UNIVERSITETET I AGDER

Transition to a fossil- and emission-free construction industry

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I. Preface

This thesis is the final part of our Master of Science in Industrial Economics and Technology Management at the University of Agder (UiA). It is written in our final semester and accounted for 30 credits.

This research is having a look at what it will take for the Norwegian construction industry to go green, and how Nettpartner can contribute to this change.

We would like to thank our supervisor Magnus Hellström for his guidance and support. Without him we would never be able to complete this thesis in time and the thesis wouldn't have been the same.

Grimstad, 08.06.2018

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II. Summary

The object for this thesis is to see how Nettpartner, which is Norway's largest electrical infrastructure contractor, can contribute to the green change in the construction industry. To go green has become a big topic in the Norwegian construction industry during the last few years, and in 2017 a report concluded that the Norwegian construction industry could reduce their emissions of greenhouse gases with close to 99 % if the industry planned better before they started building.

The method used in this research is the constructive research. The aim of constructive research is to solve practical problems while producing an academically appreciated theoretical contribution.

We start by looking at which technology that is available for the construction industry to go green to today. Here we saw that we have excavators and trucks running on batteries already and more to come soon. We also look at some of the barriers that must be crossed, before the construction industry can go green. One of these barriers is the capacity of the power grid, but this can be solved with the use of batteries.

We then do some calculation for a couple of business opportunities that Nettpartner can use to contribute to the green shift in the construction industry.

Our main findings show that there isn't so much Nettpartner can do right away, but they must be aware of the need that will be here tomorrow and try their best, in cooperation with other companies and instances, to install an electrical infrastructure that can handle the need of tomorrow.

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1 Introduction

Earth's Temperature is increasing. According to calculations done by IPPC in 2007, the planet's temperature will increase by 2 degrees Celsius if the amount of CO_2 gas in the atmosphere reaches 450 ppm. Furthermore, the calculations show that humans are responsible for this temperature increase, because of our emission of greenhouse gasses (GHG) since the industrial revolution. Therefore, to reduce the chance of a catastrophic event in the future, man-made emission of GHG must be reduced. By 2020, it will become clear whether the temperature increment follows IPPC calculations or whether the temperature is oscillating and have other cause (Thun-Larsen, Hagman, Hovi, & Eriksen, 2009). As of now, 2018, it has become clearer that global warming is caused by humans and a noticeable effect of the global warming is being felt around the world.

This is forcing government across the world to come up with a solution and many are now moving to a more renewable way of producing energy. Norway has a goal of reducing their GHG emissions compared to the emission level of 1990 with 40 % by 2030. For 2050 the goal is to cut the GHG emissions by 80 to 95 % compared to the 1990-level. Reaching that last goal would mean that Norway is a low-emission country in 2050 (Naturvernforbundet, 2018).

These emission-cutting goals have made municipalities in Norway thinking about setting restriction regarding how much emissions different sectors and industries can have, and this is forcing companies to work as green as possible. As an example, Oslo want to have restriction like that as soon as in 2020. With this mind, Nettpartner, who is Norway's largest electrical infrastructure contractor, wanted a research on what fossil- and emissions-free construction sites could give them of business opportunities in the future.

As we'll come back to in 4.3 our intention at first was to look for new business opportunities for Nettpartner. After rewriting our research question a couple of times, our research question for this thesis became:

> **How can Nettpartner contribute to the sustainability transition to a fossil- and emission-free construction industry?**

Our focus in this thesis is the construction industry and all our findings and discussion will be linked in this direction. At the same time, it has been hard to focus some of our findings and solution to only apply to the construction industry, as the green shift isn't limited to the construction industry.

To be able to answer our research question in the best way possible, we felt the need to get a good basis on this topic, and we made some side-questions we thought would help us in the right direction. Some of them did, and some of them didn't. With input from Nettpartner on what they wanted to know, we decide a couple of the side-questions to include and answer in this thesis:

- What will be the energy demand be at various construction sites (here we want to look at one "typical" construction site and a road project)?
- What will be the energy demand for the whole construction industry in Norway?
- Is electrical energy enough to meet the energy requirement for the various machines used by the construction industry?
- Can batteries or other local renewable energy be used instead?

These questions will indirectly be answered throughout the thesis, but we will also answer them one by one in the beginning of chapter 5.

There are multiple ways to go fossil- and emission-free, and we decided to have our focus on the opportunities that exists with the use of electrical energy. This came naturally as we write for Nettpartner.

2 Background

The emissions of GHG from Norwegian construction sites can be drastically reduced. Statistics Norway's (SSB) statistics shows that building and construction activities on a national basis accounted for emission of 841.000 tons of CO_2 in 2015. Of these 841.000 tons, 340.000 tons were from construction sites. This is the same amount as all passenger cars and lighter vehicles in Oslo. In Oslo, emissions from construction machinery was responsible for 20 % of the total emissions in the city (Byggmesteren, 2017) (Energi Norge, 2017).

A report from 2017 concluded that Norwegian construction sites could reduce their emissions of GHG with as much as 99% if the industry planed better before start building. One of the main factor for achieving this goal would be to use electrical energy and district heating on construction sites earlier then what is the normal today. In fact, Norway's first fossil-free construction site came when we conducted this study. Statnett and Veidekke is upgrading the power cables between Smestad and Sogn in Oslo, and they are doing this with only fossil-free energy sources. All cars, trucks and other construction machines in that project runs on electricity or renewable diesel. This project isn't emission-free but has cut the emission with 78 % (Byggfakta, 2018).

In 2.1, we'll have a look at the energy requirements for a "typical" Norwegian construction site. The figures we operate with is taken from the report "Fossil- og utslippsfrie byggeplasser" written by Energi Norge, Norsk Fjernvarme in cooperation with Bellona, and Enova SF (2017). This report concluded that Norwegian construction sites could reduce their CO_2 emissions with over 99 %. The reason we look at the energy requirements for a "typical" Norwegian construction site is to get an understanding of how much electrical energy a construction site would need. But having those figures alone doesn't tell us much. To better understand what these figures tells us, we'll in 2.2 have a look at how much this is compared to the rest of the energy usage and the energy production in Norway. In 2.3 we'll have a look at some of the technology that is available today for the construction industry to go green, and in 2.4 we'll look at some of the technologies that have had a good development in recent years and probably will become an important part of the green shift in the future. 2.5 will end this chapter with a short look at some of the barriers that must be crossed for the green shift to happen in the construction industry.

2.1 The energy requirement for a "typical" construction site

As mentioned, all figures in this section is taken from the report "Fossil- og utslippsfrie byggeplasser" (Energi Norge, Norsk Fjernvarme i samarbeid med Bellona, og Enova SF, 2017). The energy requirements are divided into the same subsections in this thesis as it was in the report, as we felt this was a good and natural division.

2.1.1 A "typical" Norwegian construction site

Of course, no construction site will be the exact same size, or require the exact same amount of electrical energy. In the other report, a typical building site is defined as a 10,000 m^2 apartment block. It has 3 m ceilings and simple ground conditions. In addition, it is defined that the energy consumption of the brackets are powered by electricity, and those figures were not included in the calculations. The emissions of GHG were calculated as CO_2 equivalents (CO_2e) and were calculated after the generic emission factors prepared by the British Ministry of the Environment (Department of Environment, Food and Rural Affairs – DEFRA) in 2016.

2.1.2 Building heat

When talking about temporary heating and drying on a building site, this is often referred to as building heat, and is normally used for internal heating, drying of moisture, concrete curing, facade heating and thawing / frost protection.

In the report we refer to, heating and drying on a building site was divided into three activities:

1. Heating by casting of building coverings (concrete curing)
2. Facade heating
3. Internal heating

The need for heating on a building site will largely be controlled by the outdoor temperature. This is because heating on a building site is mostly used for drying material and for achieving a satisfying temperature inside. In most cases, heating will be needed from November to March. The total energy requirement for building heat will vary widely with which tasks that has to be performed, and whether it is a cold or mild winter. The report has made a high and a low estimate for the energy needed for heating at 2.500 MWh and 1.070 MWh. And in the calculation for the total energy need for a construction site, which we'll come back to in 2.1.5, the report has operated with 1.450 MWh.

2.1.3 Construction machinery

Construction machinery at a construction site can be split into two categories:

- machinery for basic work
- machinery for construction work.

For the basic work, large and diesel-driven machines are often used. During this phase of the project it will be the complexity of the basic conditions that determine the time spent and the number of machines used. Figure 1 is a great example of this. Here you see the basic work for the new health lab at the University of Agder. Here they use almost the same amount of construction machines as the report calculated for a 10.000 m^2 housing block, even though the new health lab is “only” going to be 3.700 m^2. The report has calculated with three 30-tons excavators and one mobile crane.

Figure 1 Basic work for the construction of the new health lab at the University of Agder (self-taken photo, 24th of May 2018)

For the construction work, it is only the use of diesel-powered mobile cranes that are included in the calculation. The report assumes that the tower cranes, lifts and the handheld machines are already electrical, and their electric usage are excluded from the report’s calculations.

The calculations in the report was based on a school building of 7.400 m^2 with relatively simple basic conditions. It is assumed that the energy consumption of the construction machinery in this project has been representative of a "typical" project and that the energy consumption of construction machinery will vary linearly with the number of square meters of a project.

Emissions of GHG from the construction machinery on a "typical" construction site will be in the range of 250 tons CO_2e. Should you cover the energy consumption of these machines with electricity, you will have a total energy requirement of 280 MWh.

2.1.4 Transport to and from the construction site

During a construction project there will be a lot that has to be transported to and from the construction site. Mass digested must be transported away, or more mass may be needed at the construction site to level out or stabilize the ground. Materials, tools and construction machines that doesn't drive for own engines, must be shipped to and from the construction site. Also, there will be a need to transport waste away from the construction site and this could be large quantities. Both the quantities and the length of the transport will vary for each of these segments and from construction site to construction site. This can potentially have a big impact on the total emissions associated with transportation for a construction site. It is assumed that all abovementioned transport take place with diesel-powered vehicles, and the report have chosen to exclude all passenger transport from the calculations.

The calculation for this section is based on the transport of a 9,100 m^2 commercial building. The building had two floors and parking garage underneath it. The report doesn't say anything about the actual mileage but has again assumed that this project, and the mileage on this project, is representative of a "typical" project, and that the values will increase linearly with the number of square meters. It is also assumed that the vehicles used are of heavy cargo type (> 17 tons), Euro Class IV, and the average fill rate was of 50 %.

In total, it is estimated that the emissions from transport on a "typical" construction site will be about 90 tons CO2e. It is estimated that the electrical requirement for transport to and from a construction site will be around 100 MWh.

2.1.5 Summary of energy requirements

The report we have obtained these figures from, has been made based on input and experience from the construction industry itself. It has mapped the energy requirement for a "typical" construction site and calculated emissions of GHG. The report estimates that the energy requirement for a "typical" construction site, here a 10,000 m2 housing block, could be approximately the order of 1,800 MWh. This will correspond to emissions of about 670 tons CO2e.

2.1.6 Critical view on the report "Fossil- og utslippsfrie byggeplasser"

Some of the calculation we do later in this thesis is based on the figures from this report, and therefore we decided to have a short critical view on the report. We did this too see if there is anything we had to be aware of when using these figures and we found a couple of things.

Firstly, in the introduction the report itself says that there is an uncertainty associated with the figures because every project is unique and there is limited with figures for this kind of calculations.

Secondly, activities that already runs on electricity is not included in the calculations. This is because the report assumes that this accounts for a very small percentage of the total consumption. We think that's fine, as we understood the goal of the report to research how much the construction industry can reduce their GHG emissions, and not how the construction industry can do it.

Thirdly, some of the basic calculation in this report is wrong. As an example, in 3.4 the report has calculated 130 + 30 + 90 to be 240, which is 250. Also, for a calculation that is done twice in the report (both in 4.1 and 4.3) the answer is first 79 and then 275, while the correct answer on the numbers added together is 74. There is also an error in 3.3, where a calculation that should have been 2.480 is calculated to 2.500. We have found some other miscalculations as well, but we have chosen to only comment on those miscalculations where we use the outcome in other calculations later in this thesis. Also, as one of the calculations is done twice with the exact same numbers to be added together, and the report manage to have two different and wrong answers, we choose to believe these mistakes is not miscalculations, but rather typing errors. See Appendix A for the miscalculations/typing errors mentioned above.

With all that said, we think the report gives us a good overview of the total energy requirements at Norwegian construction sites, which was what we wanted to get. But we must be aware of the uncertainty in the figures, and that some figures are left out, when we are referring to them and use them in other contexts later in this thesis.

2.2 Total need and energy production in Norway

The report assumes that the total energy requirement for all Norwegian construction sites, would be around 640 GWh per year, and this will correspond to about 340 000 tons CO_2e. This is calculated based on the average building activities between 2000 and 2016. As you can see of Figure 2, the activity in the construction industry has overall been moving upwards since 2000, increasing from 7,3 million m^2 in 2000 to 10,3 million m^2 in 2016. The biggest decreases, which happened in 2008 and 2009, can be linked to the financial crisis of 2007/2008. In 2017, Norway had a decrease in building activity of 0,1 million m^2 (<1 %) compared to 2016 according to SSB (2018) and the latest forecast from Byggenæringens Landsforening says we'll get a small increase in both 2018 and 2019, respectively 3,6 and 2,6 %. (NTB, 2017).

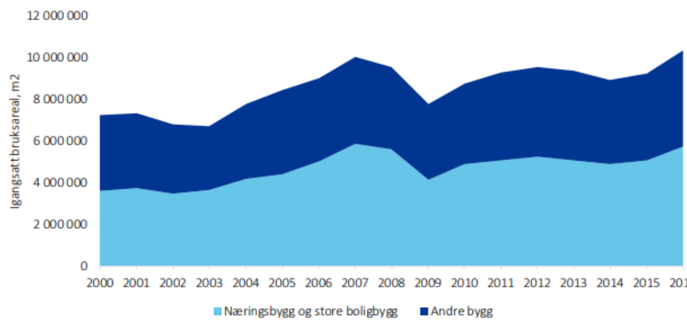

Figure 2 Commencement of use area (area of use for housing and other than housing) for 2000-2016, distributed on large construction projects and other buildings (Energi Norge, Norsk Fjernvarme i samarbeid med Bellona, og Enova SF, 2017)

According to SSB the total production of electricity in Norway in 2016[1] was 148.989 GWh (2017), which means that if all construction sites in Norway was electrical, the usage of electricity at Norwegian construction sites would account for approximately 0,43 % of the total electricity produced in Norway in 2016. In a normal year, Norway produce more electricity than we use. In 2016[1] Norway used 132.579 GWh (SSB, 2017), which a completely electric construction industry would need about 0,48 % of.

Norway's production of electricity in 2016 was more than 16.000 GWh higher than what we consumed the same year. This means that we theoretically have the electricity to make all construction sites electrical today. From 2016 to 2017 our consumption of energy increased with 600 GWh. This different, which is almost the need of the whole Norwegian construction industry,

[1] Not updated with figures for 2017 as of 7th of June 2018

is according to watercourse and energy director, Per Sanderud, the same amount as a small Norwegian city (NVE, 2018).

But even though we have the power to make the construction industry electric today, it is not as easy as that. As we'll come back to in 2.5, we also need a power grid that can handle the needs.

2.3 Available technology for zero emission constructions sites

In this section of the chapter we'll take a closer look on which zero emission technology that already exist today or is under development.

2.3.1 Construction site machinery

Construction site machinery can be divided into 4 categories;

- mobile electricals devices which runs on battery
- non-moving electricals devices which is powered directly from the power grid
- construction machines which runs on biodiesel
- construction machines which runs on battery.

As of spring 2018, Pon Equipment is making some great progress on construction machines which runs on battery. They have managed to develop a fully electrical Caterpillar 323F, which is a 25 tons excavator. Their prototype is finished, and testing was done during the first three months of 2018. Their plan is that their first delivery will be early in Q3 2018, and the buyer of the first machine is Veidekke. Pon Equipment sold two more of this excavator on "Vei og Anlegg 2018", a trade fair for the Norwegian construction industry, in May 2018. Pon's plan is to produce 5-10 of this excavator in 2018 (Anlegg & Transport, 2018) (Homleid, 2018). If everything goes according to the plans, a fully charged machine would run for 5-7 hours and have the same performance as the model that runs on diesel. The machine will charge on a 400V outlet and one hour of charging will give one hour of operational time. The plan is also to include a fast-charger, where between one and two hours of charging at a 400V or 1000V power supply will give a fully loaded battery (Pon-Cat, 2018).

2.3.2 Transportation

As we mentioned is 2.1.4, transportations can possibly have a huge impact on the total emissions from a construction site. We see that multiple companies are soon coming with battery driven trucks, and Tesla is one of these companies. Their truck, Tesla Semi, are coming in 2019, and are said to have a range of 800 km. Tesla also says that this truck will have a power consumption of less than 2 kWh per driven km (Tesla, 2018).

But Tesla is not the only company making electrical trucks. Daimler has already started to deliver electrical trucks, both in the US, Europe and Japan (Engadget, 2017) (Daimler, 2017). Their trucks are maybe not as big as the Tesla Semi and they don't have the same range, but they are already in use. For now, Daimler's eCanter only has a range of 100km, but Daimler Trucks Asia chief Mark Llistosella says, *"…within about two years "we know there will be a next level of technology" that will produce batteries with longer range, lower cost and lower weight"* (White, 2017). Because of this, Daimler is limiting the sales of their eCanter to 500 unit for the two first year of the production. With this limitation in mind, Mark Llistosella said *"The market demand is much higher"* (White, 2017).

2.3.3 District heating

District heating is a heating system where water gets boiled in a heating central and then get transferred in isolated tubes to buildings in a bigger area, a part of a city, or a whole city. The energy sources in district heating varies and includes gas, oil, waste, biofuel and heat pumps. In district heating it is possible to use more than one energy sources at the time, which make district heating a stable and flexible supply of heat to the customers.

From the heating central it runs two insulated pipes out to the costumers, one for feeding the hot water to the costumers and one for returning the "not-so-hot" water back to the central. The heat the customers receives from a district heating central can be used to underfloor heating, ventilation, radiators, heating and tap water. You can also use district heating for refrigeration.

2.3.3.1 District heating in Norway

In 2016, Norway had an "all-time" high production of district heating with a total of almost 6 TWh, which is 0,5 TWh more than 2015. About half of this production came from waste heat from waste incineration.

"- This illustrates the important function of district heating in using resources that would otherwise not be used to anything. ..." says Guro Bøe Wennsaas, Industrial Policy Advisor in Energi Norge (Energi Norge, 2017, own translation).

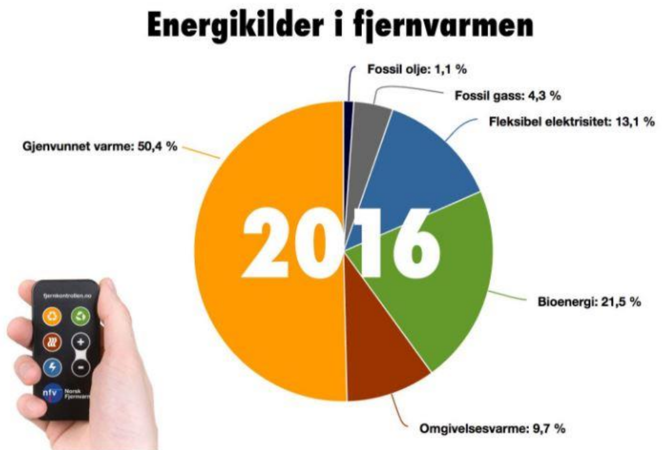

Figure 3 Energy sources in district heating in Norway (Energi Norge, 2017)

District heating in Norway isn't 100% green, but the total amount of fossil energy sources in district heating is only about 5,4%, where 4,3% is fossil gas and 1,1% is fossil oil. Trygve Mellevang-Berg, manager of communication in Norsk Fjernvarme, says it is good to see that the use of fossil energy sources in district heating is on a so low level, even though 2016 was an even colder year than 2015. He also added that the use of fossil energy sources in many district heating plant are completely gone or just used in emergency preparedness (Energi Norge, 2017).

2.3.3.2 District heating for inside heating and dehydration

To use district heating for inside heating and dehydration during the construction phases, a district heating central must already be installed. This could either be the district heating central that will be used when the building is completed or a temporarily district heating central. If the construction site is in an area where district heating is no option, an alternative solution would be to use waterborne heaters based on biofuel, for example pellets. There is also a possibility to use biofuel for heating with a mobile heating aggregate.

2.4 Upcoming technology

It is always hard to predict what is going be the next big thing, or what will be the standard in 10 or 20 years, and we're not going to trying to do that here either. With that said, we are going to have closer look at two of the renewable energy sources that guarantee will be here as long as we are and will become a bigger part of the world's energy production in the future. The sun and the wind. We'll look at the some of the latest development in both technologies. We'll end this subchapter with a short look at the improvements made over the last year in battery-technology, and how and why batteries probably will become a more important part of our power grid in the future.

2.4.1 Solar cell

The record for the most efficiency mass-produced solar panel was set in 2017 by researchers in Japan. They managed to create an efficiency of 26.6 %. This was done with silicon solar cells (Nield, 2017). But this is not the highest efficiency reached with solar panels. Researchers at UNSW Engineering have managed to create solar panels with an efficiency over 40 %. This was done with commercial solar panel, but they were modified and used in a new way (MacDonald, 2014).

2.4.1.1 Perovskite solar cell

Developing a new technology takes time, as it must be perfected and proven in the laboratory before it become available to the public. Silicon solar cells, as we known them today, has been developed for the last 60 years, and normally they have an efficiency a bit over 20 %[2]. The first report of perovskite solar cell came in 2009, and already now they are reaching the same efficiency as the silicon solar cells. With more lab development of the perovskite solar cells, scientist believe that perovskite solar cells will be able to beat the efficiency of the more traditional mono- or poly-crystalline silicon cells (Marsh, 2018).

[2] Here we think of solar panel in mass-production

The main problem with the perovskite solar cell today, is the durability, as they today only last for one or two years, while silicon solar cells can last up to 20 years (Okinawa Institute of Science and Technology (OIST) Graduate University, 2018).

2.4.2 Wind

In 2015, the global wind power generation accounted for 950 TWh, which is almost 4 % of the total global power generation and had a capacity of 435 GW, which is around 7 % of total global power generation capacity (World Energy Council, 2016). Even tough wind will vary widely in strength and consistency, it is available basically everywhere around our planet. In their research, "Geophysical potential for wind energy over the open oceans", Anna Possner and Ken Caldeira (2017) end their conclusion chapter like this: *"On an annual mean basis, the wind power available in the North Atlantic could be sufficient to power the world."*

2.4.2.1 Floating wind farm

In 2017, Equinor[3] completed the world's first floating wind farm, Hywind Scotland. The farm is 30MW and it supposed to deliver electricity to 20 000 homes. According to Irene Rummelhoff, the Executive Vice President for "New Energy Solutions" in Equinor, these wind turbines can be used on places where the ocean is as deep as 800 meters. The offshore wind farms that exists today is bottom-fixed and isn't made for an ocean much deeper than 60 meters. Rummelhoff also says that close to 80 % of the worlds wind resources at sea is where the ocean is more than 60 meters deep. These new turbines will therefore make it possible to create wind farms in places not possible before. After operating for three months, Hywind Scotland has achieved better result than expected. While a bottom-fixes offshore wind farm normally delivers between 45 and 60 % of the theoretical maximum, this floating wind farm managed to deliver 65 % of the theoretical maximum during the three first month of operation (Equinor, 2017) (Equinor, 2018). Today Hywind Scotland only consists of five turbines, but as the first of its kind and with great results, it shows us the potential of floating wind farms.

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[3] Previously known as Statoil. They officially changed their name on 16th of May 2018

As of today, this technology is expensive, but Equinor hopes to reduce the cost down to 40 – 60 Euros/MWh within 2030. With that cost reduction, floating wind turbines would be able to compete cost-effectively with other renewable energy sources. Equinor have already reduced the costs for these turbines with 70 % since the first Hywind Demo was built in 2009 (Haugstad, 2017).

2.4.3 Batteries

Every year we see a little improvement in the capacity of lithium-ion batteries. As a result of small tweaks to the batteries chemistry or new techniques for filling battery cells with lithium-rich electrolyte, we see an increase in the battery performance by a small single-digit percentage every year. But according to researchers, developers and manufacturers this jump is going to be double-digit within a few years, and some think this increase in capacity can be as much as 40 % (Mims, 2018).

Every lithium-ion battery has an anode and a cathode and when a battery is fully charged, all the lithium ions is sucked up by the anode. In today's battery the anode is made up of graphite, which is carbon in a crystalline form. Researchers has known for a long time that silicon can hold up to 25 times as many lithium ions as the graphite anode. The director of the Joint Center for Energy Storage Research, established by the U.S. Department of Energy at the University of Chicago Argonne lab to accelerate battery research, George Crabtree, says that one of the problems with silicon as an anode in batteries is that an anode made of pure silicon will soak up so many lithium ions that it gets "pulverized" after only one single charge (Mims, 2018).

> "*"The first commercial consumer devices to have higher-capacity lithium-silicon batteries will likely be announced in the next two years,"* says [Amperex Chief Operating Officer Joe Kit Chu Lam] … who expects a wearable to be first. (Mims, 2018)

2.4.3.1 Batteries already has an impact

In 2017, Tesla and Elon Musk built the largest battery in the world in South Australia. This battery has a capacity of 100MW/129MWh (MailOnline, 2017). The battery has already been put to a test, as one of Australia's biggest plant had an unexplained drop in output in December 2017. The battery reacted in only 0.14 seconds after det plant dropped in output. Not only do the battery reduce the number of power outages, but it also reduces the cost of a power outage.

> “ *“In the first four months of operations of the Hornsdale Power Reserve (the official name of the Tesla big battery, owned and operated by Neoen), the frequency ancillary services prices went down by 90 per cent,”* said Godart van Gendt, a partner at consulting firm McKinsey and Company, at the Australian Energy Week conference in Melbourne on Thursday [10th of May 2018] ” (Gabbatiss, 2018).

The Hornsdale Power Reserve is built of many Powerpacks. One of these Powerpack is 2,1 m tall, 1,3 m long, 0,8 m wide and the weigh 1.200 kilograms. Each of these Powerpack has a capacity of roughly 200 kWh.

2.5 Barriers

In 2.1 – 2.4, we have seen on the possibility for the Norwegian construction industry to go green. In this subchapter, we'll look at some of the barriers that has to be crossed before we can have a green construction industry.

2.5.1 Power grid

In this section we'll have a short look on the power grid in Norway, and how the power grid will affect the transition to a green construction industry. We have looked on NVE's report "Hva betyr elbiler for strømnettet?" as this is another "industry" which will require more of the power grid in the future. That report assumes that there will be 1,5 million electrical personal vehicles in Norway in 2030 and that the increased need of energy to charge all these vehicles will be 4.000 GWh.

Today, Norway's power grid doesn't have the capacity for everyone to get home and charge their electrical vehicles at the same time. Øyvind Leistad, director of development in Enova, compares it to if everyone should shower at the same time.

> *"If everyone showers simultaneously, the pressure in the water will be lower. There is enough water in the pond to allow everyone to shower [simultaneously], but the thickness of the pipeline limits the amount of water coming through. Then the pressure drops. …"* (Olsen, 2017, own translation)

With that said, the power grid is getting an upgrade all over the country. Statnett is planning to use between 35 and 45 billion NOK to upgrade the power grid until 2022. When this upgrade is done the yearly energy production in Norway can, according to Statnett's estimate, increase with 15.000 GWh before new investment on the power grid is needed (2017). This increase is a little more than 10% of the total energy production in 2016. One of the premise for this to be true is that we do a favorable geographical distribution of the production. Indirectly this means that the yearly consumption of energy in Norway can increase with more than 30.000 GWh, if we spread our usage throughout the hours of the day.

In fact, calculations done by NVE show us that the power grid in Norway will be ready for 1,5 million electrical vehicles in 2030. One of the premises for this to be a possibility is that many of the vehicles is charged at night, when the use of electricity for other purposes is low (NVE, 2016).

In the same report, NVE is also suggesting that batteries could to become a part of the power grid, to keep the strength in the power grid at a stable level at all time. We'll come back to how batteries can be used for this purpose later.

2.5.2 Solar and wind

That the sun shine and the wind blow is something that will be true for as long as we are here. And as the technology develops, it will be possible to produce more electrical power from sunshine and wind than it does today. But two of the biggest problems/barriers for the use of solar and wind energy are:

1. The sun isn't always shining, and the wind isn't always blowing.
2. Electric energy is a perishable, and the power grid is a carrier. It transports electricity from the producer to the costumer/consumer, but it can't store the energy. We must use electricity the second it is produced, and there must always be a balance between how much electricity that is created and how much is consumed.

But the solution to those two problems is already here: Batteries. Big batteries.

But again, it is not as easy as that. Even if the power was available, either straight from the wind turbine, the solar panel or a big battery, the power grid still need to have the capacity required to transfer the electricity.

2.5.3 Batteries

The main problems with the use of batteries in the construction industry today, is the size of them, or more precisely, the size per kWh. Tesla's big battery in Australia, which we mentioned in 2.4.3, is the size of a football field, but it is "only" 100MW/129MWh.

As we have seen here in 2.5, batteries are the solution to many of the problem to a green construction industry. Therefore, much of our discussion and solution is directly or indirectly connected to the usage of batteries.

3 Business theory

We'll use this chapter to describe and explain different business theories. Our focus will be on tools that help one develop new business strategies.

3.1 Business Model canvas

A business model canvas is a framework and a tool for decomposing and understanding your business models. It will help you map, discuss, design and invent new business models, and it works as well for start-up entrepreneurs as for the most senior executives (Strategyzer, 2018).

A business model can be described with nine basic building boxes (Strategyzer, 2018):

- Customer segments
- Value propositions
- Channels
- Customer relationships
- Revenue streams
- Key resources
- Key activities
- Key partnerships
- Cost structure

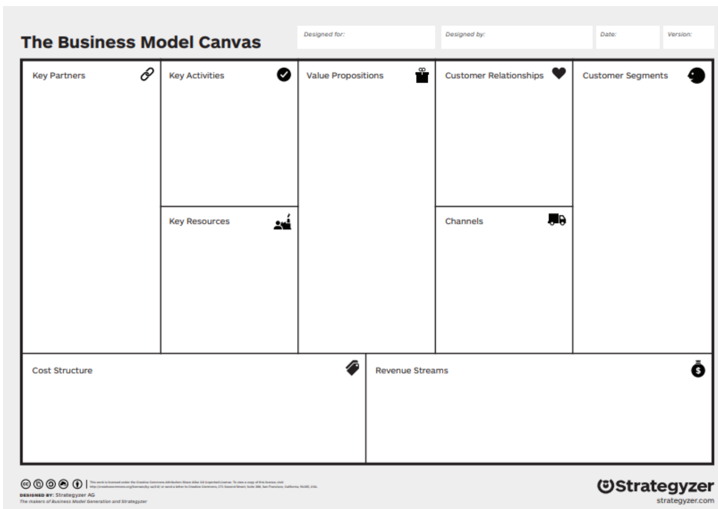

Figure 4 Business model canvas

Knowing these nine building boxes isn't enough. You want to map them out on a pre-structured canvas, as seen in Figure 4, to make it easier to map, discuss, design and invent new business models.

3.2 Total addressable market

Total addressable market (TAM, occasionally referred to as total available market) demonstrates the entire revenue opportunity that exists within a market for a product or service. By doing a TAM exercise, the business will shed light on the level of effort and funding that needs to be put into the new business line. Lately, TAM has become an important metric since new markets are evolving faster than before (Berry, 2014).

The primary function of a TAM exercise is to understand the revenue opportunity for new business ideas, but there are also some other advantages:

1. Focuses owners on their future roadmap and product evolution.
2. Provides a current waypoint for assessing product market fit.
3. Attracts and appeases investors by showing accuracy and conviction.
4. Puts competitors within a line of sight early on. (Berry, 2014)

3.2.1 TAM – Total addressable market

Total addressable market means the entire potential market for your business. If your business rent out construction lifts, your TAM would be the whole construction industry in Norway. Often TAM is a very large and useless number.

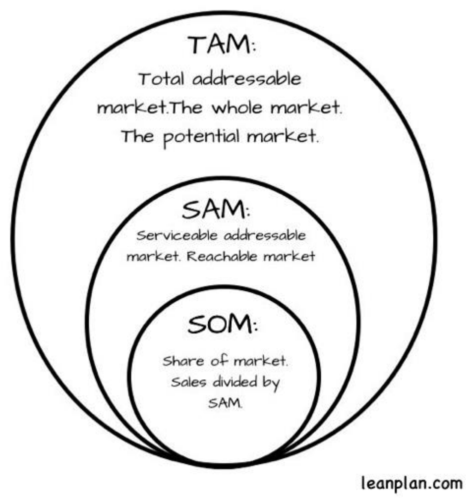

Figure 5 TAM (Berry, 2014)

3.2.2 SAM – Serviceable addressable market

Serviceable addressable market would be the part of TAM that your business can serve. One can say that SAM is the part of TAM that are within your geographical reach.

3.2.3 SOM – Serviceable obtainable market

Serviceable obtainable market is how much of SAM your business can capture in the short/med term.

3.2.4 Calculating TAM, SAM and SOM

According to Alex Graham at Toptal (2017) there is four ways to calculate your TAM; top-down approach, bottom-up approach, value theory, and referring to external research.

3.2.4.1 Top-down

With this approach you start with the total population and work your way through eliminating irrelevant segments of the population because of the demographic, geographic or economic aspect. The advantage with this approach is that accurate and open statistics on macroeconomic data can easily be found online.

3.2.4.2 Bottom-up

With this approach you start at the bottom (SOM) and calculate your way up. You look at one company's share of market and their revenue and put those figures together to calculate the TAM. If a company has 20 % share of a market, and their revenue is 2 mill NOK, this market has a TAM of 10 mill NOK. The disadvantage with this approach is that the figures can be a vast assumption based on a figuratively small subset, making it a possibility that the TAM can be way off.

3.2.4.3 Value theory

While the top-down and bottom-up approaches look at paradigms that already exists and assume that your new product will fit in to them, the value theory approach try to figure out how much a customer is willing to pay for a new product, or the improvement of an existing one.

3.2.4.4 External research

One can also calculate TAM by refer to data already collected by professionals. The disadvantage with this approach is that you in most cases can't explain how you got those numbers.

4 Method

The purpose of this section is to describe and explain the methodological approaches used in the thesis.

4.1 Choice of method

Jacobsen (2000) defines a research as a systematic examination of one or more questions. When doing a research, you can choose between different methods to collect, process, analyze and present data, and the method is the tool to help one have a systematic approach to the research question.

According to Ragin (1994) every research strategy must be targeted. Which strategies you choose will depend on what you want to accomplish with the study. For most studies this will be defined by the research questions. If one's research questions require depth knowledge among a smaller range of informants, qualitative methods will be beneficial, but if you want to identify general patterns in a larger society that requires a large representative selection, it is advisable to use quantitative methods. In addition to the qualitative and the quantitative methods, it is possible to use a combination of these two.

If the researcher has little or poor knowledge of the topic to be studied, Jacobsen (2000) suggest a qualitative approach. Our pre-knowledge to the construction industry is limited.

When choosing a qualitative research, data is often collected via interviews, participatory observation, or analyzing documents to understand the meaning of them. In our study the last two methods where used to collect data, as we were attending one workshop, and analyzed documents on the construction sector in Norway regarding energy requirements and emissions of GHG.

According to Yin (2014), case studies are preferred when the researchers are dealing with questions of "how" and "why", because it allows the researcher to investigate a contemporary phenomenon within its real-world context.

4.2 Research design

The research design will give guidelines on how the researcher imagine conducting the study (Thaagard, 2009). These guidelines will describe what the study will focus on, who we'll get the information from, and where and how the study will be conducted.

4.2.1 Constructive research

The aim of constructive research is to solve practical problems while producing an academically appreciated theoretical contribution (Pasian, 2015), as well as to improve an existing system or performance. The result of a constructive research can be processes, practices, tools or organization charts. Constructive research can be qualitative or quantitative, or a combination of both (Oyegoke, 2011).

According to Pasian the constructive research process goes as follows:

1. Selecting a practically relevant problem
2. Obtaining a comprehensive understanding of the study area
3. Designing one or more applicable solutions to the problem
4. Demonstrating the solution's feasibility
5. Linking the results back to the theory and demonstrating their practical contribution
6. Examining the general disability of the results (Pasian, 2015)

Kasanen et al. present the constructive research as a type of research where the aim of the research is to produce new knowledge. This means that the result of the study should explain how to act in a given situation to achieve a desired state.

As stated above, the first step in the constructive research is to find a practically relevant research problem. Normally this is done by identifying a gap in the literature or getting a problem by a company. When having found a problem, the researchers need to achieve an understanding for the problem situation by getting an overview of the theory that already exists, which then can contribute to construct a solution.

Although the center of all constructive research is to solve a problem, not all problem-solving activities should be called constructive research. In Figure 6 you can see the four elements Kasanen et al. means always should be a part of a constructive research (Pasian, 2015).

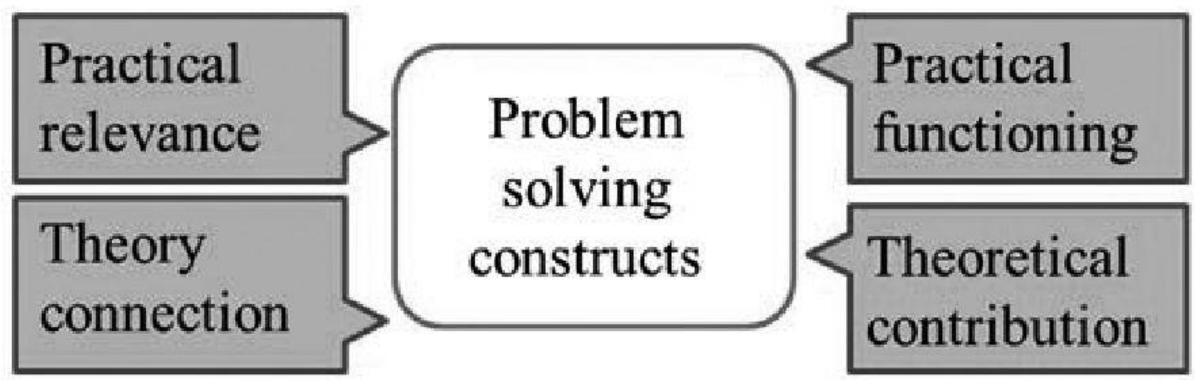

Figure 6 Elements of constructive research (Pasian, 2015)

Within the constructive approach, it is essential that the problem and its solution is tied together with accumulated theoretical knowledge.

4.3 The research processes

In this section we'll describe how we executed our research and explain the choices we have taken. Throughout this subchapter we have put a number at the end of some of the subheadings, and where is applies, this number will correspond to which of the step, or steps, of the constructive research we have conducted. The steps of the constructive research were listed in 4.2.1.

4.3.1 Finding and defining research question [1]

For us, finding our research question took some time. We touch upon several topic within the construction industry, before we found Nettpartner's suggestion on kompetansetorget.uia.no in November 2017. As multiple municipality wants to restrict how much emissions the construction industry can have, Nettpartner wanted students to look on how fossil- and emission-free construction sites could give them business opportunities in the future. After our first meeting with Magnus Johansen from Nettpartner, we decided to have closer look on the opportunities this topic could have for us. We soon realized that this was an interesting topic that we wanted to research, and our research question was at first:

> **"Which business opportunities is coming for Nettpartner as it in the future will be required to have lower emissions from construction sites?"**

As our research proceeded, the study started to go in another direction than intended, as we'll describe further in the next subsection, and we found out that we had to change our research question.

4.3.2 Existing theory and redefine of our research question [1, 2]

As mentioned above, the original intension with this study was to develop new business opportunities for Nettpartner as the green shift have become a big topic in the construction industry in Norway. To be able to do that, we needed to have a good basis on the existing theory of this area. We needed to know which fossil- and emission-free options that already exists today and which that are soon to come. For this we needed to do a literature review.

The point of doing a literature review is to get an overview of what already exist on the topic we are researching. Easterby-Smith et al. (2015) explains a literature review as a reproduction of existing research, describing, evaluating and explaining what is known in the current research area.

In our search for literature both Google and Google Scholar was used. Google Scholar were used to see if there was any research already done on this topic. Google was used to find news and articles about upcoming electrical solution that could be helpful when we tried to find a solution to our research question and to see which technologies that are under development.

During the literature study we realized that for us to come up with new business ideas for Nettpartner, we needed to know how the construction industry could go green. After a lot of research, we understood that literature today could tell us that it is possible for the construction industry to go green, but it didn't say much about how the construction industry could do it.

After rewriting our research question a couple of times, our final research question ended up being:

> **"How can Nettpartner contribute to the sustainability transition to a fossil- and emission-free construction industry?"**

With this research question we can still look for business opportunities for Nettpartner, as they wanted us to do. But we can also look at what Nettpartner can do help the construction industry to go green, without necessarily make some completely new business opportunities, strategies or models.

4.3.3 Looking for solutions [3]

When we felt we had collected enough background stuff and theory about our topic, we started to look at how the construction industry could to move towards being emission-free, and how Nettpartner could contribute to this change. Our results, solutions and conclusion will be given in chapter 5 and 6.

4.3.4 Discuss and evaluate our solutions [4, 5, 6]

Multiple factors, such as limited time and our possibility to make a physical object, made the last three steps hard to execute to the fullest. In chapter 5 we have done our best to discuss and evaluate the potential of our solutions and link them to our findings in chapter 2.

4.3.5 Data collection [2]

In this research, data collection became a big part of the second step in the constructive research design, "Obtaining a comprehensive understanding of the study area". This was because we needed to get a better understanding of the area we were researching. We have, as much as we could, relied on multiple sources to maintain the validity and the reliability of this study (Yin, 2014).

4.3.5.1 Primary and secondary data

The literature is divide between two forms of data. *Primary and secondary.*

Primary data is when the researcher gets the information straight from the source, which often is one person or a group of persons. With no one or nothing between the researcher and the source of information, one eliminates the processing or variation from others than the researcher and the source of information. This way the researcher has the possibility to collect data which is tailored to the research question. In this study most of our primary data was collected at the workshop, which we'll come back to in 4.5.

Secondary data can be different types of data, but generally one can say that secondary data is data which is collected by other than the researcher and for other purpose than the research. While primary data is collected during the research process by the researcher, secondary data normally is data that already existed. (Hansen, 2015)

Most of the data we have used in this study is secondary data. This is because we needed to have a good and big basis of the technology available today and soon to come for zero-emissions.

4.4 The quality of the research design

The quality of a research is defined by the validity and reliability of the study. In “Management & business research” we can read the definition of these two words as:

- Validity: the extent to which measures, and research findings provide accurate representation of the things they are supposed to be describing (Easterby-Smith, Thorpe, & R.Jackson, 2015, s. 343)
- Reliability: the consistency of measurement in a composite variable formed by combining scores on a set of items; can be measured by Cronbach’s alpha coefficient (Easterby-Smith, Thorpe, & R.Jackson, 2015, s. 340)

According to Yin (2014), the validity can be dived into three forms of validity; construct, internal and external validity.

4.5 Workshop

During the time of this research we got invited, via Nettpartner, to a workshop on the topic we are researching. The workshop was called «Veileder for tilrettelegging av fossilfrie og utslippsfrie byggeplasser». This was a workshop arranged by Energi Norge, Norsk Fjernvarme, Enova, Byggevareindustrien, Entreprenørforeningen Bygg og Anlegg (EBA), Oslo Kommune og Nelfo. The workshop found place at "Næringslivets hus" in Oslo at the 28th of February 2018. Unfortunately, only one of us (Magnus) had the opportunity to be there together with Magnus Johansen from Nettpartner. At that time, our research was still focusing on finding new business opportunities for Nettpartner, but this workshop can be considered the turning point regarding our research question. It was after this workshop we understood that the construction industry knew the could go green, but they needed more information on how to do it.

At this workshop we had different firms and organizations presenting what they were working on, and how they contributed to reducing emissions from the construction industry. For example, this was where we first heard about Pon's electrical excavator. After three presentations and a little lunch, all the participants at the workshop were split into groups of five or six and we sat down to work on a task we were given. Our task was to make a guide on how to get fossil-free and emission-free construction sites. A guide was already developed by the organizer, and our task on this workshop was to discuss the guide and suggest improvement or missing parts. You can see the guide we were given to work with at the workshop in Appendix B, and in Appendix C you can see the revised version they sent us after looking at the feedback and suggestions we gave at the workshop. The final version will be published on 15th of June 2018, and a report will also follow which puts the guide in a context and explains the different points. As our deadline on this research/report were 8th of June, we were unable to put the final version of the guide as an appendix in this report.

The point of that guide is to make the industry more aware of the opportunities to go green when working on larger construction site, like the "typical" construction site we have described earlier. The guide is like a checklist to follow through the whole life of the construction project, from the idea phase to the execution phase. In the guide it is included who's responsible for the different tasks.

While we didn’t get any physical data out of this workshop, except the guides in the appendix, we got a better understanding at where the construction industry is today regarding this topic, and what the industry itself is working on.

5 Results and discussion

In this chapter we'll start by answering our side-questions one by one. We'll then have a discussion on why we think batteries will be an important factor to have a sustainability transition to a fossil- and emission-free construction industry. Then we'll have some TAM-calculations for two business opportunities for Nettpartner.

- **What will be the energy demand be at various construction sites (for example, the construction of large office building or a defined road project)?**

Our intension was to have two different cases to study, one "typical" Norwegian construction site and a road building project. Unfortunately, we were not able to get any document or info about a road building project in time to do any calculation and had to rely on our "typical" construction site to answer this question.

Relying on the report we have referred to earlier, a "typical" Norwegian construction site would need a total of approximately 1.800 MWh.

- **What will be the energy demand for the whole construction industry?**

The total need for every construction sites in Norway will be approximately 640 GWh per year. As we wrote in 2.2, this total is an assumption made based on the average building actives between 2000 and 2016. Byggenæringens Landsforening forecast that the activity in the construction industry will slightly increase in 2018 and 2019, respectively 2,6 % and 3,6 %. Based on this and the fact that the report didn't include electricity for brackets, tower cranes and handheld machines in their calculations, we don't find it unlikely that the Norwegian construction industry will need as much energy as 1 TWh per year before 2030. See Appendix D on how we calculated this. Here you will also find an explanation for the number we have used in the calculations.

- **Is electrical energy enough to meet the energy requirement for the various machines used by the construction industry?**

It depends whether you look at one single construction site, or the whole construction industry. For one single construction site it would be no problem, but if every construction site would do it today, it would cause some problem regarding the capacity of the power grid in Norway, as mentioned in 2.5.1. On the other hand, the power grid in Norway is under upgrading and the electrification of

Magnus Hjelmfoss

Rabin Junior Osuma

every single construction site in Norway won't happen over night. It will be possible to meet the energy requirements for construction sites with electrical energy in the future, but it won't happen automatically. As we'll soon discuss, batteries could be an important factor to make this happen.

Can batteries or other local renewable energy be used instead?

We'll discuss batteries in the next subsection, and we'll only answer whether other local renewable energy sources can be used right here.

As we as touch upon earlier, district heating can be used to do some tasks at the construction site, like heating and concrete curing, and in many cases, the finished building is going to be connected to and use district heating anyway.

Within a few years we also think that wind energy, and to some degree solar energy, will be technology that can be used for this purpose. In the case of using wind energy, we assume that we will get more offshore wind farms by the coast of Norway in the future.

5.1 Batteries and the green shift

We believe that batteries will be an important factor for achieving a green construction industry. And in this section, we'll spilt our result and discussion in two, small batteries and big batteries. Our definition of small and big batteries for the rest of the thesis will be as follows:

- Small batteries: All battery that can be moved, whether it is stuck on a machine or not.
- Big batteries: Like Tesla's battery in South Australia, "The Hornsdale Power Reserve".

5.1.1 Small batteries

With the electrification of the Norwegian construction industry, small batteries are a must, and the development of electrical construction machine must continue. As of today, we have the 25 tons excavator developed by Pon, we have the medium sized duty trucks by Daimler, and next year, hopefully, we'll have the Tesla Semi. This shows us that the industry is moving in the right direction, but still has a long way to go. Even tough small batteries will be a must, we don't think this is anything Nettpartner can do so much with. Here we think that the companies that need them will produce or buy them themselves. But as we'll come back to a bit later, we think Nettpartner can be an important part in how these battery driven vehicles will be charged in the future.

5.1.2 Big batteries

To achieve a fully electrical construction industry, we think that big batteries, like the one Tesla has built in South Australia, will be necessary. We are fully aware that the Tesla's battery is "only" 100MW/129MWh, which isn't much compare to the need of the Norwegian construction industry. In fact, it is only 7% of the need of one single construction site. With that said, we don't think that one big battery will be used for one single construction site or that big batteries will be used for the construction industry alone. We think that batteries will become a part of the Norwegian power grid system sooner or later. In Norway, batteries won't be needed to store energy for cases of power outages, in the same way as the Tesla's battery in South Australia which is mainly built for this purpose.

So, when we know that we have a good power grid, which can handle the energy need in 2030, and that the power grid we'll have in 2022 can handle quite an increase in both the energy production and consumption in Norway, why do we need batteries in our power grid?

Batteries in the Norwegian power grid will be needed to keep the strength of the power grid stable, as we explained in 2.5.1. We also wrote that the capacity of the power grid could handle the need in 2030, if we spread out the usage. But if batteries are a part of the power grid, we won't have to spread out the usage in the same way, as the batteries can put in extra power to the power grid when needed and be charged at time with lower needs. That's why we think batteries will be an important factor to get a sustainability transition to a fossil- and emission-free construction industry and maintain a green construction industry in the future.

In the future it's not only the construction industry that will need more electricity, but the whole society. Even though Pon's 25 tons electrical excavator can be fully loaded with fast-charging in 1 or 2 hours, this probably won't be the normal way of charging them. If they have, as Pon says, 5-7 hours of operation time in one charging, this would in most cases mean that a fully loaded excavator would run for a whole working day and could be charged "normally" in the evening or at the night. Imagine every excavator in the Norwegian construction sector charging at night. Based on the figure in the report, 8.33 %[4] of the total electrical usage at a construction site would be needed for the excavators, and more precisely this would mean the charging of them. If we also include the electricity for the mobile crane, we can almost double it to 13.38 %[4]. We have not included the handheld machinery, as we assume they are charged during daytime. If the whole construction industry requires 640 GWh for a whole year, this would mean that only the charging of excavators and mobile cranes at construction sites in Norway would need about 85 GWh a year. This number by itself is fine, and probably won't cause any problem since we know that the charging of electrical personal vehicles will need 4.000 GWh, and that our power grid can handle that. The problem occurs when everyone is using more electricity at the same time, which will be in the evenings. As we mentioned in 2.5.1, it will be enough energy for everyone, but the strength of it will be lower than normal. Therefore, batteries probably will be a must in an electrified construction industry (and in an electrified society, for that matter). We imagine that one solution to this is to put up batteries around in the bigger cities, and especially on places far from the production of energy. In

[4] 1800 MWh for one construction site. 150 MWh for only the excavators, and 250 MWh including the mobile crane. 150/1800 = 0.08333 = 8.33%. 250/1800 = 0.13888 = 13.88%.

that way, when the pressure drops, these batteries can help the power grid to keep its strength and keeping a stable and high output to all the customers.

If these big batteries are placed close to residential area, a natural way of charging them would be from the power grid, at hours of the day when the consumption from other sources are low, like in the middle of the day, when most of the people living there most likely is at work, and their electricity usage in the homes are lower.

5.2 Ways for Nettpartner to contribute

In this section we'll look at the different ways for Nettpartner to contribute to get the construction industry to go green. For each idea/business opportunity we'll try our best to do a TAM-calculation and we'll try to discuss the pros and cons, for both Nettpartner and the construction industry.

5.2.1 Charging stations

5.2.1.1 TAM-calculations

We'll first go through our TAM with the CO_2e as the metric and sum up the NOK estimates at the end of this subsection. These figures are for one "typical" construction sites.

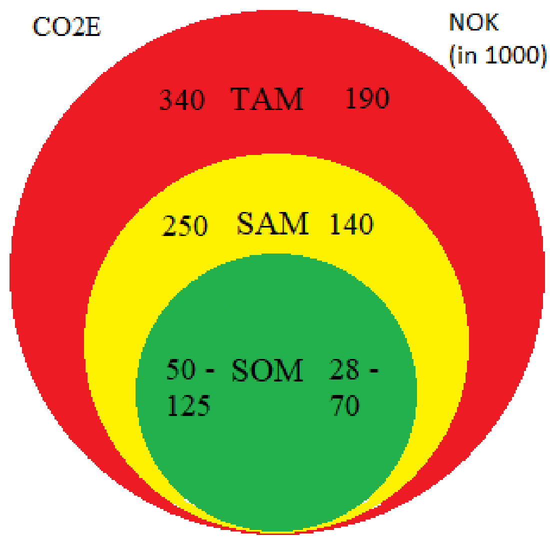

Figure 7 TAM, SAM and SOM for charging stations at one construction site

TAM: We think renting out charging stations to the construction industry can be mostly used for the charging of the different construction machinery at the construction site like excavators and mobile cranes. But we choose to include transportation to and from the construction site in the TAM, as we think the transportation in the future could have a need for charging when they are at the construction site to deliver or pick up stuff. For one construction site this value would be 340 tons CO_2e.

SAM: In the beginning we think SAM for renting out charging station will be the machinery at the construction site that runs on battery, which will mean the excavators and mobile cranes. This will account for 250 tons of CO_2e. We exclude the transportation we included in the TAM, as we think it will take several years before they will need charging at the construction site, if ever. We have chosen to keep all of Norway as the geographical reach, as Nettpartner is working in all of Norway.

SOM: This one was the hardest one of these three factors to calculate. As Nettpartner is Norway's largest electrical infrastructure contractor, we assume they have the possibility to get a big share of this market. On the other hand, there could be other companies that has a business model which is fitted better for this business opportunity. We assume that Nettpartner maybe could get between 20 and 50 % of SAM. The SOM would then account for between 50 and 125 CO_2e. We think that the main key to get a big share of this market is to be the first one to offer the solution. We have chosen to calculate with between 20 and 50 % because “Nettpartner Drift AS” had a market share of 28 % in 2017 (Nettpartner, 2017). We have used this division of the company because the core activities for “Nettpartner Drift AS” is to “Construct and operate power line, cable, substation and transformer installations for HV and LV distribution” (Nettpartner, 2017). And one of their related activities is “Job site power supply and temporary installations” (Nettpartner, 2017).

On the right side in Figure 7 we have valued this business opportunity at 190 mill NOK (TAM), 140 mill NOK (SAM) and 28 – 70 mill NOK (SOM). These figures are calculated based on the total need for electricity for those activities we have included in TAM, SAM and SOM. The calculations can be seen in Appendix EAppendix . As you will see in Appendix E we have calculated with three different prices of the electrical energy; 25 øre/kWh, 50 øre/kWh and 100 øre/kWh. The numbers in Figure 7 are from the calculation with 50 øre/kWh.

These NOK-calculation is based solely on the price for the electricity. We haven’t included the price for setting up and taking down the charging station. We have neither included the price for renting the charging stations.

The biggest construction machinery doesn’t run on batteries today, but because of the development in the battery technology we wrote about in 2.4.3, we think this will happen sometimes soon and then even more of the machinery at a construction site would need charging. Also, to get construction companies to choose an electrical construction machine over a fuel-driven one, we think there must be an easy access on charging station at the construction site.

5.2.1.2 Pros and cons

As electrical construction machinery will become a more natural part of construction sites over the next few years, it will also require a spot at the construction site to charge these machines. On bigger project, where multiple traders are involved, it may be more natural that the project owner is responsible for the charging stations, rather than every single trader involved must be responsible for their own charging station.

One challenge with this idea could be if every single trader for electrical construction machines on the market goes for different outlets to charge their machine. Another problem could be the length of the project. If the project doesn't run over a certain amount of time, it might not be as profitable as needed, as we imagine that most of the cost related to this business opportunity would be setting up and taking down the charging stations. Another factor here is that the construction site most likely already must be connected to the power grid, for this to be a possibility, and as we stated earlier, the fact that construction sites not already are connected to the power grid is one of the reason for the big emissions from construction sites today.

In the long run, it is not only the construction machinery that will need charging at the construction site. Another example of vehicles that could need electrical power when at the construction site, is trucks that deliver material. Trucks that come for delivering material and then leaving right away would most likely don't need charging, as they probably were fully loaded when leaving their starting point. But as were mention at the workshop, an example of trucks that will need energy while at the construction site is concrete trucks, as their drum must spin around all the time, so the concrete doesn't stiffen.

5.2.2 Batteries

Small batteries, as we mentioned in 5.1.1, we expect the companies that has the need for them, will produce or buy themselves, but big battery as wrote about in 2.4.3, we imagine could be something for the big electrical infrastructure contractors like Nettpartner. Therefore, we have tried to make a TAM-calculation for these.

5.2.2.1 TAM-calculations

TAM: Here we think that the whole country would be the TAM. As we wrote earlier, to have a stable power grid in the future, we think big batteries needs to be a part of it in the future. With that said, the whole country doesn't need it tomorrow.

SAM: For this business opportunity we think SAM can be the same as TAM. The reason for this is that Nettpartner operate in the entire value chain, from design and construction to maintenance, upgrades, control and inspection, and they work across the whole country. Also, in the long term, with the floating wind farm, like those Equinor has developed, and Norway's long coastline, Norway has an amazing opportunity to generate a lot of wind energy, and at times more than our power grid can handle. Then to have some batteries to store the energy would be good.

SOM: As we wrote in 2.5.1, when the upgrade of the power grid is done in 2022, Norway can increase the energy production with 15 000 GWh before we need to upgrade the power grid again.

So, where and why will big batteries be needed in the short and medium term? In other word, what is the SOM? The bigger cities. Firstly, for the power grid to handle the increase in production mentioned right above, the production must be favorable geographical distributed. With a new and better power grid, the power grid can handle the production increase. But the energy production and our usage of energy is not spread out during the hours of the day in the same way. While the production of energy can be almost the same at every hour of the day, our usage of electricity can vary widely.

5.2.2.2 Pros and cons

We feel we have covered the pros and cons for batteries throughout this thesis, but we will make a short list here with the most important ones:

Pros:

- Batteries will help to keep up the strength in the power grid when the usage is at the highest.

Cons:

- The battery technology today requires big space. As an example, the 100MW/129MWh battery in South Australia is the size of a football field.

5.3 Some outside-the-box ideas

We got some ideas during this research, which is maybe not so realistic to do today and might be a bit on the side of what Nettpartner does, but with the development of different technologies, we think they could be possible in the future. Therefore, we haven't made any TAM-calculations on these, but we wanted to include one of the ideas here.

- **Batteries on the back of a truck – A "battery-trailer"**

As the battery-technology will evolve, we think that this could be an idea on how to deliver building power to the smaller construction sites, which isn't already connected to the power grid. Here we think that one can fill the back of a truck with batteries. Here we think the batteries on the back of the truck will be batteries like those Powerpack The Hornsdale Power Reserve is built of.

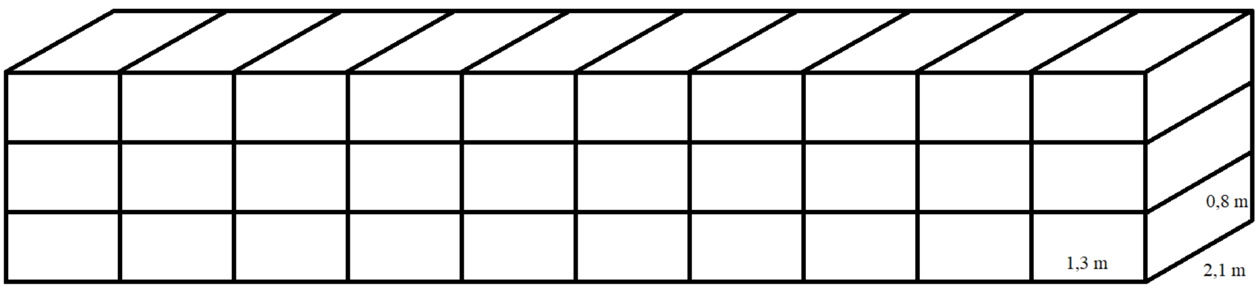

Figure 8 The back of a battery truck

As mentioned earlier, one of these Powerpacks is 2,1 m tall, 1,3 m long, 0,8 m wide and the weigh 1.200 kilograms. Almost every European semi-trailer is 13,6 m long, 2,46 m wide and between 2,65 and 2,80 tall. If we place the Tesla's Powerpack laying sideways, as shown in Figure 8, we can fit as many as 30 of Tesla's Powerpack on the back of one trailer. This will make the back of trailer weigh 36 tons, which is the same weight as the new Tesla Semi will have as maximum load capacity. A European semi-trailer today normally has a maximum load capacity of 24 tons, which means it could have 20 of these Powerpack on the back.

30 of these Powerpack would hold roughly 6 MWh and 20 would give us about 4 MWh. This isn't much compared to the total need. As mentioned earlier, to keep the strength in the power grid stable in the future, we must spread out our usage. With this battery-trailer one can charge the batteries on the trailer when the usage on power grid from others are low and use the battery-trailer to charge the construction machines at the evenings/nights. This way, charging the construction machinery won't affect the power grid's strength in the same way as if you charge them directly from the

power grid in the evenings and nights, when the power usage of others is high. If solar panel in the future reaches a better efficiency then they have today, it could also be a possibility to put solar panel around the side of the truck to charge the batteries.

A battery-trailer could be used to deliver building power to construction site where it is a long way to the closest power grid, or just hard to deliver building power the regular way. Assuming there is a place there to park the trailer.

6 Conclusion and further research

How can Nettpartner contribute to the sustainability transition to a fossil- and emission-free construction industry?

As we discussed in chapter 5, there are multiple ways for Nettpartner to contribute to this transition. Some of them are linked directly to the construction industry, and some of them are not, but we believe that all of them are necessary for the construction industry to be green in the future. With a closer look at the different opportunities we've discussed, we've found one thing in common amongst all our findings, which also is the short answer to our research question:

Nettpartner must be a facilitator and think of the need of electrical energy that will be needed tomorrow.

Of course, they can't do this alone and would need to cooperate with other companies and instances. But as Norway's largest electrical infrastructure contractor, they must make it easy for the construction industry to go green, and not wait for the construction industry to come with their needs to them. When the technology is available and the solution on how to use them are there, people will go for them. In this research, the technology that needs to available can be seen as the development of electrical construction machine, while the solution to use them is that we have a power grid that can handle the increased need of electrical energy that will be needed in the future.

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8 Appendix A

In Figure 9 we have shown four of the calculations we have found that is wrong in the report "Fossil- og utslippsfrie byggeplasser". From left in Figure 9 the calculations are taken from chapter 3.3, 3.4, 4.1 and 4.3 in “Fossil- og utslippsfrie byggeplasser". As we wrote in 2.1.6, we assume that this only is typing error on the total, and that the other numbers are correct. The numbers in red are the correct answer to the calculations.

		25 kWh	25 kWh
		6 kWh	6 kWh
720 MWh		3 kWh	3 kWh
	130 tonn	0 kWh	0 kWh
560 MWh	30 tonn	30 kWh	30 kWh
1 200 MWh	90 tonn	10 kWh	10 kWh
2 500 MWh	240 tonn	79 kWh	275 kWh
2 480 MWh	250 tonn	74 kWh	74 kWh

Figure 9 Calculation in "Fossil- og utslippsfrie byggeplasser" that is wrong

9 Appendix B

“Guide to the facilitation of fossil-free and emission-free construction sites” as handed out at the workshop

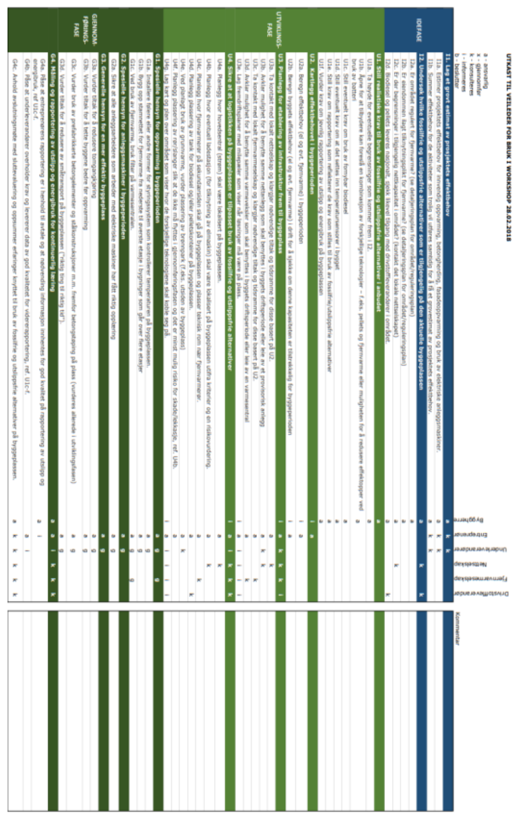

Figure 10 “Guide to the facilitation of fossil-free and emission-free construction sites”

10 Appendix C

Revised version of the “Guide to the facilitation of fossil-free and emission-free construction sites"

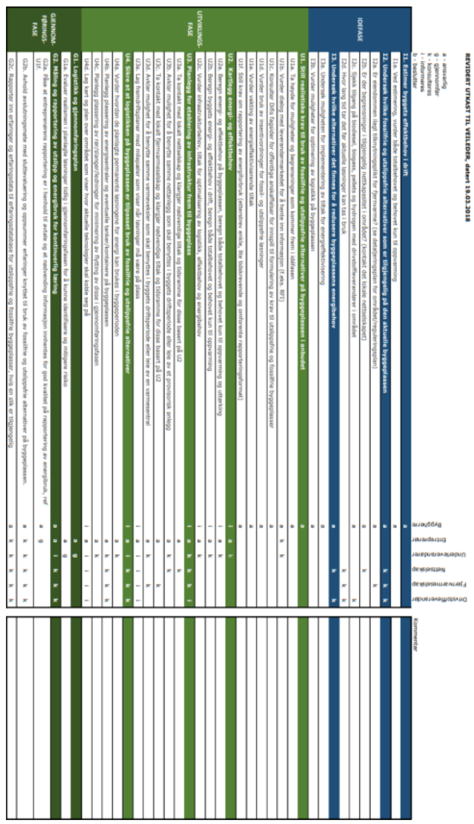

Figure 11 Revised version of the “Guide to the facilitation of fossil-free and emission-free construction sites"

11 Appendix D

Year	Built in million sqm	Grow rate	Needed in GWh
2005	8,45	-	
2006	9,05	7,10 %	
2007	10,05	11,05 %	
2008	9,58	-4,68 %	
2009	7,79	-18,68 %	
2010	8,79	12,84 %	
2011	9,30	5,80 %	
2012	9,54	2,58 %	
2013	9,40	-1,47 %	
2014	8,92	-5,11 %	
2015	9,25	3,70 %	
2016	10,36	12,00 %	
2017	10,29	-0,68 %	761,46
2018	10,66	3,60 %	788,87
2019	10,94	2,60 %	809,38
2020	11,16	2,00 %	825,57
2021	11,38	2,00 %	842,08
2022	11,61	2,00 %	858,92
2023	11,84	2,00 %	876,10
2024	12,08	2,00 %	893,62
2025	12,32	2,00 %	911,50
2026	12,56	2,00 %	929,73
2027	12,82	2,00 %	948,32
2028	13,07	2,00 %	967,29
2029	13,33	2,00 %	986,63
2030	13,60	2,00 %	1006,37

	Year	Built in million sqm	Grow rate	Needed in GWh*
Low estimate	2018	10,66	3,60 %	842,17
	2019	10,94	2,60 %	864,07
	2020	11,05	1,00 %	872,71
	2021	11,16	1,00 %	881,44
	2035	12,83	1,00 %	949,07
	2036	12,95	1,00 %	958,56
	2037	13,08	1,00 %	968,14
	2038	13,21	1,00 %	977,82
	2039	13,35	1,00 %	987,60
	2040	13,48	1,00 %	997,48
	2041	13,61	1,00 %	1007,45
High estimate	2018	10,66	3,60 %	788,87
	2019	10,94	2,60 %	809,38
	2020	11,27	3,00 %	833,66
	2021	11,60	3,00 %	858,67
	2022	11,95	3,00 %	884,43
	2023	12,31	3,00 %	910,97
	2024	12,68	3,00 %	938,30
	2025	13,06	3,00 %	966,45
	2026	13,45	3,00 %	995,44
	2027	13,86	3,00 %	1025,30

Grow rate beteen 2005 and 2017	
Total	Average
24,46 %	2,04 %

Grow rate beteen 2010 and 2017	
Total	Average
16,83 %	2,40 %

Grow rate beteen 2011 and 2017	
Total	Average
11,03 %	1,84 %

Figure 12 Calculation for estimated growth in construction industry in Norway

The figures for “Built in million sqm” from 2005 to 2017 in the figure above are taken from SSB’s statistic “Byggeareal” (SSB, 2018).

The report “Fossil- og utslippsfrie byggeplasser” concluded that the average Norwegian construction site use 74 kWh per sqm and we have used that number when calculating the need for future years.

In the tables on the previous page, we have tried to predict the total need of energy at Norwegian construction sites in the future, and when it will reach the need of 1 TWh. To decide what average growth rate per year to predict in the future, we have seen on the average growth rate for three different periods; 2005 – 2017, 2010 – 2017 and 2011 – 2017.

The first period is chosen because 2005 was the first year in SSB’s statistic “Byggeareal”. The average growth in this period was 2.04 %. The second and third period is chosen because of the financial crisis of 2007/2008. This crisis had an impact on the construction activities in the following years. We believe that the growth rates in 2008, 2009, 2010, and to some degree in 2011, was affected by the financial crisis. The calculations for those two periods gave us an average growth per year of respectively 2.40 % and 1.84 %. Therefore, we have chosen to use 1, 2 and 3 % as our low, expected and high estimate for future growth. By our calculations the only estimate that will not reach 1 TWh by 2030, is the low estimate.

As a final comment to these calculations, we will want to emphasize that we are no experts on this area. We have predicted the future need based solely on the statistics we have from 2005 to 2017 and assume that the average grow over time will continue, but with variation from year to year, as in the period 2005 - 2017.

12 Appendix E

	CO2e	Elekstrisitet (MWh)	Income in NOK 25 øre/kWh	Income in NOK 50 øre/kWh	Income in NOK 100 øre/kWh
3 excavators, 30 ton	130	150	kr 37 500,00	kr 75 000,00	kr 150 000,00
1 mobile crane, 60 ton	30	100	kr 25 000,00	kr 50 000,00	kr 100 000,00
Various small machines	90	30	kr 7 500,00	kr 15 000,00	kr 30 000,00
Transport	90	100	kr 25 000,00	kr 50 000,00	kr 100 000,00
			kr -	kr -	kr -
TAM	340	380	kr 95 000,00	kr 190 000,00	kr 380 000,00
SAM	250	280	kr 70 000,00	kr 140 000,00	kr 280 000,00
SOM (20% av SAM)	50	56	kr 14 000,00	kr 28 000,00	kr 56 000,00
SOM (50% av SAM)	125	140	kr 35 000,00	kr 70 000,00	kr 140 000,00

Color explanation:
TAM
SAM
SOM

Figure 13 TAM-calculations for charging station

The prices (25, 50 and 100 øre/kWh) we operate with is chosen based on the prices we have found online, as well as statistics from Statistics Norway. Her we have included both power and network rent. We have also included three different prices as the power price can vary over time.