and surplus heat (grey) production

Comparing tons of CO2 per ton produced cast iron shows a quite large reduction of CO2-emissions throughout the years from 2010 to 2019, starting at 0,389 tons ending at 0,206 tons CO2 with an estimated production of 15000 tons in 2019, which is a decrease of 738 tons of iron compared to 2018.

To make a roughly overview of the different sources' impact on the emissions, the total carbon footprint is calculated with a 10% reduction of emissions from fossil fuels, afterwards with a 10% reduction of electricity and last district heating. Of course, electricity makes the largest cut in CO2, as 10% is about 1500 MWh compared to 300 MWh for fossil fuels combined.
But fossil fuels reduce a lot in proportion to the small amount of energy, due to the high carbon content.

The total CO2-emissions for 2019 is 3093 tons CO2 based on yearly data, see appendix 1.

The CO_2-emissions for electricity represents 73.6% of the total CO_2-emissions in 2019. The rest of the CO_2-emissions comes from fossil fuels (23.7%), transportation (0.2%) and district heating (2.6%).

The CO_2-emissions from transportation and fuels are calculated to be 5.5 tons CO_2 from transportation and 732 tons CO_2 from the fossil fuels. A change to electric vehicles (EV) will give a CO_2-reduction of 4.8 tons if a Nissan Leaf is chosen, other EV have been considered in appendix 1. Regarding the fuel's conversion to electricity, it is probably not practically possible. But if it is, and the same energy amount is assumed, a reduction of 280 tons is expected.

HOMER results

The first simulation is a simple model based on the electric consumption and the average CO_2-data for 2019. By our simulation we get a price for the electricity of approx. 7,475,000.00 DKK. The consumption is approx. 17187 MWh. In this case the LCOE is 0.435 DKK/kWh. The CO_2-emissions are 2578 tons CO_2/yr.

A solar farm on 400 kW can be installed for approximately 10 million DKK. This will give a REP of 2%, which means that 2% of the electricity consumption will come from the solar panels. In this case the LCOE is 0.459 DKK/kWh. There is no break-even point for this case.

To cover 10% of the consumption with solar power, it is required to have about 2667 kW solar power, which will cost around 30 million DKK. In this case the LCOE is 0.530 DKK/kWh. There is no break-even point for this case as the LCOE is higher than the base case.

A wind turbine of 1.5 MW can be purchased for approx. 10.75 million DKK without taking installation into account. This gives a REP of 25.7%. The LCOE for this case considering sellback to the grid is 0.793 DKK/kWh if the case is only run for the year 2019. This is due to its high initial cost.

If the case runs for 10 years assuming the same inputs, the breakeven point is after approx. 4 years. The LCOE over the 10-year period is 0.300 DKK/kWh. The CO_2-emissions for this case is 1915 ton CO_2/yr.

Considering two of these wind turbines with a combined power of 3 MW, for approx. 21.5 million DKK. This will result in a REP of 44.9%. This case result in a LCOE of 0.192 DKK/kWh. The CO_2-emissions for this case is 1421 ton CO_2/yr.

Comparison of CO2-emissions

The CO_2-emissions for the different scenarios are compared in this section. The results are shown in Table 1 for the following scenarios:

Scenario 1: Base case, based on yearly data
Scenario 2: Base case, based on hourly data
Scenario 3: With 400 kW solar (hourly)
Scenario 4: With 2667 kW solar (hourly)
Scenario 5: With 1.5 MW wind turbine (hourly)
Scenario 6: With 3 MW wind turbine (hourly)

	Electricity from grid (GWh)	**REP (%)**	**CO2-emissions of electricity (tons)**	**CO2-reduction (%)**
1	15.17	0	2276	-
2	17.32	0	2515	-
3	16.85	2	2456	1.8
4	15.47	10	2271	7.3
5	12.77	25.7	1912	18.1
6	9.48	44.9	1421	32.8

Table 1, results for CO2-emissions from electricity in different scenarios

	LCOE (DKK/kWh)	**Initial investment (mil. DKK)**	**Payback time (Years)**
1	0.445	0	Not available
2	0.445	0	Not available
3	0.459	10	Infinite
4	0.530	30	Infinite
5	0.300	10.75	4.02
6	0.192	21.5	4.16

Table 2, costs and payback time for scenarios

IV. Discussion

There has been looked at scope 1 and scope 2 emissions for Tasso A/S. The reasoning behind not including scope 3 is because of its complexity.

When Tasso A/S makes their products from scrap iron, shall emissions from the entire life cycle of this iron be included in scope 3 calculations? Or shall scope 3 only include emissions regarding the collection of the scrap iron when looking at the iron's downstream emissions?

If the scrap is rims from a car, would emissions from the car be included in Tasso A/S' emission? This is a very complicated topic, as limiting your view and inclusion of different steps in the product's life cycle, both up and down stream, is complicated. If they make iron that would eventually be a turbine in either a hydro plant which is RE or if the turbine is a part of a fossil energy plant, would the upstream emission then be different? Because of this difficult decision-making scope 3 has not been considered.

As mentioned, there are different ways of reducing the carbon footprint. Some have direct impact while others are more indirect. There has been looked at reducing or replacing fossil fuels, timeshifted consumption and investment of renewable energy.

To make a local impact on CO2-emissions, Tasso A/S can consider replacing the burners using fossil fuels with electrical based heaters. That kind of investment will continuously reduce the carbon emissions by following the development of the grid. Though it depends on the demand for electrical energy to heat the line to an acceptable level.

Tasso A/S can have advantages of looking into their fuel consumption and electricity consumption. It is seen that their consumption per tons produced iron has increased a little during the past 10 years. Especially when comparing electricity in 2019 with 2017 an increase by approximately 20 kWh per ton is seen without knowing the reason.

The reduction of tons CO2 per ton produced cast iron, and their total emissions in general, is mainly due to a reduction in CO2-emissions of the energy in the electrical grid. The development of emissions in proportion to electricity production and Tasso A/S' reduction in carbon footprint have the same tendency and are illustrated in the figures below.

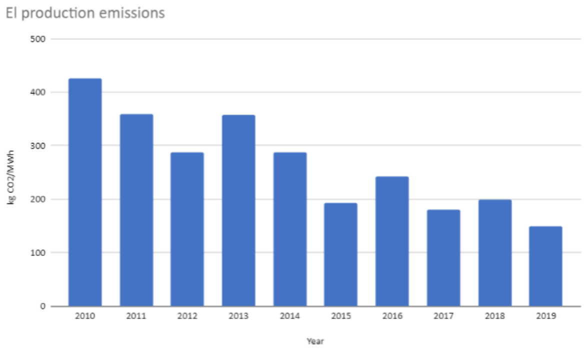

Figure 4, CO2-emissions per kWh electricity in Denmark

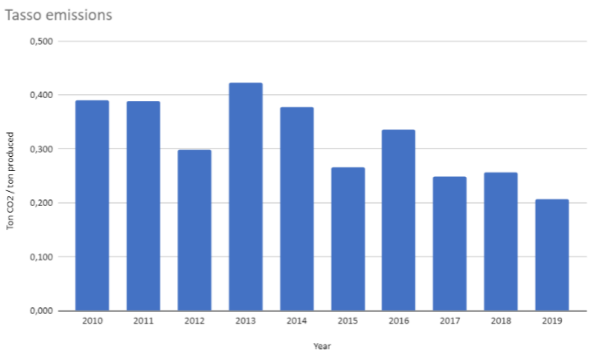

Figure 5, CO2-emissions per ton produced iron by Tasso A/S

To improve the calculations and simulations, the data used could be better. As data for fuel consumption is only given per year, calculations on scenarios, where the fuels are replaced by e.g. electricity or other more sustainable sources will be very rough estimation, according to price and CO2-emissions.

The weather data used in the simulations are based on typical data made over a ten-year period, which both have advantages and disadvantages. The advantages of using typical data is that it will be a statistical better representation of the weather conditions, than using data for one specific year. The disadvantage is that there is a close connection between the actual weather, electricity price and CO2-emissions, which will not be the represented in the simulations, when using typical data. Another drawback of the weather data provided by HOMER Pro is that it is almost 30 years old (weather data is from 1983-1993).

There could have been made more data analysis to give an even better understanding of the factors that influence the CO2-calculations. There could have been looked more into the CO2-emissions per kWh electricity by e.g. finding the deviation in each hour of the day, to see if some hours are more consistent than others. It could also have been investigated how an average winter day looks compared to an average summer day. This would give better argumentation when recommending solutions.

The change in CO2-emissions when timeshifting the electricity consumption is small as expected, as both consumption and the CO2/kWh is almost constant during the day.

The simulations of renewable energy show that the price of PV is too high to make a good business case. On the other hand, the wind turbines have an interesting business case.

One of the factors that has an impact on the business case is the electricity price. As the electricity price, Tasso A/S pays, is low compared to private consumers, the savings per kWh will be lower than for private consumers. On the other hand, excess electricity production will be more attractive to sell, as it has almost the same value as bought electricity.

When looking at the investment of RES from the CO2-perspective it is relevant to discuss their impact. When constructing some sort of renewable energy source in a different location than where the actual consumption is, then every consumer connected to the grid reduces their emissions a bit, as the produced energy is injected to the grid.

If Tasso A/S makes an investment in RES, the produced electricity of this source could get a certificate, which proves the energy's origin. When this energy is used, the credits for RE goes back to Tasso A/S when using the marked-based method of scope 2 in the GHG protocol. If Tasso A/S makes an investment in for example wind turbines which equals their consumption over a whole year, then they can state themselves as CO2-neutral, as of the present definitions. [7]

This is not how it is calculated in this project, as only RE, which is present at consumption time, is used. It is important to notice that the calculation of a CO2-reduction depends on the method which is used at that time. Therefore, a CO2-reduction from today, will not necessarily be the same reduction in 10 years, due to the possible change in its definition.

The 44.9% REP is for a case where Tasso A/S is connected direct to the wind turbines and represents the energy that, they can consume based on the production according to weather data. With some sort of electric energy storage, they could be able to use all of the produced energy from the wind turbines resulting in a REP of 59.1%.
The simulation is performed with offshore wind turbines outside of Esbjerg, because the actual location in Odense is not a practical solution.

It is worth to consider the difference between buying existing RES and buying and installing new RES. Buying existing RES will probably give Tasso A/S a certificate of using green energy, but it will not add any green energy to the grid, as somebody just give up their RES. By buying and installing new RES, the company will help to increase the share of RE in the grid and thereby making everyone greener. It has not been investigated what difference, there is in these two cases, when reporting CO2-emissions to the GHG protocol.

V. Conclusion

It can be concluded that there is a potential for reduction in their energy consumptions, both electricity and fossil fuels. Moreover, replacement of the current fossil fuels with electricity can reduce the yearly CO2-emissions.

Investment of RES has been investigated and it can be concluded that a CO2-reduction of 1.8-32.8% can be achieved depending on the case. The wind turbines give a much higher reduction compared to the investment. It can also be concluded that the LCOE of solar power is higher than the current LCOE and therefore not an attractive business case. However, it seems like the wind turbines can be a good business case, though it shall be mentioned that the economic calculations have not been the focus and is necessary to investigate this in more details. The investment of RES also has to be considered regarding the CO2-reduction, and there is a chance that there will come fees or other economic aspects related to the CO2, which can turn the investment into a good business case in the near future.

As a result of the knowledge, points and simulation results discussed in this article Tasso A/S is now considering looking more into investing in wind turbines as a tool to reduce their carbon footprint and as a business case.

Future work can be to investigate their consumption and how they can reduce this and streamline it, before investing in RES as they then will not need as much energy. They can also look more into the potential of extraction of heat energy. Different parts of the production releases large amounts of heat, that could be used to heat up water and probably run a turbine.

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