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Investment Analysis of Rooftop Solar Photovoltaic Panels for Energy-Efficient Residential Areas in Norway, under Different Regulatory Scenarios

- Zero Village Bergen as a case study

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Abstract

In Norway, buildings are responsible for 50% of stationary energy consumption; therefore reducing their carbon-footprint is an important area of research. Solar photovoltaic (PV) panels have seen significant technological improvements and cost reductions over the last years. The high degree of scalability and ease of integration into buildings have made solar panels a potential means of reducing the carbon footprint of buildings. Zero Village Bergen (ZVB) is a large-scale residential real estate project in Western Norway that aims to use solar panels to achieve a near-zero emission residential area.

This thesis analyses the risks and net present value (NPV) of projected investment in solar panels in ZVB, across four regulatory scenarios and two different ownership structures. It is found that, in this context, the NPV would be negative for all scenario-ownership structure combinations, but that the results vary significantly between scenarios and ownership structures. Substantial improvements in the cost or revenue side of the project would be required to reach profitability. These results suggest that either the house-owners must pay a premium for the apartments in ZVB, or the government would need to provide subsidies.

Key Words: Renewable Energy, Distributed Generation, Plus Customer Agreement, Solar Panels, Ownership Structure, Government Regulation

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Abbreviations

AMS – Advanced Metering System
BRA – Gross usable area of a building
CAPEX – Capital Expenditure
CfD – Contract for difference
CPI – Consumer Price Index
DG – Distributed Energy Generation
DSO – Distribution System Operator
EU – European Union
FIT – Feed-in Tariff
GHG – Green House Gas
NLS – Net Living Space
NVE – Norges Vassdrags- og Energidirektorat
NPV – Net Present Value
OPEX – Operating Expenditure
OTC – Over the Counter
O&M – Operation and Maintenance
PBP – Payback Period
PV – Photovoltaic
RECs – Renewable Energy Certificates
TSO – Transmission System Operator
VAT – Value Added Tax
ZEB – Zero Emission Buildings
ZVB – Zero Village Bergen
WACC – Weighted Average Cost of Capital

1. Introduction

In Norway, approximately 50% of stationary energy[1] is consumed in buildings (Olje- og Energidepartementet, 2015). Therefore, developing and deploying technology and solutions to reduce the carbon footprint of buildings is an important way to reduce the overall national environmental footprint.

The European Union (EU) has mandated that all new buildings should have a near-zero emission level by 2020, and public buildings by 2018. These requirements have also been included in Norwegian legislation although their specific interpretation in the Norwegian context remains to be decided.

One way for a building to achieve an emission status close to zero in accordance with the EU directive, is by offsetting some of the energy consumed in the building by generating renewable electricity onsite. Solar photovoltaic (PV) panel technology is one of the most widespread and fastest growing sources of such renewable distributed generation (DG) systems globally.

In Norway, electricity generation from solar panels has historically represented only a marginal part of the energy market, mostly fulfilling the needs of small electricity consumers located far from the power grid such as lighthouses and cabins. However, over the last few years, solar panels seem to be appealing to a broader market, due to increased attention to environmental issues on the demand side, in combination with cost reductions on the supply side.

Despite significant cost reductions in recent years, solar PV technology has still not reached grid parity[2] in Norway. The main push for solar panels in Norway currently comes from real estate developers, tenants, and owners of commercial and public buildings who wish to achieve a certain level of energy efficiency for their building, rather than cost considerations.

The regulatory framework for distributed generation in Norway is still evolving, and central regulatory schemes such as the plus customer agreement[3] are still being refined by decision-making bodies. In this context of regulatory uncertainty, it is interesting to analyze the profit potential of solar PV projects under different regulatory scenarios.

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[1] Stationary energy consumption is defined as the total energy consumption disregarding the consumption in the transportation sector.

[2] Grid parity refers to the total cost of electricity paid by an end consumer of electricity buying from the grid. In addition to the wholesale price of electricity it includes grid tariffs, taxes, fees and potentially a retailer mark-up.

[3] The plus customer agreement is described in section 4.3.2

As the market for distributed electricity generation using grid-connected solar panels in Norway is still in the initial stages of development, it remains to be seen which kind of ownership structures will become prevalent.

This uncertainty around regulations and ownership structures of distributed solar panels in Norway led to the research question for this thesis.

For different ownership structures and regulatory scenarios, what is the expected return on investment in rooftop solar panel systems aiming to achieve a near-zero emission status for a residential area in Norway?

The risks of such an investment and the potential distribution of these risks on different stakeholders are also qualitatively analyzed as part of this research.

The energy-efficient residential area of Zero Village Bergen (ZVB) in Western Norway has been used as a case study. ZVB is a pioneer project in Norway, aiming to combine low-emission materials and building processes, energy efficient houses and renewable energy solutions, to become near carbon neutral in operation by producing almost as much energy from renewable sources as is consumed over the year. One of the options being considered at ZVB is using rooftop solar panels to generate electricity for the buildings in the area. This solar panel system is the subject of analysis in this thesis. The analysis has drawn on information provided by BKK, a Norwegian utility company engaged in the project, Bybo AS, the real estate developer planning the project, and other participants in the ZVB project.

The research question is answered through the following steps:

- Reviewing the existing regulations in Norway regarding distributed electricity production. Based on different possible combinations of regulations, defining the possible regulatory scenarios for analysis.
- Identifying the potential ownership structures for DG infrastructure in ZVB. Matching the different feasible combinations of regulatory scenarios and ownership structures.
- Determining the parameters and input factors that have an impact on cash flows for solar panel investment in ZVB. Based on yearly cash flows, calculating the NPV for all combinations of scenarios and ownership structures.
- Establishing key sensitivity parameters, and analyzing the sensitivity of investor returns to change in these parameters.
- Identifying the risks associated with solar panel investments, and how these can be distributed between different stakeholders.

In chapter 2, the scope of the thesis is presented together with the main limitations of the study relating to the method and data employed. Chapter 3 contains a review of academic literature on the topic of distributed generation. Background information on ZVB, the Norwegian electricity system, regulations, tariffs and taxes as well as the status of the solar panel market in Norway is presented in chapter 4. In chapter 5, the research problem is formulated and the evaluation criteria are presented. Chapter 6 describes the input data used for the calculation, and chapters 7, 8 and 9 present the methods and results from the NPV analysis, sensitivity analysis, and the risk analysis. Chapter 10 contains the conclusions drawn from this research.

2. Scope and limitations

The scope of the analysis conducted in this thesis is governed by the input factors specific to the context of the chosen case study and geography. Therefore, the regulatory context is specific to Norway, the electricity price level is specific to Western Norway (NO5), the grid tariffs are specific to the distribution grid operator in the area (BKK Nett), and the consumption profiles are specific to the energy-efficient buildings designed for ZVB.

Further, the relative novelty of solar panels in the Norwegian electricity market adds uncertainty to other input factors in the analysis, such as the installation cost, operation and maintenance costs, equipment lifetime and actual electricity output. Due to the long lifetime of solar panels, the future price of electricity in the Nordic market is also a source of uncertainty, which affects the value of the electricity produced by the panels.

The data used to represent the electrical load of individual households is simplified in that only 8 different categories of household consumption patterns are assumed. In reality, the load profile for each individual household would be unique. It is therefore reasonable to assume that the benefits from pooling production resources would be higher in reality than the figures presented in this thesis suggest.

Hourly data has been used for calculating electricity consumption and production. However, in reality consumption and production vary on much finer intervals, which might change the share of production considered to be consumed locally.

The discount rate for different investors such as corporates and individuals would depend on factors such as the source of funding, and diversification. However, due to a lack of research on the discount rates to be used for private households' investment in such projects, the same discount rate has been used for private and commercial actors. The determination of their respective discount rates could be an area for future research.

Potential increased costs related to the solar panel system beyond those described in chapter 6.4 are not included in the analysis. Such costs could be an increase in the grid capacity due to the large surplus production in some summer months, or extra costs related to distributing the electricity generated internally in ZVB.

Finally, the potential effects of elements that might influence the share of electricity consumed locally, such as the introduction of electrical cars, batteries or dynamic demand management systems, have not been considered in this thesis, and could have a significant impact on the profitability of the solar panel investments.

3. Literature review of distributed generation

This section presents the academic literature and previous research on distributed generation (DG), its benefits and costs, as well as the impact of different support schemes on the penetration of DG systems.

3.1. Definition

There is no consistent definition of DG in academic literature (Ackermann et al., 2001). In this thesis, the definition of DG by Kenneth W. Costello (2015) is used, as it is the best fit for the ZVB and Norwegian context:

> *Small-scale generation largely devoted to self-consumption on the site of utility customers connected to the local utility distribution system for backup power and the sale of surplus power. […] In addition to solar panels, DG includes small wind turbines, combined heat and power, fuel cells, microturbines, as well as other sources* (Costello, 2015).

3.2. Benefits & costs

There have been various studies analyzing the cost-benefit of DG. In a report published in 2007, the U.S Department of Energy analyzed the benefits of DG on different parameters. The report concludes that different forms of DG can help to reduce and defer the investment in distribution grid by decreasing the peak load, reducing greenhouse gas emissions, and decreasing the vulnerability to terrorist attacks and other catastrophic disruptions (U.S. Department of Energy, 2007).

Anaya and Pollitt (2015a) analyze the distribution of benefits of DG among distribution system operators (DSOs), power producers and the wider society in the UK. They analyze DG projects based on wind, solar, and anaerobic digestion used for combined heat and power systems. They concluded that under the current UK regulations, power producers benefit the most, and all other stakeholders are better off after taking into account the carbon cost (Anaya & Pollitt, 2015a).

Gulli (2006) did a social cost comparison between centralized supply and DG. He states that after accounting for all the internal and external factors, central production has a lower social cost. However in some cases, the cost of DG was lower than central production. Therefore, he recommends undertaking case-by-case reviews of DG rather than having a blanket policy for all projects. Lastly, he concludes that, even after considering a cost reduction of up to 50% in the future, DG will still have a higher social cost (Gulli, 2006).

Costello (2015) points out that *"from a public-interest perspective, utilities, regulators and other policymakers should evaluate both the aggregated benefits and costs of DG to determine its desirability"*. The regulators must consider the net benefit or loss of introducing more DG. If the status is a net loss, but due to a market failure, the cost-benefits analysis must be done for removing that market failure. He also states that the introduction of smart meters and smart grids would allow for more accurate measurement of cost or benefits of DG to the grid system (Costello, 2015). However, smart meters and smart grids will have an added cost associated with their introduction.

In many markets, the DSOs cover a part of their fixed costs through volumetric tariffs. This can be an issue in terms of grid costs, as the DG customers consume less electricity from utilities than non-DG customers. This necessitates a higher tariff per unit of electricity to cover the fixed costs, which penalizes the customers without DG relatively more than the customers with DG. This provides a stronger incentive to install DG, and consequently creates a vicious cycle of higher DG penetration and higher tariffs (Costello & Hempkill, 2014).

3.3. Impact of regulations on DG

Costello (2015) states that the effect of DG on society is heavily dependent on each society's economic and political context. What is a reasonable regulatory scheme in one country may be inefficient in another; therefore, the proposed regulatory framework must be evaluated in the context of each area or country in question (Costello, 2015). Costello argues that:

> *The regulator's task of approving rates and rate designs is essential for creating an efficient and socially desirable DG market. Rate making affects the utility's incentive to accommodate or promote DG, the economics of third-party DG investments, and the well-being of non-DG customers* (Costello, 2015).

Carley (2009) is one of the few examples of an empirical analysis of different regulations and schemes that help to increase the deployment of DG. The paper concludes that state policies aimed at reducing economic barriers, standardizing the interconnection procedures and increasing the competition in the industry help to promote DG. However, their effect on different kinds of owners varies. End consumers are more likely to use DG with better technical development, and the utilities are more motivated by increased competition in the industry (Carley, 2009).

Rafael et al. (2009) identify several regulatory issues that might hinder the successful integration of DG, and provide recommendations to tackle these impediments. They find that the grid connection mechanism has a potentially large impact. Most EU countries have adopted a shallow connection approach, where the DG operator has to pay only for the cost of a new connection, and not for any reinforcement required in the existing infrastructure. On the DSO side, support for operational expenditure (OPEX) and capital expenditure (CAPEX) is required to promote the integration of DG into the grid (Rafael et al., 2009).

Anaya and Pollitt (2015b) cover the deployment and integration of DG into the grid in Germany, Denmark and Sweden. They state that Germany has the most favorable DG connection regime, by prioritizing clean DG electricity in the case of oversupply. Further, the network connection costs for DG projects are subsidized by distributing them across all customers. Sweden on the other hand gives the same priority to all the customers irrespective of generation source (Anaya & Pollitt, 2015b).

The academic literature clearly indicates that regulations can play a very important role in the large scale deployment of DG. Regulators have different tools in terms of connection mechanisms, financial support and environmental policies. Regulators also need to take a long-term view, to reduce the amount of uncertainty for the potential investors.

3.4. Support schemes

To attract investment into a particular renewable energy technology, it is essential to offer sufficient investment security and a reasonable return on investment (IEA, 2008) (Dinica, 2006). There are various support schemes and incentives used in different parts of the world to encourage DG using renewable energy sources. Some of the more prevalent of these are green certificate schemes (with or without a cap on emissions), carbon tax, net metering, upfront subsidies, soft loans and feed-in tariffs (FIT).

3.4.1. Feed-in tariffs

FITs drive market growth by providing renewable energy system owners with long term price certainty at which they can sell the renewable electricity produced to the grid (Couture & Gagnon, 2010). FIT is a simple mechanism and easy to understand in comparison with some of the other support schemes. Another advantage of FIT is the flexibility that it provides to support different technologies by customizing FITs for each technology (Lin et al., 2007). FITs can be linked to the market rate or independent from the market rate.

The market-independent price model is the most commonly employed method for FIT policies (Klein et al., 2008). A market-independent FIT is generally accompanied by a purchase agreement for a long period, typically 15-20 years (Mendonca, 2007). This gives a guarantee of a fixed price for the electricity sold over a period of the project lifetime or until the investment is recovered.

A variation of the market-independent FIT policy can be front-loading the benefits to be provided through FIT. This is done by having high tariffs for the initial period, and then tapering the tariffs for the remaining period (Couture & Gagnon, 2010). The benefit of this method is to provide higher return in the initial years, when it is needed the most, to reduce the pressure of the initial investment. However, this can also be done by sharing part of the investment cost by providing upfront subsidies, and giving the rest as support in form of FIT.

Germany has employed a market-independent FIT policy for its solar panel generation since 2004. The nominal tariffs stay constant for the entire tenure of the contract, and no adjustment is made for any future changes in electricity prices or costs. Inflation expectation is priced in during the initial calculation, which results in relatively higher prices initially, in real terms. The high initial price encourages aggressive deployment, while diminishing the returns in the later years. Inflation adjusted FITs could be more relevant for the countries that have high inflation levels (Couture & Gagnon, 2010).

In contrast, the market-dependent or premium FIT model allows the producer to sell electricity to the grid, and receive a fixed premium over the spot price. Under this policy, payment levels rise with a rising retail price, and vice-versa. In order to avoid excessive high and low FIT payments in case of market-dependent FIT, some countries have started implementing cap and floor prices for the FITs.

Spain has introduced a cap and floor for the premium offered above the spot price. This is to ensure that the renewable producer gets a minimum amount in case of a large drop in spot prices. On the other hand, in case of very high spot prices, the amount that the producer gets is equal to the spot price, and the premium above the spot price is reduced to zero. This helps to reduce unnecessary support in case the grid electricity prices are much higher than the cost of production (IEA, 2009).

A large number of research papers have shown that the market-dependent FIT policy tends to be more costly for society than the market-independent model. This could partly be explained by the higher uncertainty related to the market-dependent FIT policy (Held et al., 2007) (Mendonca, 2007). On the other hand, it is argued that the variable rate incentivizes higher surplus production at the time of peak price, which is also when most electricity is needed in the system (Ole et al., 2009).

A market-independent FIT is useful, especially for the early stages of a technology's deployment, to reduce uncertainty for investors regarding the returns and payback period of the investment. On the other hand, in more mature markets, a market-dependent FIT policy may be more beneficial by providing dynamic ways of maximizing return for investors. It might also be easier for investors to get loans under a market-independent FIT policy because of the more certain cash flows (Mendonca, 2007). In order to offer greater flexibility some markets also provide an option of choosing between market-independent and market-dependent FIT (Couture & Gagnon, 2010).

3.4.2. Net metering

A net metering policy enables a DG producer to offset electricity used from the grid, by supplying renewable electricity produced locally to the grid. Therefore, under the simplest form of net metering, the grid acts as a battery with 100% efficiency and unlimited capacity for the renewable electricity producer (Campoccia et al., 2009). Net metering is widely used in the US and Australia to support renewable electricity production. A variation of the simple net metering is the 'time of use' system, wherein the electricity is priced dynamically according to the retail electricity prices at a specific time (Poullikkas, 2013).

Net metering has the advantage of being the simplest form of support, in that it is easy for the grid companies to administer, and for the customers to understand (Poullikkas, 2013). Further, the customers can feed any extra electricity into the grid, and take it back at any time. For the producer, this eliminates the requirements and costs of having an electricity storage system for the surplus electricity produced locally. In the case of DG production using solar panels, the cost of producing the electricity is higher than the electricity prices in most parts of the world, and hence net metering alone is not sufficient to promote the technology (Burns & Kang, 2012).

An issue with a net metering policy is that it can lead to non-DG customers subsidizing the grid cost for the renewable producers in cases where a variable grid fee is primarily used for charging grid tariffs. This happens because the producers under a net metering policy only have to pay electricity costs for the net electricity consumed, and hence avoid paying any grid tariffs for the actual electricity consumed, or that fed into the grid (Eid et al., 2014).

3.4.3. Investment subsidies

While FIT provides the assurance of a stable revenue flow in the future, investment subsidies may help to lower the barrier of the high upfront investment cost of many renewable DG technologies. However, in the past, upfront subsidies have suffered from the unpredictable nature of changing policies, and hence have not been instrumental in the widespread adoption of renewable technologies (Rolf & Bilharz, 2006).

Subsidies are easy to administer and mostly do not require continuous or periodic monitoring. They also provide certainty to the regulator and government on how much they have to pay, and there are no additional liabilities to pay in the future (IEA, 2011) (Mitchell et al., 2011).

A problem with using investment subsidies to promote renewable DG technologies is that, once the producer has received the upfront support from the government, there is no incentive for the producer to ensure high performance of the panels, other than the cost of electricity. Even if this is not a serious problem, it could lead to sub-optimal efficiency. On the other hand, subsidies can be very effective for promoting the technologies with low marginal cost.

3.4.4. Green certificates with emission cap

The issue common to all the policies discussed above is that they do not directly address the behavior of polluting industries, which in many countries are key to achieving emission reduction targets. Green certificates with an emission cap can help to achieve both objectives (Lin et al., 2007).

Green certificates are the instruments provided for the environmental benefits from generating electricity from renewable energy sources or for reducing the emissions linked with traditional technologies. Green certificates can be used in combination with an emission cap, at the national or individual level. The cap enables the green certificate holders to sell the certificates to the entities that are required to lower their emission to meet the capping. (Campoccia et al., 2009) (Morthorst, 2001).

The cap works by having green certificates issued for the electricity produced from renewable sources, and potentially for emission reductions achieved by energy efficiency measures. Having a limit on the total emissions ensures that the stated targets are met in each period.

Green certificates are mostly market-driven, and can therefore be very efficient in a well-functioning market with strong competition (Lin et al., 2007).

Green certificates can be technology-neutral or technology-dependent. A technology-neutral green certificate scheme would not differentiate between the different technologies for renewable electricity generation, and would therefore favor the most competitive technology at any given time. Less developed but potentially promising technologies would receive less support (Contaldi et al., 2007). A technology-dependent green certificate scheme can be used in order to promote promising, but presently immature renewable energy technologies as well as mature ones.

Over time, the price of green certificates has seen strong fluctuations, and determining the level at which to cap the emissions is difficult. Green certificates also have costs associated with transactions and trading, which should be taken into account. Furthermore, the government and the authorities need to put in place a system for monitoring and verifying green certificates, which can be costly (Lin et al., 2007).

3.4.5. Carbon tax

Environmental taxes have been used as a way of mitigating environmental problems such as pollution and climate change. Taxes are used as a way to make the polluting agents refrain from such activities or to at least mitigate them. Pollution is one of the best examples of negative externalities, and carbon tax is an effective way of internalizing the costs of pollution (Miller & Vela, 2013). A carbon tax sets the price for emissions, and lets the market determine the most cost-efficient way to reduce emissions.

However, the implementation of CO_2 related taxes could be tricky. The most common challenge with the CO_2 tax is how to arrive at the accurate external costs caused by different activities, and to translate them into an effective tax level. An example of inaccurately priced CO_2 tax is presented by Parry and Small (2005) in their study on taxes for gasoline in Britain and the US. They conclude that the taxes in the US are 2.5 times lower and in Britain two times higher than the required levels (Parry & Small, 2005).

Norway has had a carbon tax since 1991. It was observed that during the period 1991 to 1999 the effect of carbon tax in reducing emissions was modest. There was a reduction in carbon intensity of 14%, out of which the carbon tax only accounted for a 2% reduction. The minimal impact of the carbon tax is caused by the extensive tax exemptions for some of the polluting industries, and relatively inelastic demand in the sectors in which the tax is actually implemented (Bruvoll & Larsen, 2004).

As demonstrated in this literature review, the costs and benefits of different DG technologies are very case-specific, and it is difficult to arrive at generic recommendations which would be relevant for all cases. Furthermore, the kind of policies and schemes for promoting the adoption of DG also depend on various characteristics of the given market. Therefore, technologies and regulations should be adapted for each specific market, to ensure their efficacy.

4. Background

This section presents background information and establishes the context for the analysis. First, the key information on ZVB, including its design specifications, energy requirements, solar panel infrastructure and other elements, is presented. This is followed by an overview of the Norwegian electricity market and the key regulations, tariffs, subsidies, taxes and fees that influence investments in solar panel technology in Norway. Finally, the status and prospects for the growth of the solar panel market in Norway are presented.

4.1. Zero Village Bergen

4.1.1. Introduction

Zero Village Bergen (ZVB) is a planned pioneer project in Norway, combining low-emission materials and processes, energy efficient houses and electricity generated by renewable energy sources. ZVB will be the largest residential area with an ambition of having net zero emission from operations in Norway. The project is being coordinated by the real estate developer Bybo AS in close cooperation with the Research Centre on Zero Emission Buildings (ZEB), SINTEF, NTNU, Multiconsult, Snøhetta and several other partners (ZVB, 2015).

ZVB will be built in the Ådland area in the south of Bergen. The area will include approximately 700-800 households, distributed across 11 housing clusters (Tun 1-11) and two central areas called Ådlandsbyen West and Ådlandsbyen East. The housing clusters consist of two or three-story terraced houses and the central parts consist of four-story apartment blocks.

In addition, ZVB will include a commercial center, kindergarten, offices and green recreational areas. The construction is expected to commence from 2016-2017, subject to approvals from the necessary authorities (Haug, 2015).

The project is intended to serve as a learning platform for future zero-emission buildings, and will use the competences and ideas of leading Norwegian experts in the fields of environment and energy. As a pioneer project, it is planned for completion in several stages, each stage building on the experience of the previous steps (Haug, 2015).

The solar panels would in part be used as building materials, providing some protection for the roofs and thus reduce the cost of other materials. The scale of savings per m^2 is impossible to determine at this moment, and is therefore not explicitly included in the calculations, but rather used as an argument for using investment costs in the lower range of the existing estimates in section 6.4.

In order to keep the energy demand of the area as low as possible the buildings are constructed in accordance with heat loss standards for passive houses, and with the architecture that enables energy efficient ventilation (Haug, 2015).

For more details regarding the ambitions, methods and progress of ZVB, readers can refer to the project's webpage www.zerovillage.no .

4.1.2. Energy system

In the report *Energikonsepter for Ådland boligområde*, several concepts for covering the operational energy consumption of ZVB have been explored (Risholt et al., 2014). The solution analyzed in this thesis entails the use of rooftop solar panels for electricity generation, in combination with a heat-generating system that has yet to be determined.

The methods for estimating electricity and heat demand for both the residential and commercial buildings in ZVB, as well as for the estimated production of electricity from the solar panels are thoroughly presented in the soon to be published report *Zero Village Bergen - Aggregated Loads and PV generation profiles* produced by several of the ZEB partners (Sartori et al., 2016).

The report divides the energy demand into electrical and thermal energy. For the residential sector, the total annual electrical demand is estimated at 2,553,000 kWh and for the non-residential sector at 705,000 kWh (Sartori et al., 2016).

The thermal demand is estimated to be 3,124,000 kWh for the residential sector and 160,000 kWh for the non-residential sector. Following discussions with Bybo AS, it is assumed in this thesis that thermal demand will be covered by a heat pump system that requires 1/3.5 kWh of electrical energy in order to generate 1 kWh of thermal energy. Thus, the total electrical energy necessary for heating per year is 893,000 kWh and 46,000 kWh for the residential and non-residential sectors respectively (Sartori et al., 2016).

Both thermal and electrical energy load profiles were estimated per m^2 BRA[4] for each hour of the year for two different building categories – terraced houses and apartment blocks (Sartori et al., 2016).

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[4] The BRA refers to the gross usable area of a building

The consultancy Multiconsult has estimated an annual electricity generation of 2,941,000 kWh from 4,037 kW(p)[5] (22,045 m^2) of solar panels spread over buildings containing 685 households. The capacity factor[6] of the solar panels varies with the azimuth[7] of the panels, but on average for all the panels it is 8.32%.

The parameters for solar panels, production, consumption and buildings can be seen in table 1 and table 2 below for building areas and individual households respectively.

Building area	Number of house-holds	Heated BRA (m^2)	Installed solar panels kW(p)	Azimuth	Estimated annual production in kW(p)	Estimated annual electricity consumption excluding heating (kWh)	Estimated annual electricity consumption including heating (kWh)
Tun 4 – 1	19	2,600	140	-48	101,621	78,059	105,435
Tun 4 – 2	14	1,625	88	-40	64,920	40,306	54,461
Tun 4 – 3	14	1,625	125	-48	90,819	66,211	89,431
Tun 4 – 4	16	2,275	88	-40	64,920	55,090	74,439
Tun 3 – 1	16	2,603	140	-53	100,749	76,404	103,263
Tun 3 - 2	38	4,880	265	-48	192,440	144,143	194,769
Tun 1	31	4,450	229	-53	164,345	135,178	182,580
Ådby West -N	70	8,740	254	-29	189,091	266,773	359,002
Ådby West – S	70	5,339	109	-40	79,766	162,963	219,304
Ådby East	90	9,478	255	-40	187,470	289,045	389,016
Tun 7	40	4,604	243	-45	177,153	136,768	184,794
Tun 10	35	4,523	250	-45	181,843	134,410	181,599
Tun 8	36	4,518	250	-45	181,843	137,061	185,181
Tun 11	32	5,533	283	-45	205,964	120,881	163,347
Tun 9 - 1	31	3,906	206	-45	149,816	159,613	215,684
Tun 9 - 2	22	3,580	206	-40	150,894	82,233,2	111,097
Tun 6	42	5,959	302	-40	221,617	202,562	273,732
Tun 5	37	4,848	266	-40	195,028	155,590	210,250
Tun 2 – 1	11	1,439	82	-60	58,455	42,145	56,958
Tun 2 – 2	11	1,199	82	-53	59,233	43,304	58,482
Utsikten	10	1,971	174	-60	123,443	31,138	42,007
Total		**85,693**	**4,037**		**2,941,430**	**2,559,875**	**3,454,831**

Table 1: Key parameters for residential building areas ZVB (Sartori et al., 2016) (Multiconsult AS, 2015a) (Sartori, 2015)

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[5] kW(p) (also known as peak power or Pmax) refers to the rated capacity of a solar PV panel under a given set of standard conditions regarding solar irradiation levels, solar spectrum air mass etc. (Alchemie Limited Inc, 2013).

[6] The capacity factor of an energy source refers to the relative size of the observed or estimated annual production to the theoretical output of the maximum annual production. The maximum annual production is defined as the maximum peak capacity (kW(p)) multiplied by the hours of the year (8,760) (University of Massachusetts - Renewable Energy Research Laboratory, 2014).

[7] The azimuth of a solar panel refers to the number of degrees the panel's direction diverges from facing directly south (Solarserver, 2013).

Building area	Number of house-holds	Heated BRA per household (m^2)	Installed solar panels per household kW(p)	Estimated annual electricity production per household (kWh)	Estimated annual electricity consumption per household excluding heating (kWh)	Estimated annual electricity consumption per household including heating (kWh)
Tun 4 – 1	19	137	7.37	5,348	4,108	5,549
Tun 4 – 2	14	116	6.29	4,637	2,879	3,890
Tun 4 – 3	14	116	8.93	6,487	4,729	6,388
Tun 4 – 4	16	142	5.50	4,058	3,443	4,652
Tun 3 – 1	16	163	8.75	6,297	4,775	6,454
Tun 3 - 2	38	128	6.97	5,064	3,793	5,126
Tun 1	31	144	7.39	5,301	4,361	5,890
Ådby West -N	70	125	3.63	2,701	3,811	5,129
Ådby West – S	70	76	1.56	1,140	2,328	3,133
Ådby East	90	105	2.83	2,083	3,212	4,322
Tun 7	40	115	6.08	4,429	3,419	4,620
Tun 10	35	129	7.14	5,196	3,840	5,189
Tun 8	36	125	6.94	5,051	3,807	5,144
Tun 11	32	173	8.84	6,436	3,778	5,105
Tun 9 - 1	31	126	6.65	4,833	5,149	6,958
Tun 9 - 2	22	163	9.36	6,859	3,738	5,050
Tun 6	42	142	7.19	5,277	4,823	6,517
Tun 5	37	131	7.19	5,271	4,205	5,682
Tun 2 – 1	11	131	7.45	5,314	3,831	5,178
Tun 2 – 2	11	109	7.45	5,385	3,937	5,317
Utsikten	10	197	17.40	12,344	3,114	4,201
Average per household ZVB			**5.89**	**4,293**	**3,737**	**5,044**

Table 2: Key parameters per household for the residential building areas in ZVB (Sartori et al., 2016) (Multiconsult AS, 2015a) (Sartori, 2015)

The electricity consumption of the non-residential buildings are given per m^2 BRA. The key parameters can be seen in table 3.

Buildings	Heated BRA (m2)	Estimated annual consumption excluding heating (kWh)	Estimated annual consumption including heating (kWh)
Kindergarten	1,061	56,548	62,683
Offices	2,833	361,258	382,603
Shop	2,833	286,961	305,086
Total	**6,727**	**704,767**	**750,372**

Table 3: Key parameters for the electricity consumption for the non-residential buildings in ZVB (Sartori, 2015)

4.1.3. Peak load

Based on the data described above, the peak hourly aggregated load for ZVB is found to be 831 kW and 926 kW, excluding and including non-residential buildings respectively. The peak surplus electricity production that would be fed into the grid is found to be 2,625 kW and 2,496 kW when excluding and including the non-residential buildings respectively. As a consequence, the solar panels in ZVB increase the maximum load capacity required for the local grid connecting ZVB.

The grid operator can charge customers for customer-specific connection costs (see section 4.3.4). As a consequence, if the solar panels cause an increase in connection costs for ZVB, those costs may be allocated to the owners of solar panels.

However, there are some elements that indicate that the grid connection cost might not increase. First, the grid operator, BKK Nett AS, uses cables with a capacity of 8 MW in the low-voltage grid (11 kV). Secondly, as the maximum surplus production happens in the summer, when the demand is relatively low, it is not certain that the solar production will lead to a need for increased grid capacity for the 11 kV grid (BKK Nett, 2015b).

Due to uncertainty regarding increased costs of connection caused by the solar panel system in ZVB, increased grid connection cost is not a factor used in the calculations presented in this thesis.

4.2. The Norwegian electricity market

4.2.1. Introduction

The Norwegian electricity market was liberalized in the early 1990’s, and is now integrated with several European countries in a common electricity market. In Norway, market mechanisms determine investments, prices and production levels for stakeholders on the production and retail side. The transmission system is considered a natural monopoly, and therefore is still regulated (Wangensteen, 2007).

4.2.2. Market actors

In 2013, there were 158 companies engaged in electricity production, 154 companies operating grids and 245 companies in retail business in Norway. On the electricity production side, the 10 largest producers account for 74% of the installed capacity. A large share of the market is made up of vertically integrated companies: 110 companies were involved in both grid operation and retailing and/or production. Of these, 60 companies were active in all three areas (Olje- og Energidepartementet, 2015).

The Norwegian Water Resource and Energy Directorate (NVE) is the main regulatory body for the electricity market in Norway. The Norwegian Competition Authority ensures competitiveness in the electricity market (Wangensteen, 2007). The Financial Supervisory Authority of Norway (Finanstilsynet) grants concessions and regulates the financial trade of electricity (Olje- og Energidepartementet, 2015).

4.2.3. Power production

In 2012, hydropower, with 1,393 hydropower plants, accounted for 95% of the 31,814 MW installed capacity in Norway. Wind power made up 1.6% and thermal power generators 3.4%. The amount of water available for power generation depends on precipitation and temperature, which varies from year to year. The difference between the lowest and highest amount of available water in the period 1990-2014 corresponded to 60 TWh of electricity production capacity (Olje- og Energidepartementet, 2015).

Public entities such as municipalities, counties and the central government own 90% of the Norwegian power production capacity (Olje- og Energidepartementet, 2015).

4.2.4. Power transmission within Norway

The essential function of the electricity grid is to transport power from producers to the end consumers. Due to the non-storable nature of electricity, the production and consumption must happen at the same time, thus requiring instantaneous balancing of the grid at all times. Statnett SF, the national transmission system operator (TSO), is responsible for ensuring safe and stable operation and balancing of the electricity system (Olje- og Energidepartementet, 2015) (Wangensteen, 2007).

The grid system can be separated into three levels - the central grid, the regional grid and the distribution grid. The central grid includes 11,000 km of high capacity and high voltage (usually 300-400kV) grid, and connects the different parts of the country. It also includes interconnectors to other countries. Statnett SF owns and operates most of the central grid and the international interconnectors (Olje- og Energidepartementet, 2013).

The distribution grid includes about 100,000 km of lower-voltage (22kV – 230V) grid infrastructure that brings electricity to the end consumers. The regional grid connects the distribution and central grid. Various distribution system operators (DSOs) own and operate the regional and distribution grid (Olje- og Energidepartementet, 2015).

Large-scale producers connect to the central grid. The medium and small-scale producers connect with the regional or distribution grid. Any electricity transmission through the grid leads to some losses. In Norway, losses amount to approximately 8% of the yearly electricity production (10 TWh) (Olje- og Energidepartementet, 2015).

All grids are considered natural monopolies due to high initial investment and low marginal costs of operation. For this reason, only one entity can be responsible for the electricity transmission in a given area, and has to get permission to operate from NVE in the form of area concessions. NVE stipulates the grid tariffs which can be charged by the DSOs, based on the principle that the revenues should provide sufficient income for the DSOs to cover the operation and maintenance of their grid systems, and generate a reasonable return on investments, provided the company operates and develops efficiently. The limit on revenue is estimated based on historical costs and on cost benchmarking (Wangensteen, 2007).

4.2.5. International power transmission

The Norwegian energy system has interconnectors to Finland, Sweden, Denmark, the Netherlands and Russia. In addition, two new interconnectors, to the UK and Germany, are under development. As mentioned, Statnett SF is responsible for the international transmission capacity (Haaland, 2012).

In most years, Norway is a net exporter of electricity. However, import is still an important component amounting to 2.6 - 12.6 % of total consumption over the last 10 years (see table 4) (SSB, 2013).

Year	Production (GWh)	Consumption (GWh)	Import (GWh)	Export (GWh)	Net Export (GWh)
2014	142,399	126,366	6,503	22,536	16,033
2013	134,247	129,237	10,131	15,141	5,010
2012	147,919	130,016	4,138	22,041	17,903
2011	128,145	125,071	11,255	14,329	3,074
2010	124,458	130,400	14,671	7,124	-5,942
2009	132,792	123,809	5,650	14,654	8,983
2008	142,667	128,791	3,414	17,291	13,876
2007	137,700	127,672	5,284	15,320	10,028
2006	121,663	122,518	9,802	8,947	-855
2005	137,811	125,769	3,653	15,695	12,042
2004	110,472	121,964	15,334	23,842	-11,492

Table 4: Electricity production, consumption, import and export numbers for Norway (Hafslund, 2015)

4.2.6. Power consumption

Compared to most countries, Norway has a higher share of electricity in its final energy consumption. This is due to the presence of energy-intensive industry in the country, and the extensive use of electricity for heating buildings and water, both in the residential and the commercial sectors (Olje- og Energidepartementet, 2015).

The electricity consumption varies with changes in temperature during the year, with high consumption in winter and lower consumption in summer. As can be seen in figure 1, the stationary energy consumption increased from around 140 TWh to around 160 TWh per year from 1990-2000, whereas growth stagnated in the period 2000-2010.

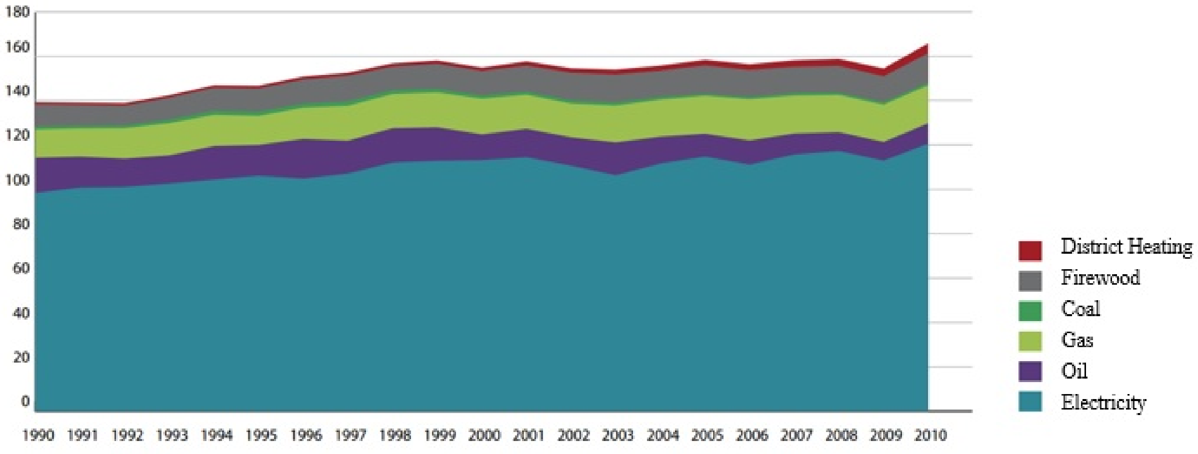

Figure 1: Stationary energy consumption in Norway by energy carrier 1990-2010 (Olje- og Energidepartementet, 2015)

The total consumption of electricity is dependent on a large number of factors, such as population growth, urbanization and economic growth both in Norway and abroad. An important change over the last years has been the increased focus on energy efficiency in the residential and commercial sectors, driven by an increase in environmental awareness. In addition, a large number of national and international regulations have been implemented to ensure increased energy efficiency and a shift towards cleaner sources of energy generation. (Olje- og Energidepartementet, 2015).

However, even if the new technology and appliances are decreasing the total electricity consumption, the momentary power consumption is increasing due to higher wattage of these appliances. This is putting higher strain on the grid system (Ingeberg, 2015).

4.2.7. Power trade

The trade of electricity can be divided into physical trade and financial trade (Wangensteen, 2007). In physical trade, the electricity bought or sold is delivered physically. The financial trade refers to derivatives and other financial instruments that enable speculation or risk mitigation (Nord Pool Spot AS, 2015c).

4.2.7.1. Physical power trade

Physical trade can be split into two main markets: The wholesale market and the end user market (Olje- og Energidepartementet, 2015).

Wholesale trade of electricity is done either on the Nord Pool Spot exchange or through bilateral trade agreements known as over-the-counter (OTC). Nord Pool Spot exchange is the market for wholesale electricity in Norway as well as several other European countries. It facilitates trade for two main products: the day-ahead market, and the intra-day market (Nord Pool Spot AS, 2015a).

The day-ahead market (Elspot) combines bids on hourly sale and purchase prices received from power producers, retailers and other large consumers. An equilibrium price, which balances production and consumption for all hours of the day, is derived based on the bids received (Wangensteen, 2007) (Olje- og Energidepartementet, 2015). Nord Pool is also a part of the Price Coupling of Regions (PCR) entity, the aim of which is to develop a single European day-ahead market (Nord Pool Spot AS, 2015a).

The intra-day market (Elbas) is a continuous market starting from the closing of the Elspot market up to one hour before the hour of delivery (Nord Pool Spot AS, 2015c).

The Norwegian electricity market is divided into five zones that are separated by bottlenecks in the transmission grid. Due to the bottlenecks, there might be a surplus in one region and deficit in another without the possibility of transferring from one region to another, causing different area prices. The area prices are calculated at the Nord Pool Spot by taking into account the de facto opportunity to transmit electricity on the grid. Within each area, the wholesale price of electricity is the same for all customers (Statnett, 2015c).

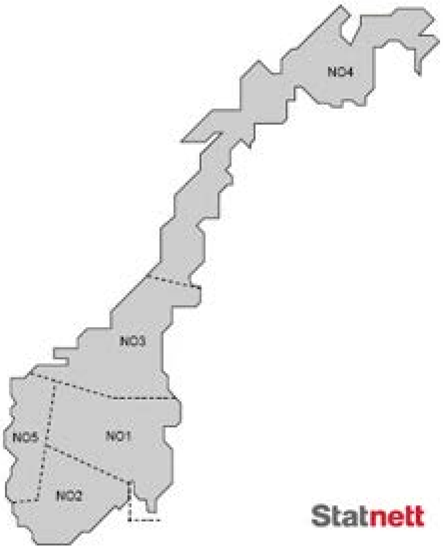

Figure 2: The electricity market zones of Norway (Statnett, 2015c)

Households, industry, and the commercial sector make up the end user market, with each accounting for approximately one-third of the end user market. Households typically buy their electricity from retailers, who in turn buy electricity on the wholesale market based on the estimated demand from their end consumers (Olje- og Energidepartementet, 2015).

4.2.7.2. Financial power trade

Financial trade of electricity can be done either at NASDAQ OMX Commodities exchange or bilaterally between two parties. The time horizon for the financial contracts stretches from the day ahead market to several years into the future, and allows actors in the energy market to mitigate risk, speculate on future development or fix electricity prices (NASDAQ OMX Nordic, 2013).

The financial exchange enables trading without any physical exchange of electricity, with Nord Pool system price[8] as the underlying for the trades (Olje- og Energidepartementet, 2015).

Four main categories of contracts are offered: Options, futures, forwards and contracts for difference (CfD). CfD contracts are forward contracts that allow trading on the difference between an area price and the system price (NASDAQ OMX Nordic, 2013).

4.2.8. Electricity Pricing Mechanism

For the physical power trade, there is an important distinction between the wholesale and the end user price of electricity, when it comes to the pricing mechanism.

For the wholesale market, the area prices are developed for the Nordic Market for each hour of the day based on sale and purchase bids received from producers, retailers and consumers on the day-ahead Elspot market, and positions may be changed up to an hour before the time of consumption on the Elbas market[9]. Supply and demand bids from the whole Nord Pool area as well as transmission constraints are used to arrive at area prices (Olje- og Energidepartementet, 2015).

The market based system for electricity means that the price is also a function of the supply and demand for electricity at any given time. On the supply side, the Norwegian power market is dominated by hydropower. Thus, the amount of precipitation and temperature (due to snow melting) play a central role in determining the cost of producing electricity. The price of coal and gas also have an indirect effect, since much of the European power generation is based on these thermal sources (Olje- og Energidepartementet, 2015). Environmental policies in Norway and Europe may also have a large impact on the supply side, for example through political goals of reducing the share of coal and nuclear power or decisions to increase taxes on CO_2 emissions (Thema Consulting Group, 2015).

On the demand side, temperature is a central driver because electricity is widely used for water and space heating. Thus, the winters have higher electricity demand than the summers. The electricity demand from power-intensive industry is more elastic, responding to the changes in the demand for its products. In periods with strong economic growth in Europe, the electricity

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[8] The system price calculation is carried out by aggregating all biddings in one purchase and one sales curve without considering potential capacity constraints between the relevant areas. The point of intersection between the two curves establishes the System Price (Nord Pool Spot AS, 2014).

[9] As mentioned, the OTC market is an alternative source of wholesale electricity. However, as it is a bilateral system, no central pricing scheme exists.

demand from power intensive industry tends to be high (Olje- og Energidepartementet, 2015). Political decisions regarding the environment and technical development may also have an impact on the demand side, for example through public requirements relating to the energy efficiency of appliances and buildings.

The electricity price for the end users consists of the wholesale price of electricity, grid tariffs, taxes, and fees as well as a potential mark-up by the retailers. Larger consumers, such as energy-intensive industry often buy electricity directly on the wholesale market, whereas small-scale consumers such as households usually buy from a retailer. End consumers who buy electricity from a retailer can usually choose between several different contract types such as fixed price, floating price or spot price (Olje- og Energidepartementet, 2015). More details on the grid tariffs, taxes and fees are presented in section 4.3.3.

4.2.9. Retailer mark-up

There is a large variation in the mark-up on the wholesale electricity prices charged by different retailers. This is dependent on the type of contract between the retailers and the end consumers, and on whether the retailer operates on the national or regional level (Ericson et al., 2009).

There are three main kinds of contracts: spot price contracts, variable price contracts and fixed price contracts. According to Ericson et al. (2009), the mark-up by the country-wide retailers is lower than by the regional retailer for all contract types (Ericson et al., 2009).

Customer loyalty stemming from before the deregulation of the retail market is one of the main factors enabling the regional retailers to charge a higher markup (Ericson et al., 2009). In this thesis, it is assumed that in the future, mark-up would develop towards the levels seen for nation-wide retailers, and the mark-up for the nation-wide retailers is therefore used for the analysis.

The mark-up by nationwide retailers is between 7-13 % for fixed contracts, 3-10% for spot price contracts and 5-9% for variable price contracts, all in percentages of the wholesale electricity price before VAT (Ericson et al., 2009). For the purposes of the calculations in this thesis, a mid-range mark-up of 7% on the wholesale price has been chosen.

4.2.10. Predicting the future price development

There is a considerable degree of uncertainty regarding the long-term development of the price of electricity in the Nordic market. Thema Consulting Group has analyzed the future price development in this market towards 2040. They conclude that as a part of this market, Norway is likely to see a drop in prices towards 2020, and considerable uncertainty in the following 20 years. However, as their base case they assume a drop in prices towards 2020 and an increase after that. The main sources of uncertainty are the European environmental policies, the state of the world economy and the phasing-out of Swedish nuclear power (Thema Consulting Group, 2015).

However, the credibility of a model developed for forecasting the electricity prices in any deregulated electricity market would be very questionable due to a number of unknowns factors at play (Fogarty & Lamb, 2012).

In some countries, the natural gas future curves are used as a proxy for electricity prices for valuing power plants. This is done because of the availability of longer duration data, both historical and futures, for the natural gas prices compared to electricity prices, and the correlation in the movement of natural gas and electricity prices. This approach has many drawbacks due to a number of factors affecting electricity prices such as weather, load, capacity constraints and government pricing policies (Fogarty & Lamb, 2012).

Different research has also regularly characterized electricity prices based on seasonality, mean reversion and periodic spikes. In fact, there has been a constant debate between the supporters of mean reverting electricity price models such as (Lucia & Schwartz, 2002) and (Knittel & Roberts, 2005), and those supporting non-mean reversion such as (Leon & Rubia, 2004).

Escribano et al. (2011) is one of the more recent papers that found evidence of mean reversion with periodic spikes of the electricity prices in the Nord Pool markets. The mean reversion in the Nord Pool Spot prices is slower than most of the other markets due to higher dependence on hydropower. Furthermore, there has been very little research on the development of intraday future prices (Escribano et al., 2011).

4.2.11. Digitalization

An important trend in the Norwegian electricity system is the digitalization of the grid. This will allow for better monitoring of the power system and more accurate data on consumption patterns. The central digitalization processes currently under development are smart meters and Elhub.

As per NVE requirement, smart meters or Advanced Metering Systems (AMS) have to be installed in all Norwegian households by 2019 (Statnett, 2015a). The AMS meters allow for two-way communication between the household and the grid, enabling both the end consumer and the grid operators to get a more detailed and continuous overview of consumption patterns and prices.

Elhub is a central component in a more digitalized grid system (smart grid) that is expected to be operational from February 2017. Elhub will gather market data for the entire Norwegian power system (Elhub, 2015).

4.3. Regulations, tariffs & support schemes for solar panels

This section gives an overview of the relevant regulations, tariffs, taxes, fees and support schemes that affect the solar system in ZVB.

4.3.1. Regulations in the Norwegian energy system

The power system is one of the most important infrastructure elements of modern society. Therefore, even if parts of the Norwegian power system are governed by market mechanisms, the government has an interest in ensuring that it operates in a safe and optimal way for society. This is achieved through different laws and regulations applicable to participants in the energy system.

4.3.1.1. The Energy Law

The main law regulating the Norwegian energy system is the Energy Law (Energiloven), which came into force in 1991 (Naas-Bibow et al., 2011). According to § 1-2 in the Energy Regulation, the purpose of the Energy Law is to:

> *Ensure that production, transformation, transmission, trade, distribution and use of energy happens in a rational way for society, including that public and private interests that are affected are taken into account [own translation]* (Olje- og Energidepartementet, 1990a).

4.3.1.2. Concessions

Concession requirements are one of the main tools to ensure governmental control over the energy system, as well as to assure non-discriminatory market conditions for all participants. The government can impose rules and requirements regarding documentation and methods in order to receive and keep concessions to operate in the Norwegian energy system. The general rules for the production, transmission and distribution of electrical energy in Norway are stated in the Energy Law §3-1:

> *Systems for production, transformation, transmission and distribution of electrical energy, cannot be built, owned or operated without a concession (…) The ministry decides how high voltage an electrical system must have in order for the above statement to be binding [own translation]* (Olje- og Energidepartementet, 1990b).

The voltage limit for a concession requirement is specified at 1,000V AC or 1,500V DC. Below these limits, certain categories of electricity producers can be relieved from the concession requirement. Some of the exceptions are:

> a) *Customer- specific systems*
>
> b) *Distribution grid that delivers power from local production to end customers, where the main fuse capacity is below 200A at three phase 230V.*
>
> c) *Cases where the concession requirement must be regarded as clearly unnecessary*
>
> *[own translation]* (Olje- og Energidepartementet, 1990a)

If ownership and operation are split between two different entities, then the entity that is responsible for operation should hold the concession (Olje- og Energidepartementet, 1990b).

A concession is also required to trade electricity. In the Energy Law §4-1, it is stated that:

> *Without a concession, no one other than the government can trade electrical energy [own translation]* (Olje- og Energidepartementet, 1990b).

However, in cases where the activities that require a concession are of a limited scale, the concession can be given on simplified terms. This implies that the entities could avoid much of the substantial demands of economic and technical reporting required from ordinary holders of a concession (Olje- og Energidepartementet, 1990b). NVE has decided that to be granted a simplified concession, the yearly production must be below 1 GWh (NVE, 2015e).

Four categories are not required to have a trade concession. Of most relevance in the context of this thesis is the category:

> *Cases where the concession requirement must be regarded as clearly unnecessary [own translation]* (Olje- og Energidepartementet, 1990a).

NVE has the final authority to decide whether an entity qualifies for any of the exceptions to the general rule of concession requirement.

Finally, as stated in §4-3 of the Energy Law, a concession is required for the transmission and distribution of electricity:

> *Power lines, transformer stations, and other electrical systems can only be built and operated if holding a concession in accordance with the Energy Law* (Naas-Bibow et al., 2011).

4.3.1.3. Balancing agreement

The electricity system needs to have a balance between consumption and production at all times. Statnett is responsible for a stable and secure operation of the national grid system and must at all times balance the demand and supply of electricity across the grid in order to keep the grid frequency stable at 50Hz. This is achieved through balancing responsibilities and balancing markets (Olje- og Energidepartementet, 2015) (Wangensteen, 2007).

Having a balancing agreement with Statnett is required to access the Norwegian market for wholesale electricity. The entities with balancing responsibilities are defined in §4-3 of the Energy Law as:

> *Anyone who completely or partially owns or operates a grid, production or organized market (…), as well as traders and end users [own translation]* (Naas-Bibow et al., 2011).

However, as this would create a very large number of small balance responsible entities, it is allowed to outsource the balancing activities to another entity. The balance responsible entities are required to follow the instructions of Statnett regarding regulating power settlement (Naas-Bibow et al., 2011).

Statnett is responsible for making a balanced schedule for the day-ahead Norwegian wholesale electricity market by combining all trades and exchange. Based on this information, the difference between the planned and actual production and consumption is calculated for each day. This difference between the actual electricity fed in or taken out and the buying or selling commitment of each balance responsible entity is called *regulating power* (Statnett, 2015b). Statnett can stipulate penalties for such deviations (Wangensteen, 2007). The regulating power is traded on the *regulating power market*, where various entities offer regulating power services (Wangensteen, 2007).

There are three levels of regulating power: the primary regulating power is a frequency-activated reserve that power producers are required to have as per Statnett regulations. The primary regulating power reacts automatically to deviations in the grid frequency to bring the frequency back to normal. The secondary regulating power is also automatic, and activates almost instantaneously if the primary regulating power is insufficient to balance the grid. The tertiary regulating power is operated manually, and can be activated within 15 minutes if both the primary and the secondary regulating power supplies are insufficient. It involves the change in electricity demand from large consumers as well as a change in production from power generators. The prices for secondary and tertiary regulating power services are market prices, based on bids to ensure that balancing is done in a socio-economically optimal way (Olje- og Energidepartementet, 2015).

4.3.2. Plus -customer agreement[10]

The plus customer agreement was introduced in 2010 to simplify the regulatory requirements for small-scale electricity producers that mainly produce electricity for their own consumption. The current plus customer agreement has a temporary legal status, and it is expected that a new and permanent plus customer agreement will be presented in 2016. In this section, the current plus customer agreement as well as the potential future plus customer agreement are presented.

4.3.2.1. Current plus customer agreement

The plus customer agreement was introduced in 2010 to facilitate the regulatory framework for end consumers of electricity with small-scale DG systems. The current definition of a plus customer is:

> *End-users of electricity that have an annual generation that normally does not exceed their consumption, but which during certain hours have a surplus of electricity that can be fed to the grid. Those production units which require trade concession or end users with a production that is also delivered to other end consumers, are not included in the plus customer scheme [own translation]* (NVE, 2015g).

The plus customer agreement is currently benefitting the end consumers by exempting them from the following requirements:

- The need for a concession for producing and feeding electricity into the grid
- The requirement of having a balancing agreement with Statnett (NVE, 2015g).

The agreement further improves the financial case for distributed generation in the following ways:

- The plus customers are not required to pay grid fees and taxes on the part of production they consume locally
- For the surplus electricity production that is delivered to the grid, plus customers pay only the variable grid fee[11], not the fixed grid fee for power producers

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[10] Plusskundeordningen

[11] Energileddet

- Based on the willingness of the DSO to buy the electricity, the plus customers can be paid (by the DSO) for the electricity they feed into the grid (NVE, 2015g).

From the definition, it is clear that delivery of electricity from one plus customer to another end consumer would not be allowed, as that would require a trade concession.

The typical plus customer would be a house owner with a small-scale solar panel system installed on the roof. Under the current plus customer agreement, a plus customer and the local DSO can enter into a voluntary agreement. Once the agreement is finalized, the customer can feed surplus electricity into the grid at the price offered by the DSO (NVE, 2015g).

The plus customers have the same rights as all other end consumers, and have to follow the standard requirements for voltage levels and other specifications for feeding electricity into the grid. NVE does not provide any specific guidelines regarding the price that the DSOs must pay to the plus customers for the electricity fed into the grid. However, NVE suggests that the price should reflect the wholesale market price of electricity in the area (NVE, 2015g).

BKK, in its concession area, allows its customers to enter into a plus customer agreement. Under the agreement, the customers pay normal grid tariffs for consumption. For the surplus production, customers receive Nord Pool Spot’s area price, with a deduction to adjust for the marginal energy losses in the grid.

The marginal prices for distribution of electricity to power producers from BKK is based on the average marginal loss in the grid, and differs with the season and time of the day. BKK operates with the following charges: In summer (01 April – 30 September), 4% is deducted as marginal loss. During winter, 7% is deducted during the daytime (06:00-22:00) and 6% for nighttime and weekends (BKK, 2015d).

4.3.2.2. Future plus customer agreement

In June 2014, NVE published a proposal for terms and conditions for a revised plus customer agreement. The proposal is still under deliberation, and new regulations are likely to be made official in 2016. In the hearing document from 2014, the proposed new definition of a plus customer was:

> *End user with consumption and production behind the connection point, where the production fed into the connection point at no time exceeds 100 kW. A plus customer cannot have a generation facility that requires a concession behind the connection point nor trade behind the connection point that requires a trade concession* (Fladen et al., 2014).

This means that the sale of electricity behind the connection point would still not be allowed under the proposed new plus customer scheme, as it would require a trade concession. Therefore, it does not open up the possibility for a commercial actor to operate the electricity system behind the connection point. It further puts a limit on the characteristics of the production infrastructure behind the connection point, since it must be within the requirements stated in section 4.3.1.2 to be exempt from the concession requirement.

In addition to the change in the definition of a plus customer, the following three elements were also proposed:

- The plus customers should not be required to document and report total energy production. Only the figures on net electricity fed into and withdrawn from the grid should be recorded using an AMS system
- The plus customers should not be required to pay grid tariffs on the surplus electricity fed into the grid
- The plus customers should no longer sell surplus electricity to the local DSO, but are free to make an agreement with a retailer of their choice (Fladen et al., 2014).

Further, in a hearing document from July 2015, NVE clarified that only the customers that have a single measurement point in an AMS for feeding electricity in and out of the grid do not have to pay the fixed tariff for feeding in electricity. In practice, this means that plus customers must choose between receiving green certificates only on their surplus production, or receiving green certificates on the entire production but then also paying the fixed grid tariff.

In the same hearing document, NVE states that it might be possible to pool DG electricity resources from co-ownerships:

> *NVE, in cooperation with Statnett, has considered the possibility of Elhub facilitating a solution for measuring data from single households, in a co-ownership, to be corrected based on the amount of electricity produced by the co-ownership. After the preliminary considerations, it is considered feasible for such an arrangement to be ready by the introduction of Elhub, planned for 20 February 2017* (Fladen & Sandnes, 2015).

Thus, from 2017, there would be a possibility of sharing electricity from a DG system for all the households in a co-ownership.

4.3.3. Tariffs and taxes

4.3.3.1. Grid tariffs, taxes and fees for power consumers

The DSOs in Norway receive revenues through grid tariffs charged to all end consumers of electricity. The grid tariffs are divided between a variable and a fixed tariff, with some consumers also paying a capacity tariff. As mentioned earlier, because of the natural monopoly of distribution service, NVE sets a revenue cap for DSOs.

The general principle for the grid tariffs is to make them non-discriminatory and objective. This implies that tariffs can differ between customers within an area, but only based on objective measures relevant for the cost of the grid services provided. (NVE, 2015b).

Variable grid tariff

The variable grid tariff is meant to compensate for marginal losses from transporting electricity from the power source to the end consumer (Andresen & Mook, 2015).

NVE allows grid operators to cover a part of their fixed costs through the variable tariff, and all DSOs in Norway take advantage of this opportunity. The marginal loss of transporting electricity through the grid is approximately 0.05 NOK/kWh on average in Norway[12]. However, the DSOs charge variable tariffs in the range of 0.10 - 0.40 NOK/ kWh (Andresen & Mook, 2015). BKK has a variable tariff of 0.1556 NOK/kWh[13] including VAT (BKK, 2015b).

The marginal loss of electricity transportation varies with the momentary use of the grid. The effect of introducing more power to the grid can be both positive and negative, depending on whether it leads to an increase or decrease in marginal grid losses. When the amount of power transported over the grid is close to the capacity limits of the grid, the losses incurred by increased load can be substantial. However, due to complexity and potential local differences, there is no regulatory requirement for measuring the marginal losses at all connection points within an area in the distribution grid. The usual practice is to calculate a common variable tariff for the whole area of a DSO (NVE, 2015i).

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[12] Based on an average electricity price of 0.30 NOK/kWh (Andresen & Mook, 2015).

[13] 0. 345 NOK/kWh – 0.1769 NOK/kWh (Consumption tax) – 0.0125 NOK/kWh (Energy Fund fee incl. VAT) = 0.1556 NOK/kWh.

Fixed and capacity grid tariff

In addition to the variable grid tariff, the DSOs can charge a fixed grid tariff and a capacity grid tariff. The fixed tariff is a pre-determined cost for all customers, whereas the capacity tariff is calculated based on the customer's electricity load during a certain time period, typically during the peak load times. It is not mandatory for the DSOs to charge a capacity tariff, and it is mainly used for commercial customers (NVE, 2015i).

For the customers who do not pay a capacity tariff, the minimum level of the fixed tariff should cover the customer-specific costs. Many DSOs charge different fixed grid tariffs to different groups of customers, often based on their consumption patterns (NVE, 2015i).

Fees and taxes

On behalf of the government, the DSOs are required to charge a consumption tax and value-added tax (VAT) on customers' electricity bills. These taxes are the same for the entire country except for some of the northernmost regions, and are charged on behalf of the Directorate of Customs and Excise[14]. Starting from 1 July 2015, the consumption tax is 0.1769 NOK/ kWh including VAT. The VAT added to the wholesale electricity price is 25%. (BKK, 2015a).

Finally, a contribution for the Energy Fund[15] is also charged as a part of the grid tariff. It amounts to 0.0125 NOK/ kWh including VAT (EB Nett, 2015).

4.3.3.2. Grid tariffs for power producers

All power producers are required to pay tariffs for feeding electricity into the grid. The tariffs are stipulated by NVE, and consist of a fixed and a variable part.

Variable tariff

The variable grid tariff for power producers should represent the marginal costs of feeding electricity to the grid at a given moment in time. The marginal losses at different times are estimated and published in advance to determine the variable tariffs to be paid by the producers. This enables the producers to consider the expected losses while planning their production schedule (NVE, 2015d).

The variable tariff that would apply to plus customers in BKK's distribution grid is based on the average marginal grid loss in the area. BKK has stipulated a variable tariff of 7% for the

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[14] Toll-og Avgiftsdirektoratet

[15] Energifondet

winter months, 6% in the summer and 4% during nights and weekends (BKK, 2015c) (NVE, 2015d).

Fixed tariff

The fixed grid tariff for a power producer is based on the producer's average yearly production over the last 10 years. For power plants with a capacity of less than one MW, the fixed tariff is calculated by multiplying 30% of the plant's total capacity by 5000 hours (NVE, 2015d).

4.3.3.3. Future changes in the grid tariff structure

For NVE, the grid tariff is a means to signal the effect of different consumption patterns on the grid costs, and consequently a way to shift consumer behavior towards socially optimal consumption profiles:

> *The tariffs should be structured such that they contribute to an efficient use of the existing grid, and at the same time contribute to the implementation of correct investments in electricity grids, consumption, production and alternatives to electricity [own translation]* (Andresen & Mook, 2015).

In a hearing document published in May 2015, NVE presented a draft of proposed changes in grid tariff structure for withdrawing electricity from the distribution grid (Andresen & Mook, 2015).

It is mentioned that there is a shift towards more energy-efficient, but power-intensive appliances in the Norwegian electricity market. Therefore, even though the total electricity consumption per household goes down, the investments in grid infrastructure may increase in order to accommodate an increase in peak load (Andresen & Mook, 2015).

As per the current regulatory framework for distribution companies, the DSO's are free to charge a variable tariff to electricity consumers that is higher than the marginal cost of electricity transportation. Thus, the costs charged to the consumers do not reflect the real cost of the grid companies. With the trend of shifting towards more energy-efficient and power intensive appliances, this gap between marginal cost and variable tariff could increase further (Andresen & Mook, 2015).

Therefore, NVE is considering a reduction in the allowed variable grid tariff to reflect the true marginal loss in the grid, and proposes three alternative methods for calculating a more accurate grid tariff structure based on:

1) The measured power outtake of the customer in some reference hours
2) The fuse box capacity, or

3) The customer’s power subscription.

NVE has received 57 responses to their proposal, many of which agree that there is a need to change the current grid tariff structure to accommodate changing consumption patterns. However, some major stakeholders, such as Enova, point out that the electricity consumers in Norway do not necessarily behave in a rational way. Therefore, a correct pricing model should not be a goal in itself, if such a cost model does not lead to socially optimal behavior (Leistad & Berg, 2015).

In the case of BKK, a reduction in the variable grid tariff to the marginal grid losses would bring down the total variable grid tariff from 0.345 NOK/ kWh to 0.255 NOK/kWh[16].

4.3.4. Customer specific grid infrastructure

The DSO can, in accordance with §17 -5 in the prescript on technical and economic reporting[17], charge the customer for costs in the grid connection that are specific to the customer[18] (Olje- og Energidepartementet, 2010). Each DSO can decide the mechanism to charge the customer-specific grid costs, but must be consistent in its practice across all customers (NVE, 2015a).

BKK Nett AS has chosen a model where the DSO pays a part of the connection costs as a fixed contribution. Costs beyond this contribution are attributed to the customer who has caused the costs (BKK Nett, 2015a).

The costs allocated to a specific customer consist of a customer-specific part and a shared part. The customer-specific part covers the connection from a shared grid line to the individual customer. The shared part is the allocation of a part of the costs caused by the grid shared by several customers. The maximum expected power load determines the dimension of the cabling and equipment for the grid connections. Therefore, the expected maximum power load of a customer determines the share of the total infrastructure cost that will be allocated to them (BKK Nett, 2015a).

4.3.5. Green certificates scheme

Since 2012, Norway and Sweden have had a shared green certificate scheme[19] to increase the share of renewable energy in the total energy production. Under the scheme, end consumers in

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[16] 0.345NOK/kWh – (0.14NOK/kWh – 0.05 NOK/kWh) = 0.255 NOK/kWh
[17] Kontrollforskriften
[18] Anleggsbidrag
[19] Elsertifikatordningen

both the countries pay a green certificate fee on top of their regular electricity bill in order to fund new renewable electricity generation (NVE, 2015c).

The main motivation for the Norwegian government to promote the scheme is to meet its goal of increasing the share of renewable energy in total energy consumption from 62.5% in 2011 to 67.5% by 2020, in accordance with the EU directive on renewable energy (EUR-Lex, 2009).

Under the green certificate scheme, Norwegian customers have to pay for a 13.2 TWh increase in annual renewable energy generation by 2020, regardless of whether the production facilities are constructed in Norway or Sweden (NVE, 2015c) .

New renewable energy projects receive green certificates based on their total production (MWh). At the same time, some power producers and large consumers are required to buy green certificates amounting to a certain share of their electricity production or consumption. They can buy these certificates from the renewable producers, which creates a market for green certificates. The rationale behind promoting this market arrangement is to incentivize the cheapest renewable energy generation to be produced first (NVE, 2015c).

The following three categories of renewable energy projects are eligible for green certificates (Olje- og Energidepartementet, 2011):

- Renewable power plants where the construction started after 7 September 2009
- Existing renewable power plants which increased their power production after 7 September 2009
- Small hydro power plants of up to one MW of installed capacity, where construction started after 1 January 2004.

The scheme is only valid for projects that are operational before 31 December 2020, and the scheme is currently assumed to become inactive in 2035. In this thesis, it has been assumed that the solar panels for use at ZVB would be finalized by the end of 2018, and thus eligible for green certificates for 17 years. The projects that have received some other form of support from the government must pay back this support in order to be eligible for certificate payments (Olje- og Energidepartementet, 2011).

To register the power producers for the green certificate scheme, NVE charges a processing fee of 15,000 NOK for the production capacity of less than 100 kW, 30,000 NOK for the capacity between 100 kW and 5 MW, and 60,000 NOK for capacities above 5 MW (Lie, 2014).

In practice, this fee often makes it unprofitable for small-scale solar electricity producers to enroll for the green certificate scheme and trade the certificates (Lie, 2014).

Under current regulations, as long as the electricity produced from solar panels is appropriately measured, it is eligible for green certificates, even if the electricity produced is consumed locally. However, as mentioned in section 4.3.2.2, this may not be the case under the new plus customer agreement, since the green certificates would only be permitted for the surplus production exported to the grid.

For end consumers in Norway, the estimated increase in the variable price due to the green certificate scheme is between 0.017 -0.021 NOK/kWh including VAT (NVE, 2015h). A fee of 0.02 NOK/kWh for end consumers of electricity has been assumed in this thesis.

The green certificates have traded in a range between 0.158 – 0.18 NOK/kWh (NVE, 2014). For our analysis, an average price of 0.17 NOK/kWh has been assumed.

4.3.6. Taxation and accounting

Under the green certificate scheme, Sweden has received the majority of new renewable energy projects. By 1 April 2014, 10.2 TWh of new renewable electricity capacity was installed in Sweden and only 2.5 TWh in Norway (EnergiNorge, 2014). One of the reasons behind this is the favorable depreciation and corporate taxation rules for investment in the renewable sector in Sweden compared to Norway.

Sweden allows for an accelerated straight-line annual depreciation of 20% for renewable energy installations (KPMG, 2014b). In Norway, no such incentives are available, and the assets have to be depreciated as per the expected life (KPMG, 2014a). Further, the corporate tax level in Norway is 27%, versus 22% in Sweden (Espensen et al., 2015) (KPMG, 2014a).

However, the government has a promotional scheme under the General Tax Act known as SkatteFUNN to provide financial support to R&D activities. Under this scheme, support is granted in the form of tax deduction, and in certain cases direct funding of R&D projects. To be eligible for the support, the R&D projects should enable the company undertaking the project to acquire new skills to develop better goods and services. Under this scheme, there is an annual limit on the benefit of NOK 22 million per company (KPMG, 2014b).

For a commercial actor in the Norwegian market, selling a product or a service to a customer, VAT of 25% is charged on top of the selling price as a general rule (Skatteetaten, 2016b). At the same time, with a few exceptions, the VAT paid on input factors used in the final product or service sold by a commercial actor would be refunded (Skatteetaten, 2016a).

4.3.7. Building regulations

The Norwegian building sector represents close to 50% of the total stationary energy consumption in Norway, with residential buildings accounting for 27% and commercial buildings for 21%. In a report from 2012, Enova, a public enterprise, recognizes that there is a large potential for reducing the energy consumption from buildings through various means, but the amount of reduction achieved will depend on the regulatory and financial incentives available (Enova, 2012).

Technical building regulations[20] (TEK) cover the technical regulations for all buildings in Norway, and come under the Directorate for Building Quality (DBQ)[21]. The purpose of the regulations is to ensure that building projects meet existing technical requirements concerning security, environment, health and energy. Energy standard guidelines are also covered in the TEK guidelines.

TEK10 is the current framework, but a new framework, TEK15, is expected to come into force within a few years. It involves several elements that could have an impact on the solar panel market in Norway. TEK15 is expected to incorporate the EU directive on energy efficiency of buildings, which requires all new buildings from 2020 to have passive house status and nearly net zero emission from operation. For public entities' buildings, the same would apply from 2018 (Lavenergiprogrammet, 2015).

As per the EU directive, a net zero emission building is defined as a building where the balance of total energy withdrawn from the grid and fed into it during the year or lifetime is equal to or lower than zero. However, the concrete interpretation of *near-zero emission building* in a Norwegian context has not been determined, and uncertainty remains regarding its impact on distributed generation (Lavenergiprogrammet, 2015).

Further, in a hearing document on new energy efficiency standards in TEK15, under the new §14-5, it was proposed that smaller buildings could have reduced energy efficiency requirements, on condition that they have a production of 3,000 kWh of electricity from renewable sources (Direktoratet for Byggkvalitet, 2015).

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[20] Byggteknisk forskrift

[21] Direktoratet for Byggkvalitet

4.3.8. Subsidies and grants

Enova provides financial support in form of subsidies to individual households that install renewable energy generation facilities. A subsidy is granted to cover up to 35% of the total cost, including taxes, with a maximum of NOK 10,000 for production and an additional NOK 1,250 per kW installed up to 15 kW. To be eligible for the support, the system should be connected to the grid under the plus customer agreement. The investment subsidy is currently only given to individual households, and not to co-operatives or any common ownership arrangements (Enova, 2015b).

A similar scheme is also available for the companies for introducing innovative solutions to the market. Support is provided for projects that demonstrate the potential of new technologies, even if the current energy gains are not substantial. Under this scheme, Enova can cover up to 50% of the additional cost of the investment (Enova, 2015a).

In some municipalities, such as Oslo and Hvaler, the local government has provided targeted subsidies for solar panel installations. Oslo previously gave support in the form of a 1.5 NOK/kWh FIT, but have now moved to a 40% investment subsidy. These measures have reportedly led to an increase in the solar panel investments in these areas (Nilsen, 2015).

4.4. Solar panels in Norway

4.4.1. Current status

The main impetus behind the installation of solar panels in Norway has been the ability of the panels to generate electricity independently of the electricity grid. However, the main drivers behind the recent surge in solar panel installations in Norway has been environmental awareness combined with a sharp decrease in costs (Multiconsult AS, 2013).

The total installed solar panel capacity was around 11 MW by the end of 2013, and it increased to around 13 MW by the end of 2014 (NVE, 2015f). The capacity growth rate in 2014 was three times higher than in 2013, and the growth rate in grid-connected installation was 14 times higher than in 2013 (Multiconsult AS, 2015b).

4.4.2. Barriers

Norwegian electricity consumers receive most of their electricity from hydropower, which is a cheap, renewable energy source. This weakens the argument for building more renewable energy in Norway compared to other parts of Europe, where the new renewable energy contributes to decreasing the dependence on fossil fuel (SINTEF, 2011).

In Norway, the peak electricity demand is driven by heating, which naturally occurs during winter. The electricity production from solar panels will be lowest in the winter months, due to less sunshine during the shorter days. This mismatch between peak consumption and production further weakens the business case for solar panels (SINTEF, 2011).

The Norwegian market for solar panels is of limited size with relatively few professional actors. This leads to low economies of scale, and consequently higher prices for procurement and installation relative to more mature markets such as Germany. This barrier is likely to reduce with an increase in the use of solar panels (SINTEF, 2011).

Norway has a low cost of electricity compared to other European countries, where solar panels have seen widespread penetration. This also weakens the business case for solar panels in Norway, and requires higher support from the government to achieve grid parity (SINTEF, 2011).

Finally, the solar panels are still a more expensive technology than other renewable energy sources in Norway. NVE (2015f) has estimated the levelized cost of energy (LCOE) for different methods of energy production. It was found that the cost of electricity produced from solar panels is in the range of 1.10 – 1.40 NOK/ kWh for ground mounted utility-scale, 1.13 – 1.69 NOK/kWh for commercial buildings[22] and 1.31 – 1.87 NOK/ kWh for detached houses[23], all excluding VAT[24]. This is higher than other renewable alternatives such as hydropower (0.23 NOK/ kWh), onshore wind power (0.46 – 0.52 NOK/ kWh) and offshore wind power (0.70 – 1.27 NOK/ kWh) (NVE, 2015f). For the full overview of energy costs, see appendix A.

Towards 2035, NVE (2015g) expects the cost of hydropower to remain unchanged, given that it is a mature industry in Norway. For onshore wind power, the LCOE is expected to drop to around 0.34 NOK/kWh in 2035 and offshore wind to around 0.50 – 0.80 NOK/ kWh by 2035 (NVE, 2015f).

NVE (2015f) assumes that an increase in solar panel installations will lead to cost reductions in supply and installation in the Norwegian market. Further, NVE expects cost reductions and

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[22] Defined as 10-100 kW(p) installed capacity

[23] Defined as 0-10 kW(p) installed capacity

[24] The LCOE for the solar panel installations in ZVB is found to lie in the range of 1.26 – 1.65 NOK/kWh using the assumptions outlined in this analysis and the same 4% discount rate as the NVE research. See appendix I for details on the calculation.

technical improvements in solar panel technology to bring down the solar panel electricity generation cost, with ground mounted utility-scale solar panels estimated to cost around 1.00 NOK/ kWh by 2035 (NVE, 2015f).

4.4.3. Drivers

One of the main drivers for rooftop or rooftop solar panels in Norway is technical building requirements as described in section 4.3.7. In addition, energy efficiency certification schemes for buildings such as BREEAM-NOR can serve as a way for commercial actors to promote their efforts to reduce their environmental impact (Thorud, 2013).

Solar panels can be integrated in the building structure in ways that make them visually attractive. In addition, solar panels can also be installed so as to make them clearly visible on the facade of a building. Thus, solar panels can serve as a way to promote the owner of the building as environmentally friendly, thereby adding value beyond the revenues from electricity generation.

A lot of research is being done to develop ways to use solar panels as building materials, for example replacing roof tiles or wall plates. Using solar panels as building material reduces the investment cost by the amount saved on the material replaced by the panels. This could improve the business case for solar panel systems (Thorud, 2013).

5. Problem definition and evaluation criteria

This thesis analyzes the return on investment in rooftop solar panels, which form part of a project aiming to achieve a near-zero emission status for a residential area in Norway. The return on investment is considered under different combinations of ownership structures and regulatory scenarios in Norway. In addition, the thesis aims to map out risks associated with the investment.

The return on investment in solar panels in ZVB is analyzed for four different regulatory scenarios, which were determined based on what level of pooling of electricity resources might be allowed in the Norwegian market in the future. The difference between the four scenarios is the degree of pooling of electricity production and consumption allowed under the plus customer agreement. The scenarios are described in table 5 below.

Scenario	Level of pooling	Description
1	No pooling	Each individual household is connected to their individual solar panels.
2	Co-ownership	Sharing of solar panels' production is allowed across individual households within a co-ownership
3	All residential buildings in ZVB	Sharing of solar panels' production is allowed across all the residential co-ownerships in ZVB
4	All buildings in ZVB	Sharing of solar panels' production is allowed across all residential and non-residential buildings in ZVB

Table 5: Level of pooling for the regulatory scenarios analyzed in the thesis

Two main possible ownership structures have been identified through analysis of the regulatory context in the Norwegian electricity market. The first is private ownership, where the end users of electricity, either in the form of an individual household or a grouping of households in a co-ownership structure, own the panels. The second is a commercial ownership of the panels, under which panels are leased to end consumers.

The aim of this thesis is thus to:

1) Estimate the return on investment in rooftop solar panels in ZVB for the identified private and commercial ownership structures for all four scenarios; and
2) Establish the distribution of risk between stakeholders for the two ownership structures.

The evaluation criteria used to answer these questions are listed in table 6:

Evaluation criteria	Type	Questions addressed
NPV - Net Present Value (NOK)	Quantitative	Q1
Distribution of risk on stakeholders	Qualitative	Q2

Table 6: Evaluation criteria for the research question

These evaluation criteria are explained in the following sections.

5.1. Net present value

The Net Present Value (NPV) is a classical measure widely used to evaluate the profitability of projects. NPV method can be used to compare different projects while making an investment decision. If the same initial investment is required for the different options, then the option with the highest NPV is preferred. In the analysis, NPV has been used as a tool to compare the performance of different combinations of scenarios and ownership structure.

NPV is chosen as the evaluation criteria because it allows for easy comparison between different options. Further, by choosing a specific discount rate the firms can also build in the expectation for profitability from the proposed project. The cash flow projection method has been used for calculating the NPV. NPV is calculated using the following relationship:

$$NPV = \sum_{t=0}^{T} \frac{C_t}{(1+r)^t}$$

Nomenclature	Description
C_t	Cash flow in a year t
T	Year
R	Discount rate
T	Project lifetime in years

Table 7: Nomenclature for different parameters used for NPV calculations

5.2. Risks

Any investor in a project is looking for a return on their investment with the least possible uncertainty, but the variety of risks associated with investment in a large-scale project cause uncertainty. There are a number of methods for the investors to mitigate their risk, and the efficiency of these mitigation methods determines the investors’ final risk exposure.

The risks involved in the electricity generation market can be categorized as regulatory risk, technical risk, operations & maintenance risk, climate risk etc. (Nadejda et al., 2012). These risks affect the certainty of the amount electricity produced from the solar panels, and the revenues and costs associated with them.

The amount and kinds of risks associated with a particular ownership structure will also influence an investor's assessment of the optimal business model. This analysis qualitatively assesses the risks that investors will be exposed to through investment in the solar panels in ZVB. In this section, the different risks associated with the project are presented.

5.2.1. Regulatory risk

Uncertainty regarding regulations and any future changes to regulations can lead to investment risk. Different regulatory components that could potentially increase the risk for investment in rooftop solar panels in Norway are outlined below.

Support schemes

The Enova subsidies and support schemes mentioned in section 4.3.8 contain some room for interpretation in the way they are defined by the regulator. This introduces uncertainty regarding the eligibility of a project or investment for receiving support from the regulator.

In addition, for green certificates, there is uncertainty regarding the period over which the program will be available, as well as the future market price of the certificates.

Plus customer agreement

As discussed in section 4.3.2, the plus customer agreement requires the DSO to negotiate an agreement with the DG producers to enable surplus electricity to be fed into the grid. However, there is a possibility that the DSO and the DG producer cannot agree on mutually acceptable conditions, and hence the DG producers could end up in a situation where they do not have a means to sell excess electricity.

Under the proposed new plus customer agreement, there are no regulations relating to the mandatory requirement for retailers to buy electricity from the DG producers. The DG producers might therefore not find a retailer for their electricity, adding an element of risk. However, it is assumed that, similar to the model in Sweden, DG producers in Norway will not have a problem of finding a retailer willing to buy electricity from them, so this risk is assumed to be relatively limited.

Grid tariffs

Another regulatory risk relates to potential changes in the current tariffs and fees for connection to the grid. NVE is considering increasing the fixed part of the grid tariff to make the mechanism of charging grid fees fair for all customers (Andresen & Mook, 2015). Any decrease in the variable grid tariff would decrease the benefits of plus customers' avoiding the variable grid fee for the consumption of locally produced electricity.

Building regulations

As discussed in section 4.3.7, building regulations play an important role in governing buildings' energy consumption. Therefore, changes in the building regulations could also pose a regulatory risk. However, building regulations tend to be progressive, taking into account technological developments. The TEK framework clearly defines the energy saving expectations required of future buildings, therefore the risk deriving from regulatory changes is expected to be fairly low.

Regulatory risks can be one of the most influential factors in preventing or delaying investment in the renewable energy projects (Aragones-Beltran et al., 2010). To counter these risks, the government should have a clearly defined policy framework. Regulatory certainty, and clarity of specifics within regulations, can have a significant positive impact on the likelihood of long-term investment in future renewable energy projects.

5.2.2. Technical risk

Technical risks are associated with the performance of the solar panel infrastructure. The primary technical risk is the probability of solar panels and other equipment breaking down. The solar panels and inverters are covered under the manufacturer warranty for any defects for a certain number of years, typically 20-25 years, which helps to reduce the investment risk associated with breakdowns. However, there is also a risk of the manufacturer not honoring the warranty or going out of business.

Another risk is that solar panel efficiency falls more or faster than the anticipated levels. Again, the performance levels are covered under the manufacturer guarantee, but these changes could be difficult for the end users to detect. The most risk-prone part of the solar panel investment is the structure for mounting and enabling access to the panels, as these components normally have a short warranty period (Kyocera, 2013). In addition, after the warranty period, the risk of technical malfunction lies entirely with the owner of the panels.

5.2.3. Operations and maintenance risks

Solar panel systems have a very low O&M requirement, which also transmits to lower O&M risks. In ZVB, the solar panels will be mounted on rooftops with no moving parts, and therefore will have very little requirement for maintenance. O&M would primarily include the potential replacement of the inverter, keeping the modules clean, and monitoring performance. There is also a risk that maintenance costs could increase more or faster than expected over time.

5.2.4. Climate risk

Climate risk arises due to the potential for changes in the amount of sunshine received by the solar panels and damage caused to the panels by erratic weather. Whereas the risks of damage due to erratic weather can likely be covered by insurance, sunshine level changes can be hard to mitigate.

Revenue projections from solar electricity production are based on the estimation of future solar radiation. Any change in the future solar radiation can have a substantial effect on the total production. The solar radiation received can be affected by climate change, particularly bad weather in a year, or by shading on the solar panels due to tree growth or future construction. Urban plans could indicate any future construction, and it is also advisable to check for nearby trees that could grow to cast a shadow over the panels in the future, which could not be trimmed by the solar panel owner.

For ZVB, the expected electricity production is calculated using simulations conducted by Multiconsult AS. These simulations are based on assumptions of certain weather and sunshine conditions. Given the unpredictable nature of climate forecasting, there might be differences between the actual and projected production, especially taking into account the long lifetime of the project.

Damage to the installation due to erratic weather is of particular importance in Western Norway because of the prevalence of heavy storms and rainfall. Even if such damage would be covered under insurance, it is prudent to use extra caution while installing the solar infrastructure.

5.2.5. Other risks

Solar panel investors also need to consider some additional risks. Most of the risks under this category such as theft and vandalism are covered by insurance.

However, there can also be legal risks under the leasing model, for the residents leasing the panels from a commercial owner. The house-owner might decide to sell their house in the future. In such cases, the legal obligation of households towards the commercial owner has to be transferred to the new owner. This can pose legal problems for the contracting parties, and can put the long-term investment for the commercial owner at risk. This risk can be reduced by covering all eventualities in the initial legal contract.

The stakeholders would be exposed to counterparty risks, which are dependent on the arrangement between the residents and the commercial owner. The primary risks would be the risk of default and of non-fulfillment of obligations.

The distribution of these risks among stakeholders will differ across different ownership structures. An investor’s choice of a particular ownership structure will be governed by the tradeoff between maintaining control of the infrastructure versus spreading the risks. The distribution of these risks under different ownership structures will be discussed in chapter 9.

6. Input data

In addition to the information on tariffs, fees and taxes covered in section 4, five additional sources of input data are used to calculate the return on investment in the rooftop solar panels in ZVB. These are: the electricity consumption of the households and commercial buildings in ZVB, the electricity production from the solar panels in ZVB, the electricity prices in the area of ZVB, the costs of the solar panel installations, and the discount rates used in the NPV calculations. These elements are described in chapters 6.1- 6.5.

6.1. Electricity price

The value of the electricity production from the solar panel system at ZVB depends on the wholesale electricity price for the Bergen region[25] during the operational lifetime of the project. Subject to final approval for the project and the pace of development, the first buildings in ZVB will likely be ready between 2018 and 2020. Therefore, with an estimated lifetime of 30 years for the solar panels, the relevant electricity prices for calculating the cash flows will be during the period 2018 – 2050.

As described in section 4.2, electricity prices in the Norwegian market are driven by the aggregate electricity supply and demand, regulations, and by the transmission constraints in the grid. The demand and supply of electricity are dependent on a large number of factors, making the forecasting of future electricity prices for valuing electricity projects and investments challenging (see sections 4.2.8 and 4.2.10).

Due to the uncertainties regarding the future development of the wholesale electricity price in NO5, developing a credible confidence interval for the future price development until 2050 is beyond the scope of this thesis.

Assuming mean reversion with periodic spikes in accordance with the findings of Escribano et al. (2011) for the Nordic electricity prices, the mean of historic electricity prices over the last 11 years is used in this thesis as a proxy for the future prices. In order to account for the uncertainty regarding future electricity prices, a sensitivity analysis is performed as described in chapter 8.

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[25] Bergen is situated in the NO5 region covering Western Norway.

The data used has been provided by the Nord Pool Spot database, and consists of the hourly prices for the Bergen region (NO5) on the Elspot exchange (Nord Pool Spot AS, 2015b). The arithmetic mean of the inflation-adjusted hourly electricity prices for the period of 2004-2014 has been used as input for the wholesale electricity prices. Minor adjustments have been made to the data, in order to preserve the difference between weekdays and weekends while taking the arithmetic mean.

Two modifications were made to the data. First, the data was inflation adjusted to arrive at same real value for all the years. The yearly consumer price index (SSB, 2015) was used to adjust all the data to NOK 2014 by using the following relationship:

$$NOK_{2014} = NOK_T * (1 + i_{T2014})$$

Where NOK_{2014} is the nominal value in Norwegian Kroner in 2014, NOK_T is the nominal value in Norwegian Kroner in year T, and i_{T2014} is the cumulative inflation from year T to year 2014.

Second, there is a difference in the electricity consumption patterns for both commercial and residential buildings between the weekdays and weekends. Consequently, there might be some variation in the electricity prices between the weekdays and weekends. However, for different years, the weekday and weekend do not fall on similar dates, and hence taking simple average would lose this variation.

In order to preserve the information on this intra-week variation in prices, the dataset was modified to align the weekdays and weekends across different years. All years were modified to start on the same day, a Wednesday, as in 2014. To do so, some data had to be deleted or moved (see appendix C for a description of all adjustments made to the individual datasets). The difference in prices within a week is very limited, and hence shifting the data by 2-3 days has a negligible effect on the predicted data, while at the same time preserving the variation between weekdays and weekends.

The average price for each hour of the year is then calculated as the arithmetic mean of the observations for the corresponding hour over the 11 years covered. As a result, a dataset with 8,760 hourly values for the electricity price over the year is obtained. A graphical representation of the prices can be seen in figure 3.

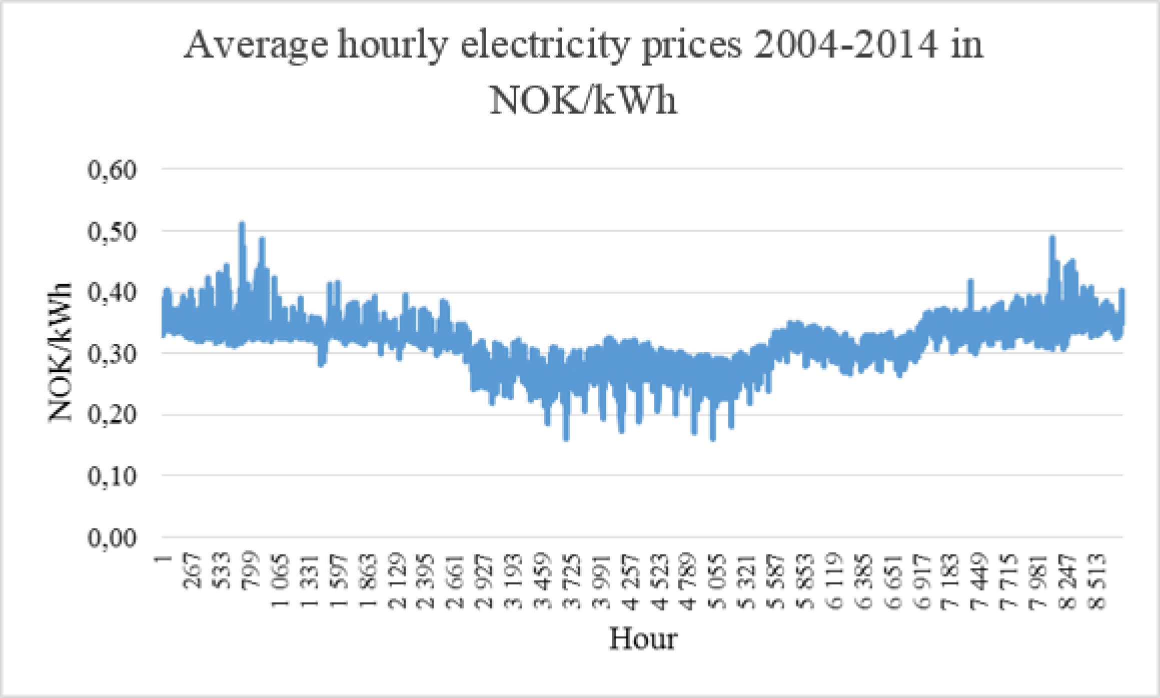

Figure 3: Average hourly wholesale electricity prices 2004-2014 in NOK_{2014}*/kWh* (Nord Pool Spot AS, 2015b)

The average price over the year is 0.32 NOK/kWh, and is higher in the winter than in the summer. The average is 0.35 from October to March and 0.30 NOK/kWh from April to September. The price also varies with the hours of the day, with higher prices during the day, and lower prices at night.

It should be noted that the wholesale electricity price variation shifts substantially from year to year, with an average price of 0.246 NOK/kWh in 2014 and 0.559 NOK/kWh in 2011 as seen in figure 4.

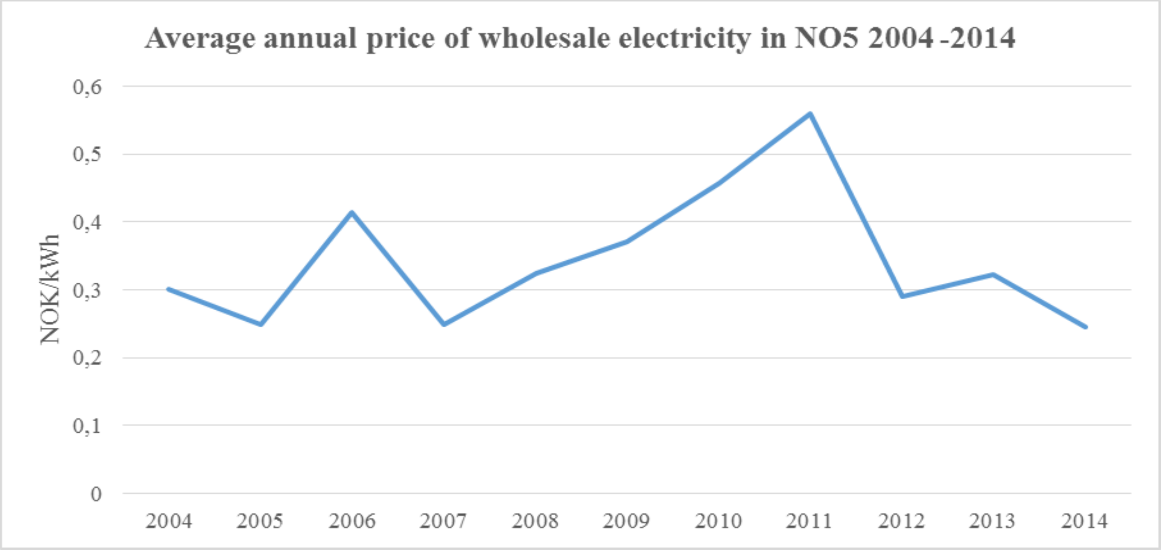

Figure 4: Average annual wholesale price of electricity in NO5 2004 -2014 (Nord Pool Spot AS, 2015b)

Given the large variation between the values for different years and the assumption of a mean reverting historic electricity price, it is more reasonable to use the mean value for the last 11 years than to use a single year as a reference. However, it is clear that the solar panel electricity producer will likely experience large variation in the alternative cost of grid electricity from year to year. As this thesis is looking at the return on investment over the 30 year lifetime of the solar panels, the mean value would be representative, and it is not necessary to take the yearly price variations into account.

6.2. Electricity consumption

The electricity load profiles of the individual households in ZVB will depend on the behavior of the occupants, and will differ depending on habits, professions, appliances, age, number of residents, and size of the residence.

In order to simulate the consumption patterns of the 685 individual households in ZVB, this thesis has combined data from SINTEF, which has estimated the hourly electrical and thermal load per m^2 BRA for ZVB, with data from a Swedish survey, which gathered data on the difference in consumption patterns between household categories.

For the non-residential buildings, data from SINTEF on the hourly electrical and thermal load per m^2 BRA has been used.

6.2.1. Residential buildings

SINTEF has estimated the hourly electrical and thermal load per m^2 BRA for two building categories (terraced houses and apartment blocks) over the year. Assuming an electricity-to-heat factor of 3.5[26], the annual electricity consumption for heating and other purposes per m^2 BRA can be seen in table 8 below.

Annual electrical and thermal consumption per m^2 BRA	Electrical (kWh/m^2)	Heating (kWh/m^2)	Electrical and heating (kWh/m^2)
Terraced houses	29.8	10.5	41.2
Apartment block	30.6	10.6	40.3

Table 8: Annual electrical and heating consumption per m^2 BRA and total for ZVB (Sartori et al., 2016).

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[26] As mentioned in chapter 4, it is assumed for this thesis that a heat-pump or a similar technology consumes 1 kWh of electrical energy to produce 3.5 kWh of thermal energy.

Apart from the central areas in Ådlandsbyen West and East, which consist of apartment blocks, all the building areas are assumed to be terraced houses. Multiplying the amount of m^2 BRA per household with the hourly load per m^2 gives 21 load profiles, one for each building area.

In order to simulate the intra-household variation in load patterns, the data from SINTEF was combined with a dataset on the variation in load patterns between different household categories among Swedish households. The dataset is the result of a survey performed by the consultancy Enertech on behalf of the Swedish Energy Agency on 400 households across different regions in Sweden in the period 2005-2008. The results are presented in the report *End-use metering campaign in 400 households in Sweden Assessment of the Potential Electricity Savings* by J.P. Zimmerman, which was published in 2009.

The dataset consists of both detached houses and apartments, with the electricity consumption measured at intervals of 10 minutes. Based on these measurements, average load profiles for different household categories for weekdays and weekends were developed (Zimmermann, 2009).

ZVB's residential housing only consists of apartments, therefore the data on detached houses was not used. For apartments, the Swedish survey identified seven household categories with corresponding electricity load profiles. The number of observations for three household categories was less than 2%, and these were not included in the consumption profile variation for ZVB. The four household categories used to simulate load variations, and their distribution in the Swedish dataset, can be seen in table 9 below.

Household category	Percentage
Single person (26-64 years)	22.77 %
Couple without children (26-64 years)	23.21 %
Couple without children (64 years+)	8.32 %
Family (26-64 years)	45.69 %
Total	**100.0%**

Table 9: Distribution of the household categories used from the Swedish survey (Zimmermann, 2009)

A graphical illustration of the load profiles of the different household categories in the weekend and on a weekday can be seen in figure 5 and figure 6 below.

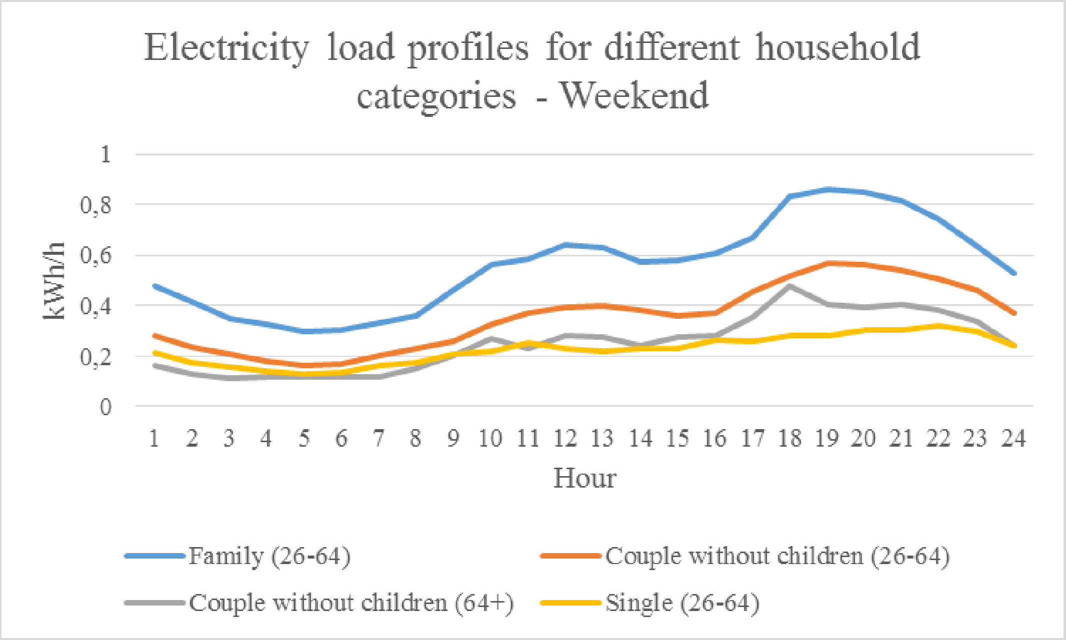

Figure 5: Load profiles for different household categories on a day in the weekend (Zimmermann, 2009)

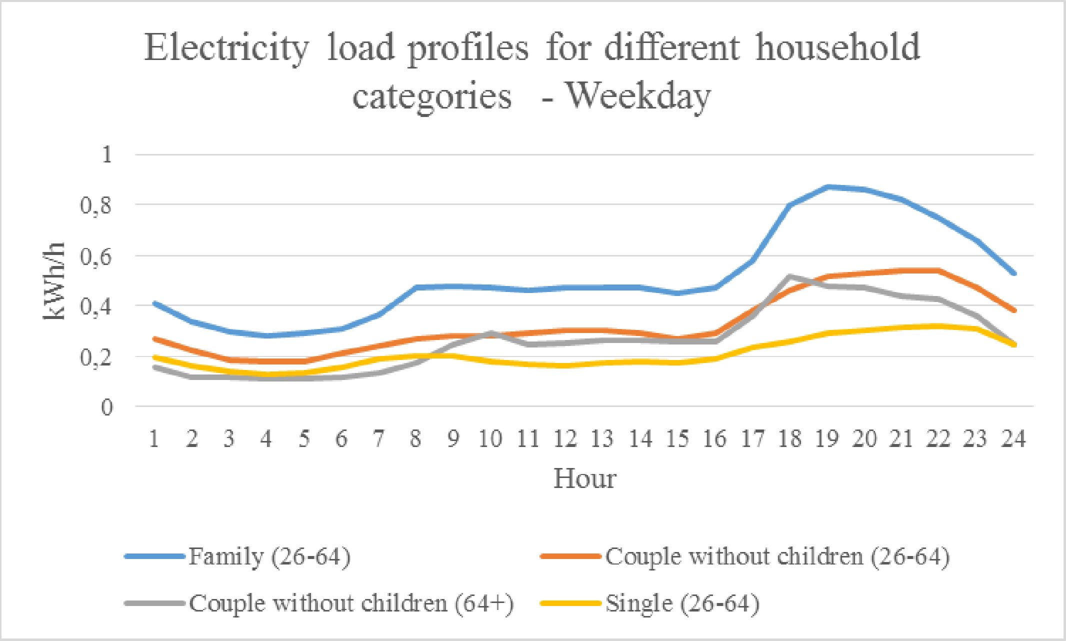

Figure 6: Load profiles for different household categories on a weekday (Zimmermann, 2009)

The variables used to combine these datasets are described in table 10, and the calculations can be seen below. The method and results from combining the two datasets are described in the rest of this section.

Factor	Description
$WEL_{p,t}$	Hourly load for household type p at hour t during weekend (kWh)
$WDL_{p,t}$	Hourly load for household type p at hour t during weekdays (kWh)
$WEL_{AV,t}$	Average hourly load for profiles 1-4 during weekend (kWh)
$WDL_{AV,t}$	Average hourly load for profiles 1-4 during weekdays (kWh)
$ADJWEL_{p,t}$	Adjustment factor for household type p at hour t during weekend
$ADJWDL_{p,t}$	Adjustment factor for household type p at hour t during weekdays
$BLD_{n,t}$	Hourly load per household in building area n [1,21] for hour t (kWh)
$BLD_{n,p,,t}$	Hourly load for household category p [1,4] in building area n [1,21] for hour t (kWh)

Table 10: Description of factors for load profile generation

1) The average consumption of the four load profiles p was calculated for each hour [1,24] on weekdays and weekends. The derived profile corresponds to the average load profile for all the households used from the Enertech dataset for a weekday and a weekend day.

$$WEL_{AV,t} = \frac{\sum_{p=1}^{4} WEL_{p,t}}{4} \quad for\ t{=}[1{,}24]$$

$$WDL_{AV,t} = \frac{\sum_{p=1}^{4} WDL_{p,t}}{4} \quad for\ t{=}[1{,}24]$$

2) For each household type, an adjustment factor was calculated for each hour during both weekday and weekend, by dividing the profile’s load for hour t by the average load at time t.

$$ADJWDL_{p,t} = \frac{WDL_{p,t}}{WDL_{AV,t}} \quad for\ t = [1{,}24]\ and\ p = [1{,}4]$$

$$ADJWEL_{p,t} = \frac{WEL_{p,t}}{WEL_{AV,t}} \quad for\ t = [1{,}24]\ and\ p = [1{,}4]$$

   As a result, 192 adjustment factors are derived, one for each hour of the day for weekends and weekdays, for all four profiles.

3) The adjustment factors are then multiplied with the load profiles developed by SINTEF for ZVB. This is done for weekdays

$$BLD_{n,p,t} = ADJWDL_{p,t} * BLD_{n,t}\ for\ n = [1{,}21], p = [1{,}4], t = [8{,}760]$$

   And for weekends

$$BLD_{n,p,t} = ADJWEL_{p,t} * BLD_{n,t}\ for\ n = [1{,}21], p = [1{,}4], t = [8{,}760]$$

As a result, four different load profiles are developed for each of the 21 building areas in ZVB, each consisting of 8,760 observations.

In order to increase the variation in intra-household load profiles, a second version of each household category was generated labelled V2. The V2 profiles differ from the original profiles by having their loads shifted two hours ahead for all hours of the year. This results in 8 different load profiles per building area, adding up to 168 different profiles. The details relating to the assumed distribution of household categories across ZVB can be seen in appendices D and E.

A graphical illustration of the load profiles for different household categories in T4-1 can be seen in figure 7 to figure 10 below.

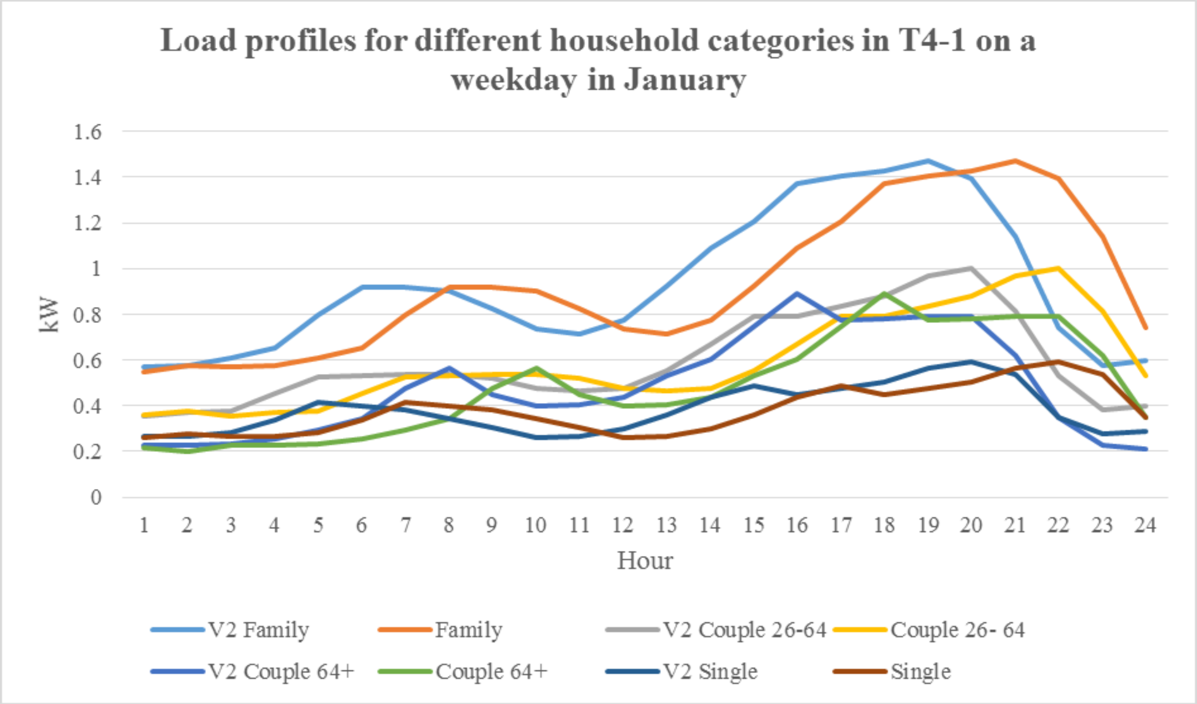

Figure 7: Load profiles for different household categories for Tun 4-1 on a weekday in January

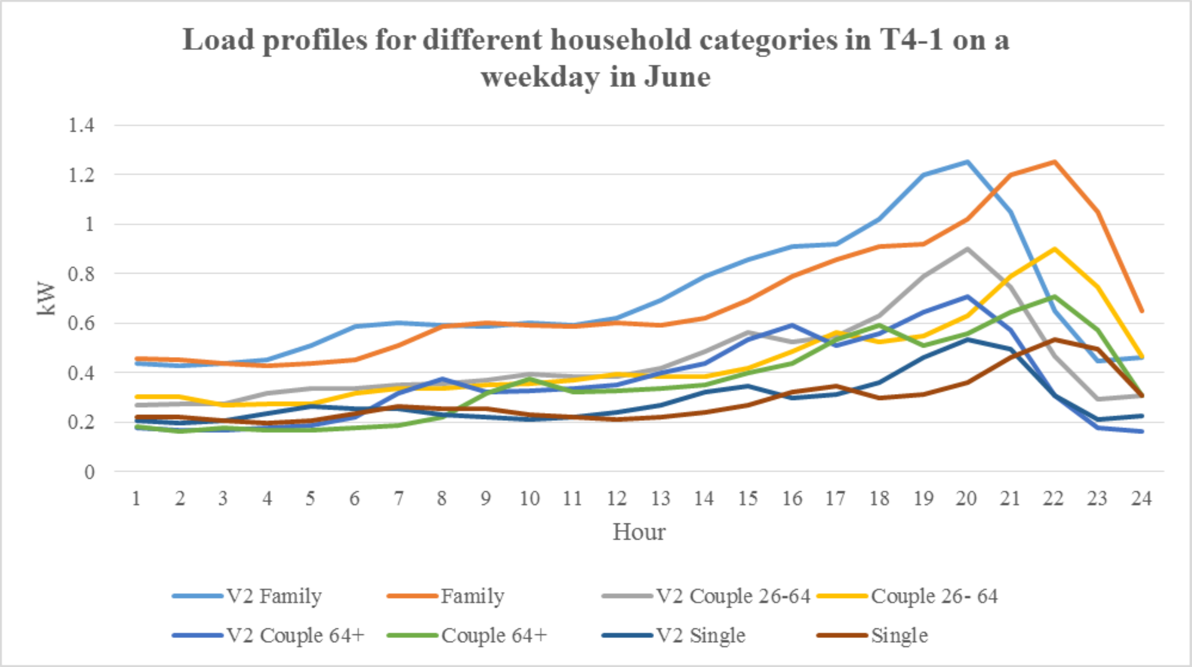

Figure 8: Load profiles for different household categories in Tun 4-1 on a weekday in June

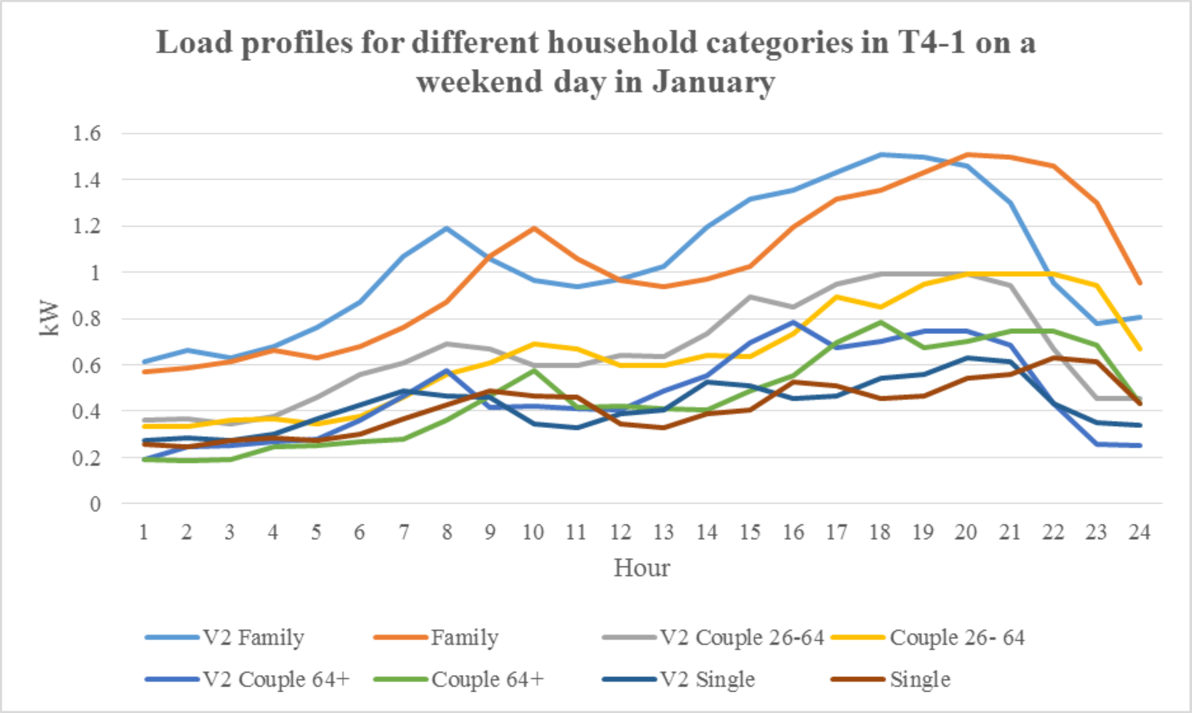

Figure 9: Load profiles for a different household categories in T4-1 on a weekend day in January

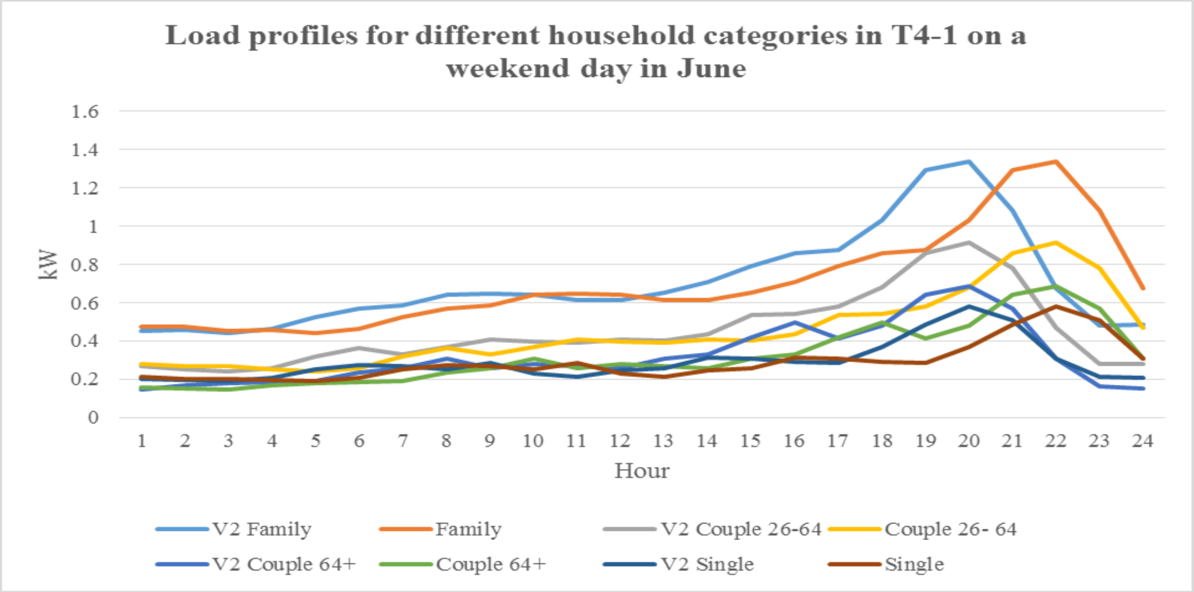

Figure 10: Load profiles for different household categories in T4-1 on a weekend day in June

As can be seen, for both summer and winter there is a clear peak load in the afternoon and evening hours. In the winter months, there is also a tendency to have a small peak load in the morning, and less consumption during the middle of the day. In the summer, the morning peak is less pronounced, and the load is more stable until it rises the afternoon to a clear peak load.[27]

The load is generally lower in the summer than in the winter months, and there is considerable difference between household categories with regards to the total daily load, with the family households consuming the most and the single person households consuming the least.

6.2.2. Commercial buildings

SINTEF has estimated the hourly electrical and thermal load per m^2 BRA for the three different categories of non-residential buildings – kindergarten, offices and shop (Sartori et al., 2016). The annual electrical and thermal consumption per m^2 BRA and for the total building areas can be seen in table 11 and table 12 respectively.

	Shop	**Offices**	**Kindergarten**
Annual electrical consumption (kWh/m^2)	53.3	127.5	101.3
Annual consumption for heating (kWh/m^2)	5.8	7.5	6.3
Annual electrical and heating consumption (kWh/m^2)	59.1	135.0	107.6

Table 11: Annual electrical and heating consumption per m^2 BRA (Sartori et al., 2016)

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[27] The load profiles changes for every day of the year, and thus the four illustrations provided here does not fully illustrate the range of different load profiles. However, they serve to illustrate some general observations.

	Shop	Offices	Kindergarten	Total
Annual electrical consumption (kWh)	286,961	361,258	56,548	704,767
Annual heating consumption (kWh)	18,125	21,354	6,135	45,605
Annual electrical and heating consumption (kWh)	305,086	382,603	62,683	750,372

Table 12: Annual electrical and heating load for non-residential buildings in ZVB(Sartori et al., 2016)

A graphical illustration of the energy consumption profile of all the non-residential buildings for a week in January starting on Wednesday can be seen in figure 11. The most important difference as compared to the residential sector is that the peak consumption takes place in the day time, which corresponds better with the production profile of the solar panels.

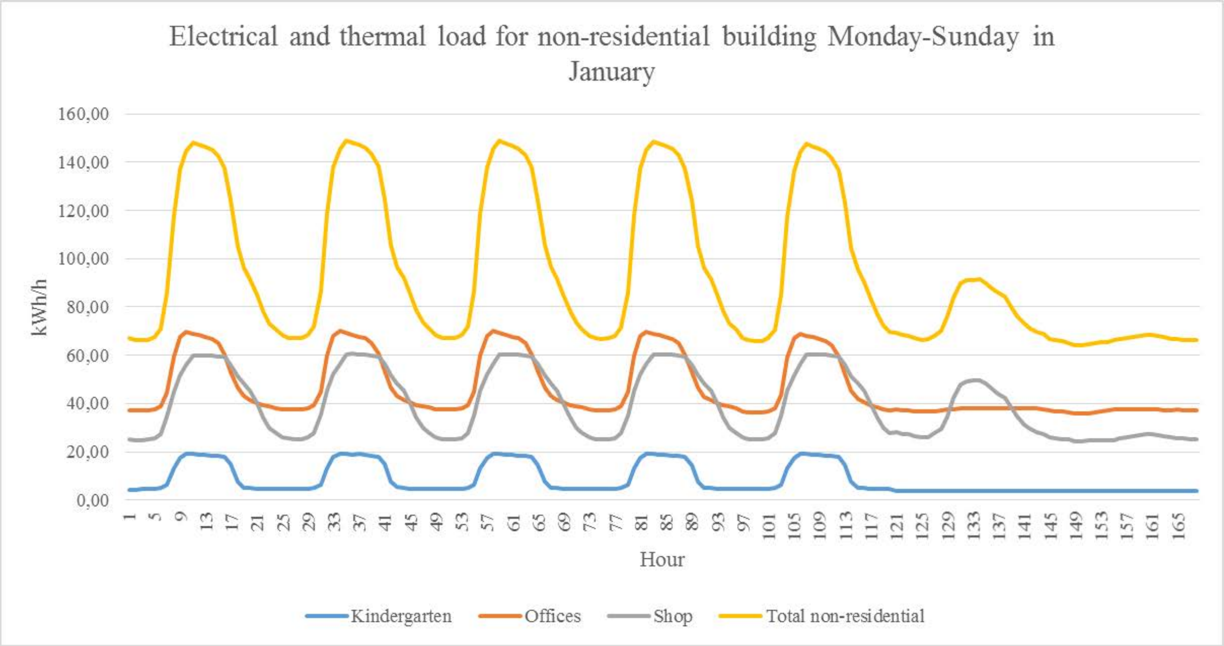

Figure 11: Load profile for non-residential buildings in ZVB Monday-Sunday in January (Sartori, 2015)

6.3. Electricity production

Multiconsult AS, a consultancy, has estimated the hourly electricity production from the solar panels in ZVB over a year based on the design for the distribution and orientation of the panels on the buildings in ZVB.

The key element influencing annual production is the orientation of the panels. The distribution of the solar panels in ZVB on different angels (azimuth) can be seen in table 13.

	Azimuth -29	Azimuth -40	Azimuth -45	Azimuth -48	Azimuth -53	Azimuth -60	Total
Area (m^2)	1,389	7,177	6,719	2,898	2,463	1,400	22,046
Annual production/m^2 (kWh)	136,2	134,4	133,5	132,8	131,7	129,9	
Total annual production (kWh)	189,120	964,675	896,677	384,886	324,309	181,923	2,941,590

Table 13: Distribution of solar panels on azimuths in ZVB (Multiconsult AS, 2015a)

Electricity production varies strongly over the daily 24-hour cycle and between seasons, with production occurring only during the daylight hours, as illustrated in figure 12 and figure 13 below.

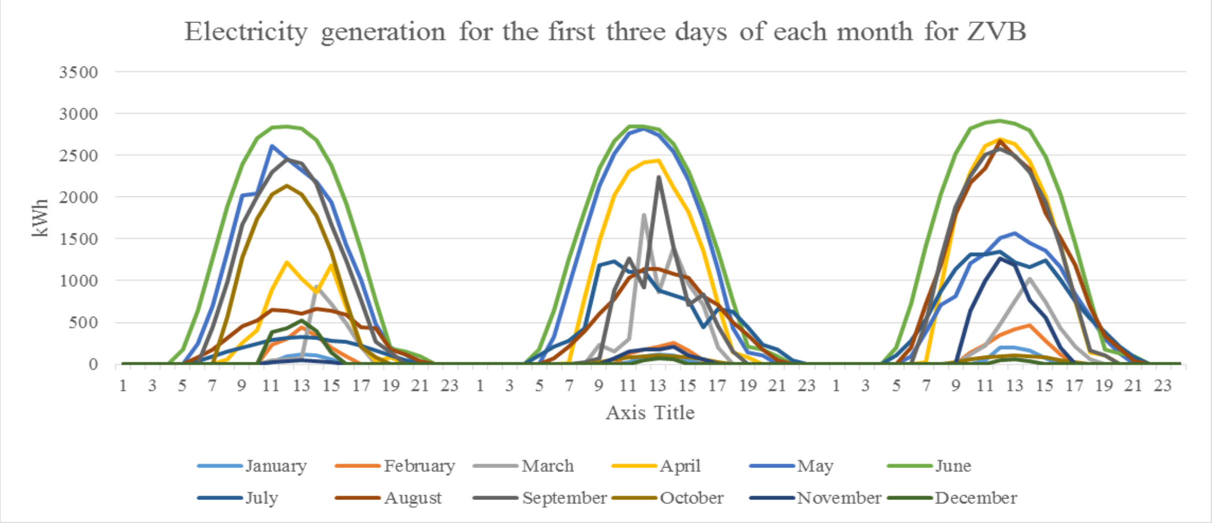

Figure 12: Electricity generation for the first three days of each month for ZVB (Multiconsult AS, 2015a)

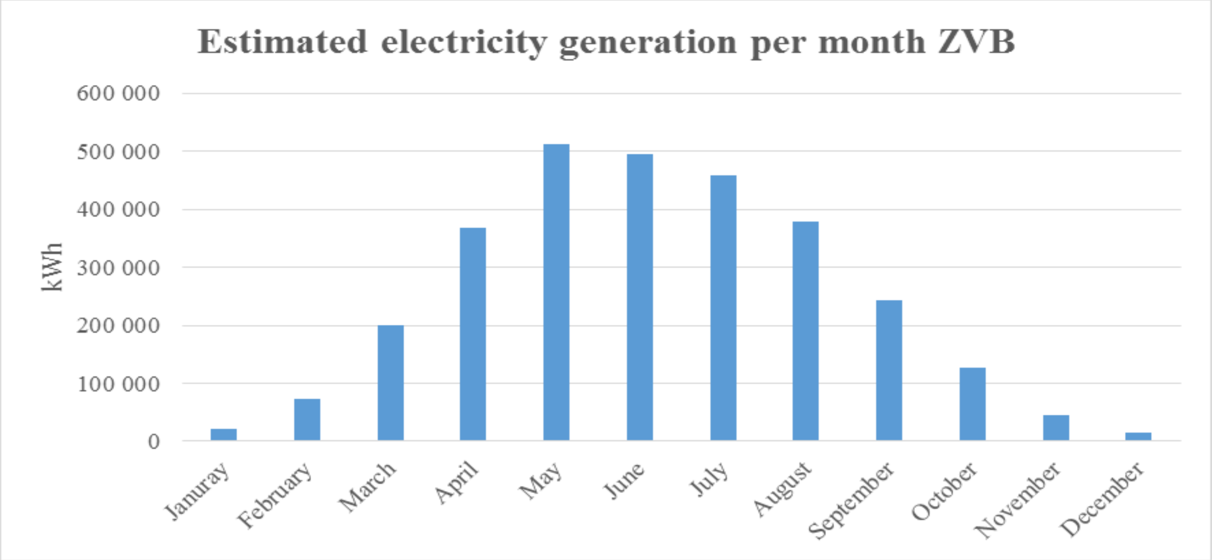

Figure 13: Estimated electricity generation per month ZVB(Multiconsult AS, 2015a)

The amount of solar panel installations per household also varies strongly between the different building areas as can be seen in figure 14 below. Most of the building areas have an estimated annual production per household of 4,000-6,000 kWh, but the central areas in Ådlandsbyen have much lower production numbers (1,100-2,700 kWh) and Utsikten is an outlier with over 12,000 kWh production per household.

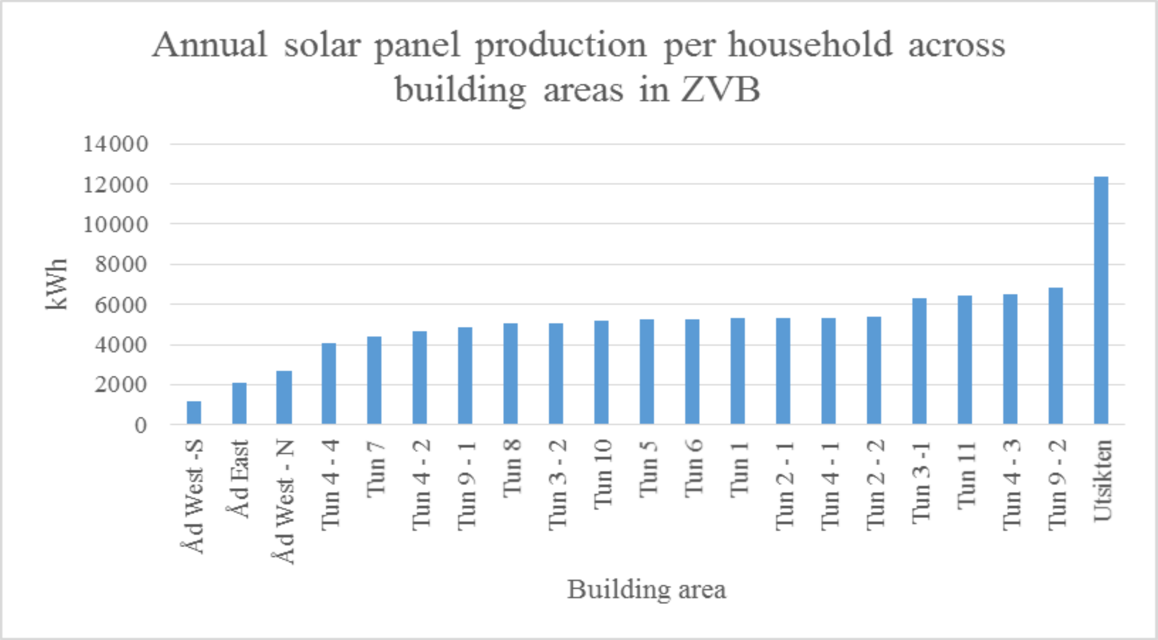

Figure 14: Annual solar panel production per household across building areas in ZVB (Multiconsult AS, 2015a)

6.4. Cost of solar panel installations in Norway[28]

Upfront investment cost

In 2013, Multiconsult AS conducted a study on behalf of Enova to determine the costs related to solar panel installations in Norway. The report concluded with an expected cost of installation of 15,000 NOK/kW(p) for ground-mounted solar installations (>100kW(p))[29], 22,500 NOK/kW(p)[30] for rooftop installations of larger buildings (10-100 kW(p)), and 26,500 NOK/kW(p)[31] for detached houses (<10 kW(p)). All numbers include VAT of 25% (Multiconsult AS, 2013).

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[28] For all costs, NOK_{2014} is assumed unless otherwise stated. The NVE report from 2015 does not inflation adjust the costs found by Multiconsult in 2013, and no inflation adjustment has therefore been performed on the costs in this thesis.

[29] Cost estimates ranged from 12,500 – 18,750 NOK/ kW(p)

[30] Cost estimates ranged from 15,000 – 25,000 NOK/kW(p)

[31] Cost estimated ranged from 21,000 -31,000 NOK/kW(p)

In the 2014 EIA national survey report of solar power applications in Norway, a large variation in the cost per kW(p) was observed for both residential and commercial scale solar panel installations. For small-scale installations (<10 kW(p)), the estimated installation cost was found to be in the range of 13,750 - 25,000 NOK/kW(p) and 12,500 - 20,000 NOK/kW(p) for medium-size installations (10-100 kW(p)). All numbers include VAT (Holm, 2014).

In a 2015 report prepared by NVE on the cost of different energy generation technologies and energy efficiency measures, the cost estimates for solar panel installations from the Multiconsult study from 2013 were used (NVE, 2015f).

For the installation costs of the solar panels in ZVB used in this thesis, costs in the lower end of the Multiconsult estimates have been assumed. There are four reasons for this.

First, the costs of solar panel infrastructure are continuously falling (IEA, 2014), and the solar panel systems in ZVB are unlikely to be installed before 2018. This makes it reasonable to assume some cost reductions.

Secondly, the solar panels will to some extent be used in place of building materials for roof-protection, thus leading to a cost reduction for the developer. Because the solar panels in ZVB will be part of the buildings, some cost reductions can be granted to them for reducing the alternative cost of protective materials.

Thirdly, some cost reductions should arise from the fact that the panels are installed at the same time as the buildings, thus leading to reduced cost of for example scaffolding.

Finally, the scale of the solar panels project in ZVB is very large in a Norwegian context, and some economies of scale in terms of materials and installation should be assumed.

Due to this, the lowest price estimate from the Multiconsult study of 15,000 NOK/kW(p) (12,000 NOK/kW(p) excl. VAT) is chosen for the medium-scale installations (10-100 kW(p)). For the small-scale installations (0-10 kW(p)), 10% was deducted from the lowest estimate, resulting in 18,900 NOK/kW(p) (15,120 NOK/kW(p) excl. VAT).[32]

As can be seen from the cost reports cited above, there is large degree of uncertainty related to the investment cost for solar panels in Norway. At the same time, the investment cost is a key element for establishing the profitability of the solar panel investment. Due to this, a sensitivity

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[32] Assuming the same cost per kW(p) for a range of installation capacities is obviously a simplification. In reality, it is reasonable to expect that the cost per kW(p) for an installation of 2 kW(p) and 10 kW(p) would differ markedly. However, as the sources used in this thesis do not indicate how the installation cost may vary within the categories small- and medium-scale installations, a fixed cost per kW(p) has been assumed within each category.

analysis is performed later in this thesis to investigate how changing investment costs affect the NPV of the project.

Other costs and parameters

NVE observes that the economic lifetime of a solar panel system is 20-30 years, but the actual lifetime is often longer (NVE, 2015f). Due to this fact and the continuous improvement of solar panel technology, a 30-year lifetime has been assumed for the solar panel systems in this thesis.

The O&M cost for solar panel systems is very low compared to the initial investment. It includes activities such as servicing the panels, inverters and wires, snow-clearing as well as monitoring of performance. An annual cost of 0.5%[33] of the initial investment cost is assumed for the small scale installations (<10 kW(p)) and 0.75% for the medium scale installations (10-100 kW(p)) (NVE, 2015f).

The cost of panel breakdown or replacement is not included because the panels are covered under a 20-25 year manufacturer warranty[34] (Kyocera, 2013). A yearly escalation rate of 0.25% is used to adjust the O&M cost for any costs escalations due to increase in maintenance as the equipment gets older (NVE, 2015f).

In the case of household ownership of the solar panel system, no insurance cost is assumed, as it is usually covered under the home insurance (DNB, 2013). In case a commercial actor owns the solar panels an insurance cost of 0.25% is assumed (Speer et al., 2010).

For an investment analysis of a solar panel project, it is a normal practice to assume replacement of the inverter halfway through the expected project lifetime (Multiconsult AS, 2013). The solar panel system at ZVB is assumed to have a lifetime of 30 years. Therefore, in the calculation the reinvestment cost for the inverter replacement is assumed at year 15. It is assumed that the cost of inverter is 14% of the initial investment cost for medium-scale installation (<10 kW(p)) and 11.6% for small-scale installations (10-100kW(p)) (Multiconsult AS, 2013). The cost of the replacement in year 15 is assumed to be the same as the initial cost of the inverter.

A summary of the assumptions on financial parameters can be found in table 14 below.

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[33] Similarly to the installation cost, it is here assumed that the annual O&M cost is fixed per kW(p) within the categories of small- and medium-sized installations. In reality, the cost per kW(p) would likely vary substantially between an installation of 1 kW(p) and of 10 kW(p). However, as indications on the nature of this variation were not given in these sources, a fixed cost per kW(p) has been assumed within the small- and medium-sized installations.

[34] The cost of breakdown after year 25 in the case of 25-year warranty and 30-year lifetime of the project is not taken into account in these calculations.

	Private ownership		**Commercial ownership**	
	Small-scale (Scenario 1)	**Medium-scale (Scenarios 2,3 and 4)**	**Small-scale (Scenario 1)**	**Medium-scale (Scenarios 2,3 and 4)**
Investment cost	18,900 NOK/kW(p) including VAT	15,000 NOK/kW(p) including VAT	15,120 NOK/kW(p) excluding VAT	12,000 NOK/kW(p) excluding VAT
Inverter reinvestment in year 15 (% of initial investment)	11.6%	14%	11.6%	14%
Annual insurance cost (% of initial investment)	0%	0%	0.25%	0.25%
Annual O&M cost (% of initial investment)	0.5%	0.75%	0.5%[35]	0.75%[36]
O&M annual escalation rate	0.25%	0.25%	0.25%	0.25%
Solar PV panels expected lifetime	30 years	30 years	30 years	30 years
Solar PV panels annual efficiency reduction	0.40%	0.40%	0.40%	0.40%
Real discount rate	8.0%	8.0%	8.0%	8.0%
Corporate tax rate			27%	27%
VAT rate	25%	25%	25%	25%
Depreciation rate			5%	5%

Table 14: NPV input parameters for private and commercial ownership structures for scenarios 1-4.

6.5. Discount rates

Discount rates incorporate the time value of money into an investment decision, by converting anticipated future cash flows into present value. A real or nominal discount rate can be used, depending on whether or not inflation is taken into account in the future cash flows. In this analysis, inflation is not considered, and therefore real discount rates are used for the calculations.

An important consideration in determining the discount rate is whether the type of investor or ownership would have an impact on the discount rate. Information gaps, financial constraints and non-financial barriers could affect the investment decision and discount rates for different

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[35] % of investment cost including VAT
[36] % of investment cost including VAT

ownership types. Therefore, discount rates can vary considerably depending on whether costs are being assessed from the perspective of an individual, a company or government (Pollitt & Billington, 2015).

This thesis examines the return on investment for both private and commercial actors' investment in solar panel infrastructure in ZVB, which would seem to suggest separate discount rates should be used for the different ownership structures. However, there are certain limitations to this approach. While there has been a considerable amount of research into the discount rate that should be used for commercial actors, not much work has been done on the discount rate to be used for private investments. The general yardstick for private investors is to use a discount rate equal to or higher than the discount rate for commercial actors, for similar projects. The rationale for this is that commercial investors have more diversified risks compared to private investors, which leads to lower cost of capital.

However, the discount rate used in calculations can have a material difference on the final NPV for the investment. Potentially, the impact of the discount rate could overshadow the combined effect of all other variables. Therefore, for the purposes of this thesis, same discount rate has been used for commercial and private investors, to prevent skewing of the model by using different and possibly misleading discount rates. The discount rates used in modelling of investments made by private households and co-ownerships may be an important area of future research.

6.5.1. Discount rate determination

There are varying discount rates which could be applied to the calculations in this thesis. A utility company evaluating a similar DG project intends to use a discount rate of 7%. However, this is the generic rate used to value the company's electricity production projects, and hence might not be appropriate for use in valuing a solar panel project.

Solar panel projects in Norway are likely to carry more risk than traditional electricity projects, due to higher uncertainty and less developed market conditions. Therefore, to further investigate the possible discount rate for such projects, it is essential to look at some other sources of discount rates for similar investments.

The most relevant literature on this topic is a report prepared by Ole Gjølberg and Thore Johnsen for Enova in 2007. In the report, the detailed analysis to calculates different variables for the weighted average cost of capital (WACC) for various renewable energy projects, results at a recommended real discount rate of 8.1% for solar panel projects (Gjølberg & Johnsen, 2007). In real terms, Enova uses similar discount rate of 8% to value renewable energy projects (Enova, 2015a).

Of these three different options, Enova’s discount rate of 8.0% is selected for this analysis. This is primarily because there is a minor difference in the discount rate used by Enova and that suggested by Gjølberg and Johnsen. Therefore, there would not be a material difference in the calculations using either of the discount rates. Secondly, using Enova’s discount rate makes the results easily comparable with the Enova’s research conducted on renewable investment.

The determination of the discount rate has an important impact on the NPV of the solar panel investment, where a large initial investment is followed by a 30-year period of revenues. In order to illustrate the effect of change in the discount rate on the NPV, a sensitivity analysis is performed in section 8.2.

7. NPV Analysis

This chapter presents the method and numbers used in the NPV calculations for private and commercial ownership structures, for different scenarios. A schematic illustration of the data that goes into calculating the NPV for the solar panel investment in ZVB can be seen in the flowchart presented in figure 15.

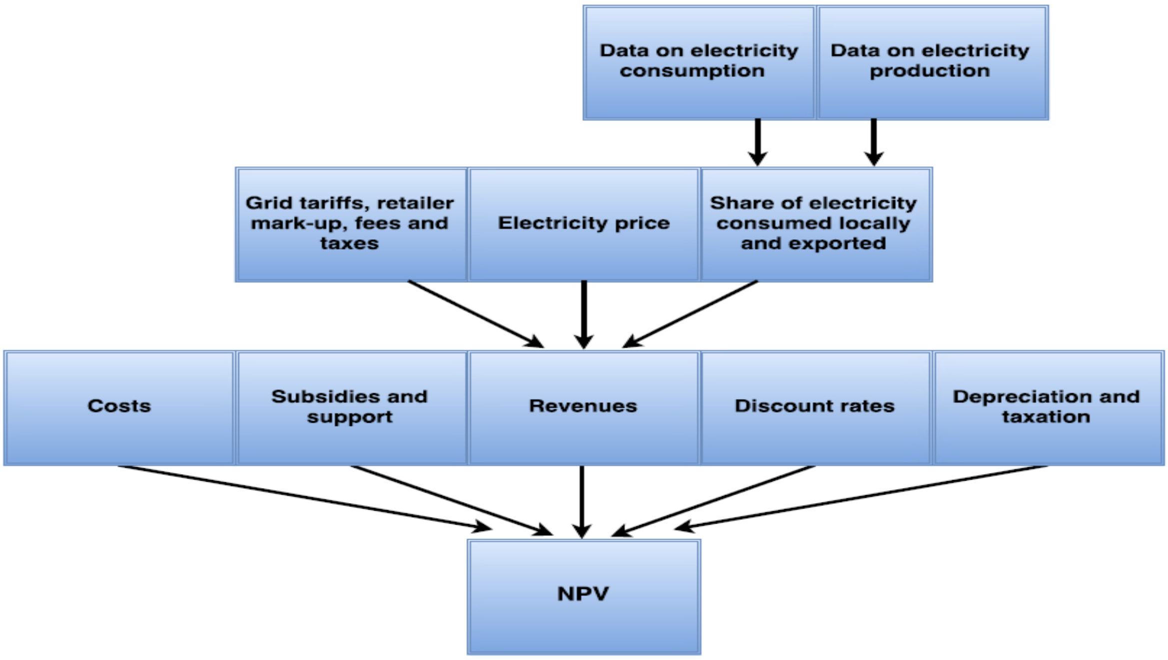

Figure 15: Flow-chart for the calculation of NPV for the solar panel investment

First, the data on electricity production and consumption described in sections 6.2 and 6.3 is combined to arrive at the share of solar panel electricity production used locally and exported[37] for each hour of the year.

This information is combined with the hourly wholesale electricity price, retailer mark-up, fees, tariffs and taxes described in sections 4 and 6.1 to determine the value of electricity consumed locally and exported for each hour of the year. The value of electricity consumed locally and exported over the year is regarded as revenues[38] in the NPV analysis, as illustrated in the flow chart above. In addition, the selling of green certificates also represents a potential source of

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[37] For each hour of the year it is assumed that the amount of production used locally is equal to the total production when consumption is larger than production, and equal to consumption when the consumption is lower than production.

[38] Selling the surplus electricity to a retailer or DSO generates revenues in the form of a positive cash flow. In the case of private ownership, the second component of the revenue consists of savings due to a decrease in purchases of electricity from the grid by replacing it with electricity from the solar panels. The value of saving in form of local consumption is determined using the alternative cost of buying the same amount of electricity from the grid at the same time.

revenue. Due to the degradation rate of solar panels, all these revenues are expected to fall every year over the 30-year lifetime of the panels.

The revenues are combined with costs, subsidies, support schemes, depreciation rates and taxes to determine the cash flow of the investment, which in turn has the discount rate applied to arrive at the present value of the investment. The combination of upfront investment costs and subsidies, and discounted cash flows, constitutes the NPV of the solar panel investment.

In the following sections 7.1- 7.4 the NPV input factors and results for scenarios 1- 4 are presented both for private and commercial ownership. A summary of NPV results are presented in sector 7.5.

7.1. Scenario 1

Under the first regulatory scenario, only individual households with solar panels can sign a plus customer agreement. A solar panel installation must be connected to the individual household, and no sharing of electricity resources is allowed between households or buildings.

For ZVB, this would imply that the common rooftops must be divided into distinct areas for each household, with each household having separate panels and connections to their dwelling. A schematic representation of the system is presented in figure 16.

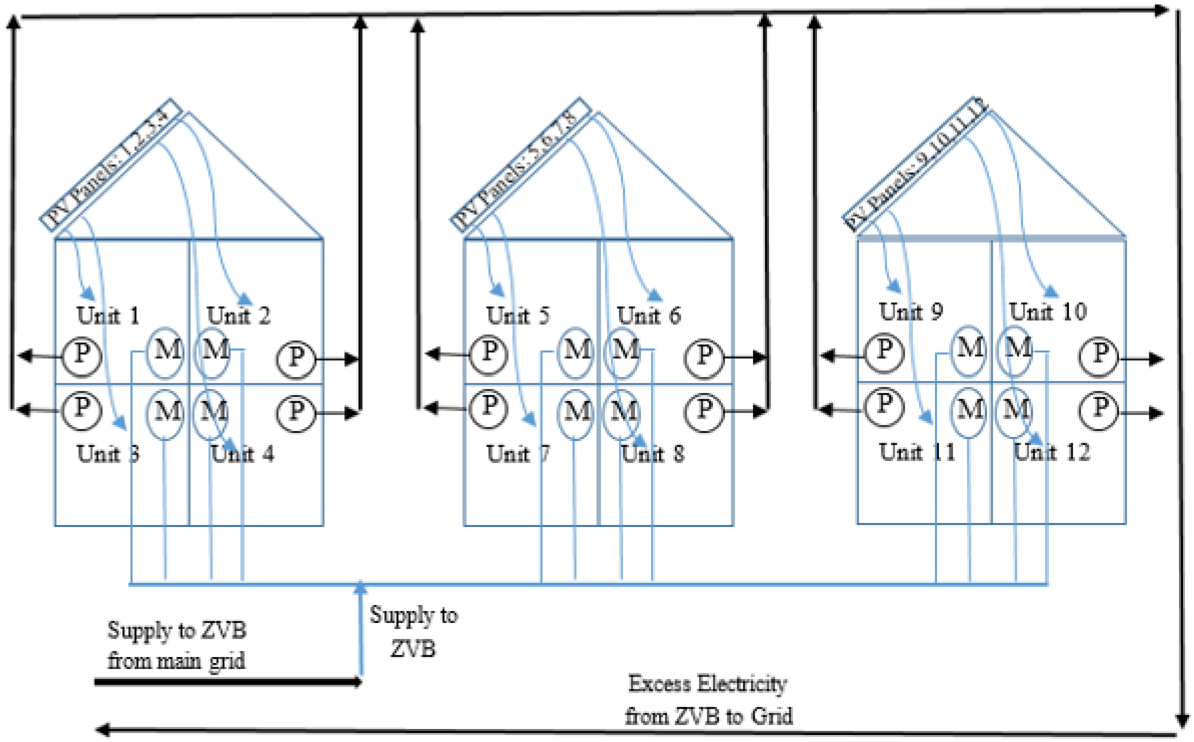

Figure 16: Schematic representation of solar panel system under scenario 1

Household *Unit 1* is directly connected to, and can only use electricity from *PV panel 1*. Electricity is fed into the main grid in case of surplus production, and vice-versa in case of deficit. In the above figure, for ease of understanding, the flow of electricity from the panels (black lines) and from the grid (blue lines) is represented using separate wires and meters. However, in reality this flow will happen using the same wires connecting the houses to the grid. Similarly, in the above figure, meter *P* measures the electricity fed into the grid and meter *M* measures the electricity used from the grid. However, this could also be done using a single two-way meter instead of two separate meters.

For scenario 1, the NPV of the solar panel installations must be analyzed for the 685 individual households in ZVB, and is estimated for both private household ownership and for commercial ownership with leasing to the households.

7.1.1. Private household ownership

Under this ownership structure, the individual households own the panels that are connected to their apartment. The households cover all the costs, and receive all the benefits of production, subsidies and support mechanisms for the solar panels.

In the subsequent sections 7.1.1.1- 7.1.1.5, the parameters used as input factors in the NPV analysis for the individual household ownership structure under scenario 1 are presented. The method for estimating the value of the solar panel production is explained in detail in section 7.1.1.1.1, and the same method is used for all the scenarios.

7.1.1.1. Revenues[39]

Three sources of revenue for the solar panels have been identified in this analysis: the value of selling surplus electricity to the DSO or retailer, the cost saving of using local production rather than buying from the grid, and income from selling green certificates.

7.1.1.1.1. The value of local electricity consumption and export to the grid

For an owner of a solar panel under the plus customer agreement there is a difference between the value per unit of electricity consumed locally, and of that exported to the grid. The value per unit consumed locally equals the alternative cost of buying a kWh from the grid at the same

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[39] All numbers relating to revenues presented in chapter 7 concern results for year 1. Due to the assumption of an annual efficiency degradation rate for the solar panels, these numbers would change in accordance with it every year.

time. This is equal to the sum of the wholesale electricity price, retailer mark-up, variable grid tariffs, taxes, green certificates fee and Energy Fund fee, all including VAT.

The value of a unit of electricity exported equals the wholesale electricity price minus the variable grid tariff for power producers. Thus, consuming a unit locally instead of exporting it leads to an increase in value by an amount equal to the retailer mark-up, variable grid tariffs for consumers, variable grid tariff for producers, green certificates fee and the Energy Fund fee, plus the VAT on the wholesale electricity price. On average for the 8,760 hours of the year, this calculation found that the value of local consumption is 0.79 NOK/kWh, whereas it is 0.30 NOK/kWh for surplus production. However, the value varies throughout the year, over the course of a day, over a week, and between weekdays and weekends.

For scenario 1, the value of local consumption and export of surplus production from the solar panels of the 685 individual households, has been represented by 168 different combinations of production and consumption profiles, with an assumed distribution of household categories as outlined in appendix E.

The calculations of the share of electricity from the solar panels used locally and exported, and of the value of production, are explained in this section. Eight variables with hourly values (8,760 observations) for the entire year were used as input factors as described in table 15. The intermediate and key output factors are described in table 16 and table 17.

Input factors	
Nomenclature	**Description**
$P_{w,t}$	Hourly wholesale electricity price at hour t excl. VAT (NOK/kWh)
$G_{v,t}$	Variable grid tariff for electricity consumers at hour t incl. VAT (NOK/kWh)
$F_{gc,t}$	Variable fee for green certificates at hour t (NOK/kWh)
$F_{ef,t}$	Variable fee to the Energy Fund (NOK/kWh)
$R_{m,t}$	Retailer mark-up of wholesale price at hour t incl. VAT (%)
L_t	Variable grid tariff for electricity producers at hour t incl. VAT (1- loss (%))
$D_{c,t}$	Electricity consumption at hour t (kWh)
$PV_{p,t}$	Electricity production from PV panels at hour t (kWh)
VAT	VAT rate (%)

Table 15: Description of input variables

Intermediate output factors	
Nomenclature	**Description**
$C_{G,t}$	Total cost of buying electricity from the grid at hour t (NOK/kWh)
$P_{G,t}$	Price received for selling electricity to DSO or retailer at hour t (NOK/kWh)
$C_{loc,t}$	Solar panel production consumed locally at time t (kWh)
$C_{exp,t}$	Solar panel production exported at time t (kWh)
$V_{loc,t}$	Value of solar panel production used locally at time t (NOK/kWh)
$V_{exp,t}$	Value of solar panel production exported at time t (NOK/kWh)

Table 16: Description of intermediate output variables

Key output factors	
Nomenclature	**Description**
$V_{loc,tot}$	Total annual value of solar panel electricity consumed locally (NOK/kWh)
$V_{exp,tot}$	Total annual value of solar panel electricity exported (NOK/kWh)
$V_{loc,av}$	Average value of solar panel electricity consumed locally (NOK/kWh)
$V_{exp,av}$	Average value of solar panel electricity exported to the grid (NOK/kWh)
$C_{loc,\%}$	Annual solar panel electricity production consumed locally (%)
$C_{exp,\%}$	Annual solar panel electricity production exported (%)

Table 17: Description of key output factors

Formulas 1-6 were used to calculate the intermediate output factors:

1. The cost of buying electricity from the grid at time t ($C_{G,t}$) equals the wholesale electricity price at time t including VAT, the retailer mark-up on the wholesale electricity price before VAT, the variable tariff and the contribution to the green certificate scheme and the Energy Fund. The retailer mark-up is a percentage mark-up on the wholesale price:

$$C_{G,t} = P_{w,t} * (1 + VAT) + (P_{w,t} * R_{m,t)} + G_{v,t} + F_{gc,t} + F_{ef,t}$$

   The average cost of electricity from the grid for 8,760 hours of the year is found to be 0.79 NOK/kWh.

2. The price received for selling electricity to the DSO or retailer (exporting to the grid) at time t ($P_{G,t}$), equals the wholesale electricity price at time t with a percentage reduction to account for the variable grid tariff for power producers:

$$P_{G,t} = P_{w,t} * L_t$$

   For the 8,760 hours of the year, the average price that would be received from selling electricity to DSO or retailer is 0.30 NOK/kWh.

3. If the production from the solar panels at hour t is lower than the electricity consumption at time t, then the entire production is used locally. If the production is higher than the

consumption at time t, then the amount of the production that is used locally ($C_{loc,t}$) equals the consumption:

$$C_{loc,t} = IF(PV_{p,t} < D_{r,t}; PV_{p,t}; D_{r,t})$$

4. The amount of the production that is exported at time t ($C_{exp,t}$) equals the total production at time t minus the amount used locally at time t:

$$C_{exp,t} = PV_{p,t} - C_{loc,t}$$

5. The value of production used locally at time t ($V_{loc,t}$) equals the amount of production used locally at time t multiplied by the total cost of electricity from the grid at time t:

$$V_{loc,t} = C_{loc,t} * C_{G,t}$$

6. The value of production exported at time t ($V_{exp,t}$) equals the amount of production exported multiplied by the price received for selling electricity to the DSO or retailer at time t:

$$V_{exp,t} = C_{exp,t} * P_{G,t}$$

Formulas (7-12) are used to calculate the key output factors:

7. The total annual value of solar electricity production used locally ($V_{loc,tot}$) equals the sum of the 8,760 hourly values of production consumed locally:

$$V_{loc,tot} = \sum_{t=1}^{8760} V_{loc,t}$$

8. The total annual value of solar electricity production exported ($V_{exp,tot}$) equals the sum of the 8,760 hourly values of production exported:

$$V_{exp,tot} = \sum_{t=1}^{8760} V_{exp,t}$$

9. The average value per kWh used locally $\left(V_{loc,av}\right)$ equals the sum of value of production used locally for all hours of the year divided by the total production used locally over the year:

$$V_{loc,av} = \frac{\sum_{t=1}^{8760} V_{loc,t}}{\sum_{t=1}^{8760} C_{loc,t}}$$

10. The average value per kWh exported $(V_{exp,av})$ equals the sum of the value of production exported for all hours of the year divided by the total production used locally over the year:

$$V_{exp,av} = \frac{\sum_{t=1}^{8760} V_{exp,t}}{\sum_{t=1}^{8760} C_{exp,t}}$$

11. The share of total production from the solar panels that is consumed locally $(C_{loc,\%})$ equals the number of kWh consumed locally divided by the total annual production:

$$C_{loc,\%} = \frac{\sum_{t=1}^{8760} C_{loc,t}}{\sum_{t=1}^{8760} PV_{p,t}}$$

12. The share of total production from the solar panels that is exported $(C_{exp,\%})$ equals the number of kWh exported divided by the total annual production:

$$C_{exp,\%} = \frac{\sum_{t=1}^{8760} C_{exp,t}}{\sum_{t=1}^{8760} PV_{p,t}}$$

On average for all the individual households in ZVB, the value per kWh produced is 0.456 NOK/kWh and the share used locally is 33.48%. However, both figures vary strongly between individual households.

The lowest value was achieved by single person households in Utsikten, and the highest was found for a V2 family in Ådlandsbyen West – S with 0.330 NOK/kWh (7.42 % consumed locally) and 0.651 NOK/kWh (74.56 % consumed locally) respectively[40].

	Minimum	Average	Maximum
Average value per kWh produced	0.330 NOK/kWh	0.456 NOK/kWh	0.651 NOK/kWh
Share of production consumed locally	7.42%	33.48%	74.56%

Table 18: Minimum, average and maximum value per kWh and share of production consumed locally under scenario 1.

However, to illustrate the range of NPV results across different households, the households with the lowest, average and highest annual value per installed capacity (NOK//kW(p)) were

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[40] A graphical illustration of the results for the share of solar panel production used locally, the average value per kWh produced, and the total annual value of production for all the 168 individual households' consumption and production combinations can be seen in appendix F.

used. The average annual value per kW(p) for the entire ZVB under scenario 1 is 332.9 NOK/kW(p), with a minimum of 234.4 NOK/kW(p) for a single household in Utsikten, and a maximum of 476.3 NOK/kW(p) for a V2 family in Ådlandsbyen West – S.

The V2 Couple (64+) household in Tun 9 – 1 performs similar to the overall average, with 332.8 NOK/kW(p) and is therefore used to illustrate the average case in the NPV calculations. A summary of the three household types that are used to represent the average and range of the NPV results in scenario 1 can be seen in table 19 below.

	Minimum: Single person in Utsikten	**Average: V2 Couple (64+) in Tun 9 -1**	**Maximum: V2 Family in Ådby West- S**
Value of annual production per kW(p) installed	234.4 NOK/kW(p)	332.8 NOK/kW(p)	476.3 NOK/kW(p)

Table 19: Minimum, average and maximum annual value per kW(p) installed across individual households in ZVB

7.1.1.1.2. Revenues from selling green certificates

Under scenario 1, there will be no revenues from selling green certificates received for the renewable production from the solar panels. The reason is that the registration cost of 15,000 NOK per production unit of rated capacity of <100 kW(p) is too high for the scheme to be profitable for individual households.[41]

It is assumed that the panel efficiency decreases by 0.4% annually, thus leading to an annual decrease in all production-related revenues.

7.1.1.2. Costs

There are five sources of costs related to the solar panels: Investment cost, cost of registering for green certificates, O&M, insurance costs and inverter reinvestment cost.

The upfront investment cost represents by far the most important cost component of the solar panel system. It includes the cost of planning, installation, and of materials such as panels, inverters, wiring, etc.

In scenario 1, the solar panels for each household will entail small-scale installations. As explained in section 6.4, the upfront investment cost for small-scale solar panel systems is assumed to be 18,900 NOK/kW(p) including VAT.

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[41] Assuming an average selling price of 0.17 NOK/kWh, 17 years of receiving the benefits (2018-2035) and a real discount rate of 8.0%.

The cost for registering for the green certificate scheme is zero under scenario 1, because the scheme is not profitable given the high initial registration costs.

The O&M cost for the solar panel system is low compared to the initial investment. It includes activities such as servicing the panels, inverters and wires, snow-clearing as well as monitoring of performance. As mentioned in section 6.4, an annual cost of 0.5% of the initial investment cost is assumed and a yearly escalation rate of 0.25% is used to adjust the O&M cost for any costs escalations due to increase in maintenance as the equipment gets older.

In the case of household ownership of the solar panel system, no insurance cost is assumed, as it is usually covered under the home insurance.

It is assumed that the cost of the inverter is 11.6% of the initial investment cost, and replacement of the inverter is assumed halfway through the expected project lifetime. The solar panel system at ZVB is assumed to have a lifetime of 30 years, and therefore the inverter replacement is assumed to take place in year 15. The cost is assumed to be the same as the initial cost of the inverter.

7.1.1.3. Subsidies

A detailed description of the Enova investment subsidy is presented in section 4.3.8. Enova provides support in the form of subsidies to share a part of the upfront investment cost. Under the current regulations, the individual households in ZVB are eligible for this subsidy, provided they pay for their own solar system.

The investment subsidy is usually received after the documentation and procedures required by Enova have been completed. However, for this analysis, it is assumed that the subsidy is received at the time of initial investment itself.

7.1.1.4. Taxation and depreciation

The individual households are assumed to be a not-for-profit ownership structure[42], and thus neither taxes nor tax benefits derived from depreciation of the panels are factored in.

7.1.1.5. Summary of NPV input factors

Table 20 presents a summary of the different input factors used for the NPV analysis.

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[42] All the private ownership structures considered in this thesis are assumed to be not-for-profit. There are two main reasons for this: first, for the private ownership structures the panels' production benefits them primarily through decreased costs, by lowering the amount of electricity that needs to be bought from the grid. Secondly, it is assumed that any revenues received through selling electricity to the grid or through the selling of green certificates will be used to cover other necessary costs in the household or co-ownership.

	Low **Single person household in Utsikten**	**Average** **V2 Couple (64+) household in T9 -1**	**High** **V2 family household in Ådlandsbyen West -S**
Installed capacity	17.4 kW(p)	6.65 kW(p)	1.56 kW(p)
Initial investment cost	328,860 NOK	125,594 NOK	29,430 NOK
Inverter investment	38,148 NOK	14,569 NOK	3,414 NOK
O&M cost for year 1	1,644 NOK	628 NOK	147 NOK
O&M escalation rate	0.25%	0.25%	0.25%
Insurance cost	0	0	0
Cost of green certificate registration	0	0	0
Enova subsidy	28,750 NOK	18,306 NOK	10,301 NOK
Annual revenues from sales of green certificates	0	0	0
Revenues from local consumption and export of electricity for year 1	4,078 NOK/year	2,212 NOK/year	742 NOK/year
Solar panels' annual efficiency decline	0.4%	0.4%	0.4%
Discount rate	8.0%	8.0%	8.0%

Table 20: Input factors for NPV analysis for scenario 1, household ownership

7.1.2. Commercial ownership

The commercial ownership structure under scenario 1 involves a commercial entity which owns the solar panel installations, and leases the panels to the individual households. Similar to private ownership, the panels would have to be separate for and connected to each individual household.

There can be various leasing models based on the variation of cash flows between the commercial actor and the households. In the leasing model analyzed in this thesis, the commercial actor owns the solar panel system, and the households enter into a long-term leasing agreement for the usage of the panels, paying an annual rent for leasing the panels. The electricity produced is used locally by the household and surplus production is sold to the DSO or retailer. The commercial actor is responsible for the O&M and insurance of the solar infrastructure.

For the analysis, it is assumed that the annual lease including 25% VAT equals the value of production from the solar panels when owned by private households[43]. The revenues received by the commercial actor in the form of a lease are therefore 25% lower than the value to the private households of owning the panels themselves. This assumption is made in order to identify the difference between the return on investment for commercial ownership and leasing structures compared to a private ownership structure. If the return on investment for the leasing structures is better than for private ownership, there would be room for transferring some of the benefits to the households through a lower annual lease.

It is unclear whether this ownership structure would be allowed under the current plus customer agreement. However, under the proposed future plus customer agreement the leasing scheme seems likely to be allowed since it only specifies the condition of having peak output lower than 100 kW at any point in time, and that there should be no need for a trade concession behind the connection point. For the individual households, these requirements are met under the leasing scheme, and may therefore be allowed under the future plus customer agreement.

The main differences in input factors for this commercial ownership structure compared to the private ownership structure are that 1) the commercial investor gets a VAT refund on the initial investment, and must charge VAT on the annual lease, 2) the commercial investor is subject to corporate tax on any profits 3) the depreciation of assets reduces some of the tax burden, 4) an insurance cost is assumed and 5) the commercial actor is not eligible for the Enova investment subsidy.

The corporate tax rate is set to 27%. A declining-balance method is used to depreciate the panels, inverters and other installations. A depreciation rate of 5% is used over the lifetime of 30 years for panels and 15 years for the inverter. The residual value for panels, inverters and other installations is assumed to be zero, and hence the remaining value of assets is depreciated in the last year (KPMG, 2014a). The real discount rate for the commercial actor is assumed to be 8.0%.

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[43] This can be illustrated by the following relationship:
$AV_p = AV_c + AV_c * VAT$

Where,
AV_p = the annual value of the solar panel production under the private ownership structure
AV_c = Annual revenue for the commercial actor in the form of solar panel lease
VAT = 25% VAT

Since the commercial owners of solar panel infrastructure cannot benefit from the extension of the household insurance in the same way as the household owners do, an insurance cost of 0.25% is assumed for a commercial ownership.

Commercial ownership structures of solar panels are ineligible for the Enova subsidy, which is only given to private households.

A summary of the input factors used in the NPV analysis for commercial ownership are presented in table 21 below:

	Low **Single person household in Utsikten**	**Average** **V2 Couple (64+) household in T9 -1**	**High** **V2 family household in Ådlandsbyen West -S**
Installed capacity	17.4 kW(p)	6.65 kW(p)	1.56 kW(p)
Initial investment cost	263,088 NOK	100,475 NOK	23,544 NOK
Inverter reinvestment year 15	30,518 NOK	11,655 NOK	2,731 NOK
Annual O&M cost for year 1	1,644 NOK	628 NOK	147 NOK
O&M escalation rate	0.25%	0.25%	0.25%
Annual insurance cost	822 NOK	314 NOK	74 NOK
Initial cost of green certificate registration	0	0	0
Initial Enova subsidy	0	0	0
Annual revenue from selling green certificates	0	0	0
Annual revenue from local consumption and export of electricity for year 1	3,263 NOK/year	1,770 NOK/year	593 NOK/year
Solar panels’ annual efficiency decline	0.4%	0.4%	0.4%
Discount rate	8.0%	8.0%	8.0%
Depreciation rate for tax accounting	5%	5%	5%
Depreciation period inverter	15 years	15 years	15 years
Depreciation period for panels and other equipment	30 years	30 years	30 years
Corporate tax rate	27%	27%	27%

Table 21: Input factors for NPV analysis for scenario 1, commercial ownership

7.1.3. Results

The results of the NPV analysis for the private and commercial ownership structures for the low, average and high NPV households can be seen in table 22.

NPV results for scenario 1 in NOK/kW(p)			
	Low	**Average**	**High**
Private ownership	-16,432	-14,260	-8,843
Commercial ownership	-15,217	-14,361	-13,116

Table 22: NPV results for scenario 1

Across all households and ownership structures there is a net loss over the lifetime of the project, with an overall best result of – 8,843 NOK/kW(p). The typical result is around – 14,260 NOK/kW(p) and – 14,360 NOK/kW(p) for private and commercial ownership structures respectively.

For both commercial and private ownership structures, there is a substantial difference in NPV between individual households. However, the difference is much more pronounced in the case of private ownership than for the commercial model.

The reasons for the difference between households are that 1) households with a lower production to consumption ratio achieve a higher value per kWh produced, 2) households with a better fit between consumption and production achieve a higher value per kWh produced, 3) the solar panels installed on different buildings have different capacity factors, and 4) in the case of private ownership, the Enova subsidy covers a larger part of the investment cost for households with lower installed production capacity. The Enova subsidy is the reason for the far more pronounced difference between the low and high results for the private ownership structure than for the commercial ownership structure.

Private ownership structures demonstrated better results for the average and high result households. This can be attributed to the effect of the Enova investment subsidy which plays a larger role for the households with a relatively small installation. In addition, the private ownership structure benefits from the avoidance of insurance costs. On the other hand, the commercial ownership structures benefit from VAT exemption on the investment cost, and perform slightly better in the low case, due to the diminished importance of the Enova subsidy for the relatively large installation in Utsikten. Due to the low revenues relative to the annual depreciation of assets, the accounting profit for the commercial ownership structure is not positive, and thus no taxes are paid[44].

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[44] The relative performance of the two ownership structures under assumptions that yield a positive return on investment is further explored in chapter 8.

7.2. Scenario 2

Under the second regulatory scenario, it is assumed that in addition to individual households, multiple households organized as a single legal entity in the form of a co-ownership will be allowed to sign the plus customer agreement.

A schematic representation of this scenario can be seen in figure 17.

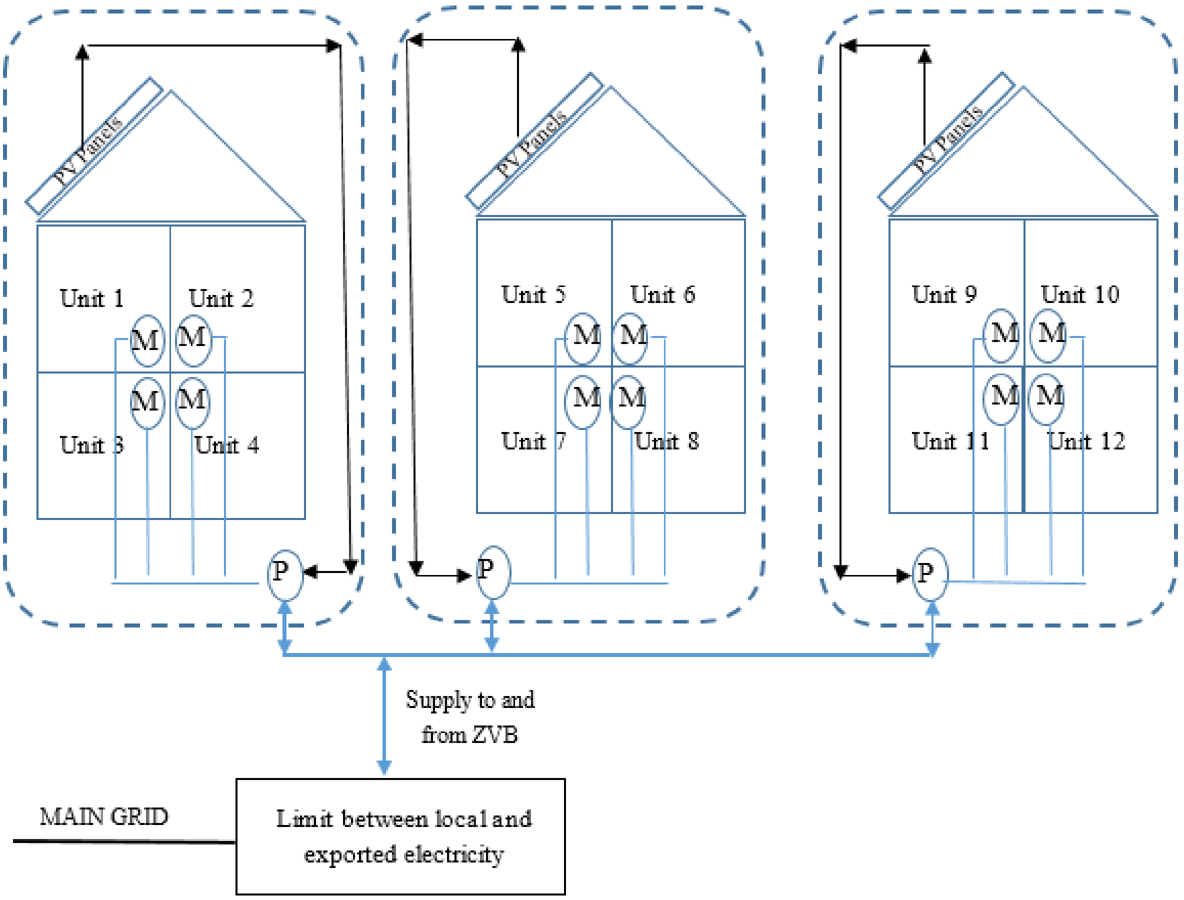

Figure 17: Schematic representation of the solar panel system under scenario 2

The dotted lines represent the boundaries for each of the co-ownerships. The electricity produced from the shared panels is either used by any of the residents within the co-ownership or is fed into the grid. The total electricity used from the grid and fed into the grid is measured by meter *P*. The meter *M* measures the total electricity consumption at the individual household level. Readings from both these meters are reconciled to calculate the individual electricity bills. NVE is looking into how this could be done by using the planned data center Elhub (see section 4.3.2.2).

For this second scenario, 21 different co-ownerships are assumed to cover all the residential buildings in ZVB as seen in table 1. The distribution of individual households is assumed to be the same as under scenario 1. A graphical illustration of the expected annual consumption and production per co-ownership can be seen in figure 18.

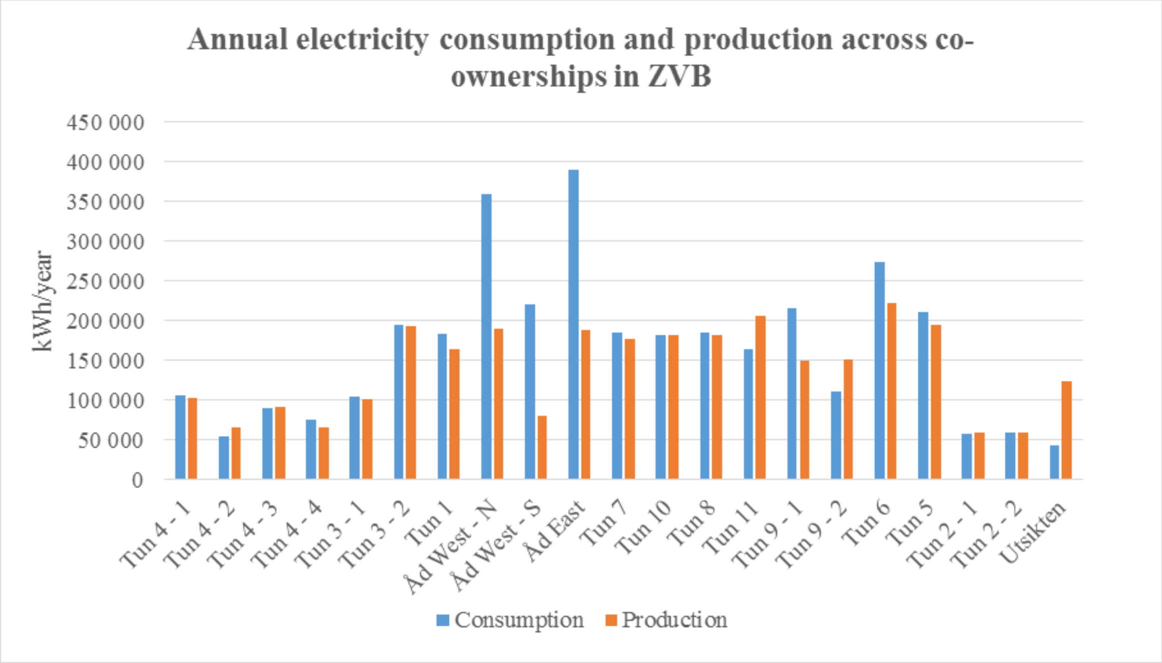

Figure 18: Annual electricity consumption and production across co-ownerships in ZVB

As can be seen, the annual production is at a comparable level with the annual consumption for most co-ownerships, except in the central areas of Ådlandsbyen, where the consumption is relatively higher, and in Utsikten, where the production is far higher than consumption. In the following subsections, the NPV input factors for private and commercial ownership structures are presented for scenario 2.

7.2.1. Private co-ownership

The residents of a co-ownership commonly own and pay for the solar panels, and share the electricity produced in accordance with each individual household's consumption. The co-ownership covers all the costs, and receives all the benefits of production, subsidies and support mechanisms for the solar panels.

In the subsequent sections 7.2.1.1- 7.2.1.6, the parameters used as input factors in the NPV analysis for the individual household ownership structure under scenario 2 are presented.

7.2.1.1. Revenues

As under scenario 1, there are three sources of revenues for a co-ownership that owns solar panels: the value from selling surplus electricity to the DSO or retailer, the avoidance of the cost of buying electricity from the grid when using local production, and income from selling green certificates.

7.2.1.1.1. The value of local electricity consumption and export to the grid

As in scenario 1, the method described in section 7.1.1.1.1 is used to calculate the share of electricity production consumed locally or exported, the average value per kWh produced and the total annual value of solar electricity production. Under scenario 2, the electricity consumption and production profiles of all the households in each co-ownership are pooled together.

The average value per kWh produced for all the co-ownerships is 0.46 NOK/kWh, and the share consumed locally is 34.39%. Both values vary substantially across co-ownerships in ZVB, with the lowest value per kWh produced in Utsikten with 0.359 NOK/kWh (13.3% consumed locally), and the highest in Ådlandsbyen West – S with 0.593 NOK/kWh (62.2% consumed locally)[45].

	Minimum	Average	Maximum
Average value per kWh produced	0.359 NOK/kWh	0.460 NOK/kWh	0.593 NOK/kWh
Share of production consumed locally	13.3%	34.39%	62.2%

Table 23: Minimum, average and maximum value per kWh (excluding revenues from green certificates) and share of production consumed locally under scenario 2.

As in scenario 1, the lowest, average and highest annual revenue per kW(p) is used to illustrate the range in NPV results across co-ownerships. The average annual value per kW(p) for the entire ZVB under scenario 1 is 335.1 NOK/kW(p), with a minimum of 254.5 NOK/kW(p) for Utsikten, and a maximum of 433.3 NOK/kW(p) for Ådlandsbyen West – S. Tun 5 performs most similarly to the overall average, with 333.8 NOK/kW(p) and is therefore used to illustrate the average case in the NPV calculations.

	Minimum: Utsikten	Average: Tun 5	Maximum: Ådby West- S
Value of annual production per kW(p) installed	254.5 NOK/kW(p)	333.8 NOK/kW(p)	433.3 NOK/kW(p)

Table 24: Minimum, average and maximum annual value per kW(p) installed across co-ownerships in ZVB, excluding revenues from green certificates

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[45] A graphical illustration of the results for the share of local consumption, average value per kWh produced and annual value of total production for all 21 co-ownerships can be seen in appendix G.

7.2.1.1.2. Revenues from selling green certificates

Due to the larger scale of the solar panel installation, registering for the green certificates scheme is profitable for all the co-ownerships. Therefore, an income of 0.17 NOK/kWh is assumed for electricity produced over the 17- year period, as explained in section 4.3.5.

It is assumed that the panel efficiency decreases by 0.4% annually, thus leading to an annual decrease in all production-related revenues.

7.2.1.2. Costs

There are five main categories of costs under this scenario: investment cost, cost of registering for green certificates, O&M cost, insurance cost and inverter reinvestment cost.

In scenario 2, the solar panel investments are larger in scale than under scenario 1, and the upfront investment cost of 15,000 NOK/kW(p) including VAT is assumed corresponding to medium scale.

The O&M cost is assumed to be 0.75% of the initial investment cost, with a yearly escalation rate of 0.25%. As in scenario 1, it is assumed that the solar panels are included in the building insurance bought by the co-ownership structure, and therefore no additional insurance cost is needed.

The cost of inverters is estimated to be 14% of the initial investment cost, and inverter replacement is assumed in year 15. The cost of replacement is assumed to be the same as the initial cost of the inverter.

The cost of registering for the green certificates scheme is 30,000 NOK for the co-ownerships with an installed capacity of more than 100 kW(p), and 15,000 NOK for those with less than 100 kW(p). No operational cost of the green certificate scheme is assumed.[46]

7.2.1.3. Subsidies

As per the current support scheme from Enova, co-ownerships are not eligible for the investment subsidy.

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[46] Benefitting from the green certificate scheme would likely entail use of sometime documenting and reporting production methods and volumes etc. In this thesis, such costs have not been included in this analysis for any of the scenarios or ownership structures considered. There are two reasons for this: first, it is difficult to identify the scope of these activities and hence quantify the monetary cost related to them; and secondly, the costs are likely to be of quite limited scale, and thus not have an important impact on the final results.

7.2.1.4. Taxation and depreciation

The co-ownerships are assumed to have a not-for-profit cooperative structure. Therefore, no taxation or depreciation is taken into account when determining the co-ownerships' cash flows.

7.2.1.5. Discount rate

A real discount rate of 8.0% is used for the co-ownerships.

7.2.1.6. Summary of NPV input factors

	Low **Co-ownership Utsikten**	**Average** **Co-ownership T5**	**High** **Co-ownership Ådlandsbyen West -S**
Installed capacity	174 kW(p)	266 kW(p)	109 kW(p)
Initial investment cost	2,610,000 NOK	3,990,000 NOK	1,635,000 NOK
Inverter reinvestment in year 15	365,400 NOK	558,600 NOK	228,900 NOK
O&M cost for year 1	19,575	29,925 NOK	12,263 NOK
O&M escalation rate	0.25%	0.25%	0.25%
Annual insurance cost	0	0	0
Initial cost of green certificate registration	30,000 NOK	30,000 NOK	30,000 NOK
Initial Enova subsidy	0	0	0
Annual revenues from sales of green certificates for year 1	20,986 NOK	33,155 NOK	13,550 NOK
Annual revenues from local consumption and export of electricity first year	44,283 NOK/year	88,570 NOK/year	47,226 NOK/year
Solar panels' annual efficiency decline	0.4%	0.4%	0.4%
Discount rate	8.0%	8.0%	8.0%

Table 25: Input factors for NPV analysis for scenario 2, co-ownership

7.2.2. Commercial ownership

The second ownership structure considered under scenario 2 is of commercial ownership and leasing of the solar panels to the co-ownerships.

As in scenario 1, it is assumed that the annual lease (including VAT) charged for the co-ownerships is equal to the annual value of the solar panel production under the private ownership structure. This assumption is made in order to explicitly calculate the return on investment for a commercial ownership structure. If the return on investment for the commercial actor is higher than that for the private co-ownership, there is room for transferring some of that increase to the households through lower leasing fees.

The main differences in input factors for the commercial ownership structure compared to the private ownership structure are that 1) the commercial investors gets a VAT refund on the initial investment, and must charge VAT on the annual lease, 2) the commercial investors is subject to corporate tax on any profits 3) the depreciation of assets reduces some of the tax burden, 4) an insurance cost is assumed.

The input factors used in the NPV analysis are summarized in table 26 below:

	Low **Co-ownership Utsikten**	**Average** **Co-ownership T5**	**High** **Co-ownership Ådlandsbyen West –S**
Installed capacity	174 kW(p)	266 kW(p)	109 kW(p)
Initial investment cost	2,088,000 NOK	3,192,000 NOK	1,380,000 NOK
Inverter reinvestment year 15	292,320 NOK	446,880 NOK	183,120 NOK
O&M cost for year 1	19,575	29,925 NOK	12,263 NOK
O&M escalation rate	0.25%	0.25%	0.25%
Annual insurance cost	6,525 NOK	9,975 NOK	4,088 NOK
Initial cost of green certificate registration	30,000 NOK	30,000 NOK	30,000 NOK
Initial Enova subsidy	0	0	0
Annual revenues from sales of green certificates for year 1	16,789 NOK	70,856 NOK	10,840 NOK
Annual revenues from local consumption and export of electricity for year 1	35,426 NOK/year	26,524 NOK/year	37,781 NOK/year
Solar panels' annual efficiency decline	0.4%	0.4%	0.4%
Discount rate	8.0%	8.0%	8.0%
Depreciation rate for tax accounting	5%	5%	5%
Depreciation period inverter	15 years	15 years	15 years
Depreciation period for panels and other equipment	30 years	30 years	30 years
Corporate tax rate	27%	27%	27%

Table 26: Input factors for NPV analysis for scenario 2 commercial ownership.

7.2.3. Results

The results from the NPV analysis for co-ownerships with the lowest, average and highest value per kW(p) can be seen in table 27 below.

NPV results for scenario 2 in NOK/kW(p)			
	Low	**Average**	**High**
Private ownership	-13,245	-12,298	-11,375
Commercial ownership	-11,312	-10,542	-9,836

Table 27: NPV results for scenario 2

The NPV across all co-ownerships and ownership structures are still negative under scenario 2. The typical results for co-ownerships are around -12,300 NOK/kW(p) and -10,540 NOK/kW(p) for private and commercial ownership structures respectively. These results are better than for scenario 1, due to economies of scale relating to the installation costs and the additional revenues from the sales of green certificates.

The range in NPV results between co-ownerships is smaller than for individual households under scenario 1, because the electricity production and consumption of the different categories of households are pooled within the co-ownerships. The difference in results between co-ownerships is caused by the ratio of production to consumption, the fit between consumption and production, and differences in the solar panels' capacity factors.

Under scenario 2 the commercial ownership structures yield better results than the private ownership structures. The main reason for this is that the benefit to the commercial owner of not paying VAT on the upfront investment outweighs the disadvantage of having to charge VAT on the annual lease and the cost of insurance. In addition, compared to scenario 1, private ownership structures are no longer eligible for the ENOVA subsidy, and this point of difference which emerged under scenario 1 is therefore no longer present.

7.3. Scenario 3

Under the third regulatory scenario it is assumed that the plus customer agreement is extended to cover the electricity consumption and production of all the residential buildings in ZVB. A schematic representation of scenario 3 can be seen in figure 19.

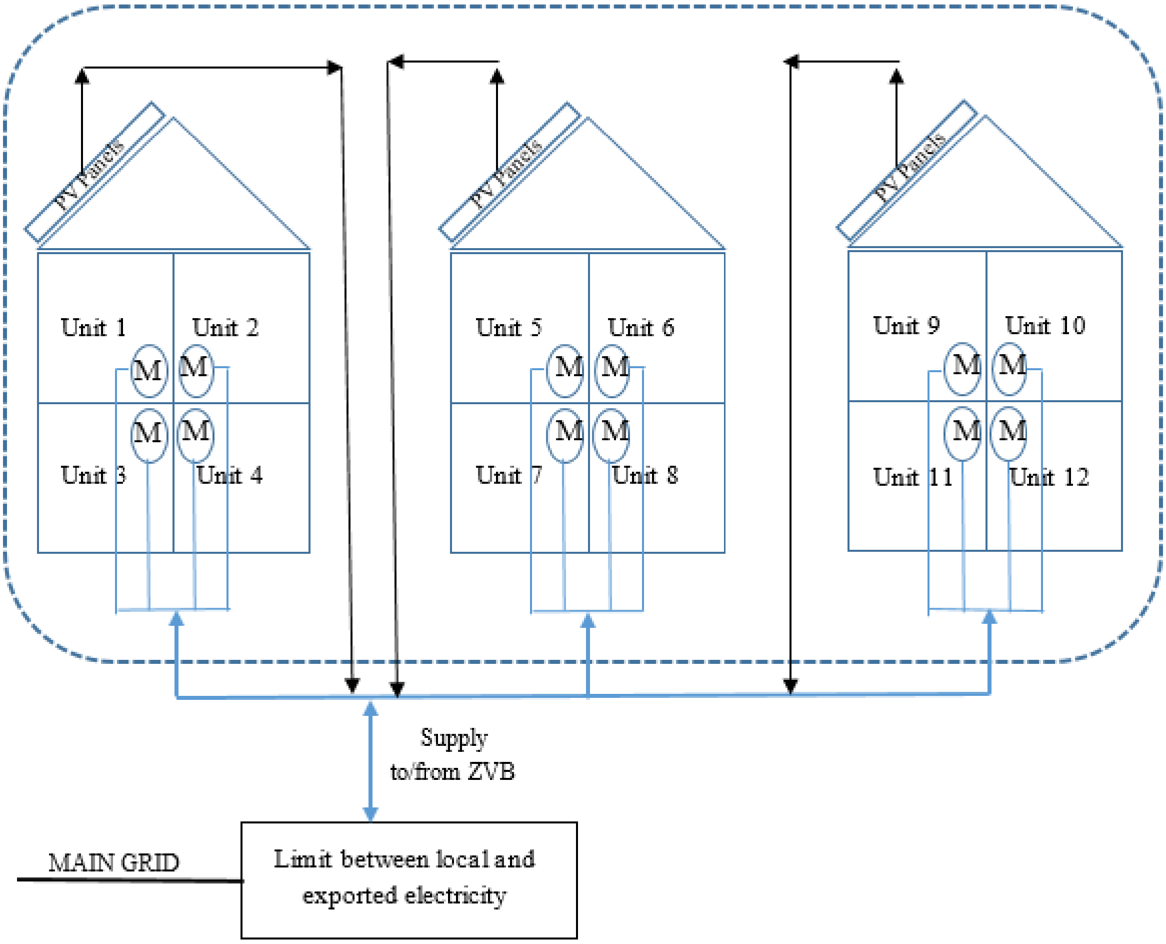

Figure 19: Schematic representation of the solar panel system under scenario 3

The principle of sharing of the DG resources is the same as under scenario 2, the only difference being that pooling of electricity consumption and production is allowed not only within a co-ownership, but also across the 21 different co-ownerships with solar panels in ZVB.

In the following subsections, the NPV input factors for private and commercial ownership structures are presented.

7.3.1. Common ownership

Under this ownership structure, a common ownership entity owns the solar panels installed in ZVB. This can be considered as a group of all the co-ownerships in ZVB. The entire electricity production from the solar panels in ZVB is therefore shared among all the households.

7.3.1.1. Revenues

7.3.1.1.1. The value of local electricity consumption and export to the grid

The calculation was carried out using the method described in section 7.1.1.1.1. For all the buildings with solar panels in ZVB, the share of production used locally was found to be 35.3%, with an average value of electricity produced of 0.464 NOK/kWh. The value of the annual production for is 1,364,739 NOK.

7.3.1.1.2. Revenues from selling green certificates

The large scale of the solar panel installations makes it profitable to register for the green certificates scheme. Therefore, an income of 0.17 NOK/kWh is assumed from selling green certificates over the 17 year period as explained in section 4.3.5.

It is assumed that the panel efficiency decreases by 0.4% annually, thus leading to an annual decrease in all production-related revenues.

7.3.1.2. Costs

The investment cost is 15,000 NOK/kW(p) including VAT. The insurance cost is assumed to be 0% and O&M to be 0.75.% of the investment cost.

The total installed capacity of the solar panels is 4,037 kW(p), and therefore a fee of 30,000 NOK must be paid to register for the green certificates scheme.

7.3.1.3. Subsidies

Under the current government regulations, this ownership structure will not be eligible for the Enova subsidy, which only covers individual households.

7.3.1.4. Taxation and depreciation

The common ownership structure is assumed to be a not-for-profit entity. Therefore, corporate tax and depreciations are not taken into account in the calculations.

7.3.1.5. Discount rate

The real discount rate of 8% is used as discussed in section 6.5.1.

7.3.1.6. Summary of NPV input factors

All residential buildings in ZVB	
Installed capacity	4,037 kW(p)
Initial investment cost	60,555,000 NOK
Inverter reinvestment year 15	8,477,700 NOK
O&M cost for year 1	454,163 NOK
O&M escalation rate	0.25%
Annual insurance cost	0
Initial cost of green certificate registration	30,000 NOK
Initial Enova subsidy	0
Annual revenues from selling green certificates	500,070 NOK
Annual revenues from local consumption and export of electricity for year 1	1,364,739 NOK/year
Solar panels' annual efficiency decline	0.4%
Discount rate	8%

Table 28: Input factors for NPV analysis for scenario 3, common ownership

7.3.2. Commercial ownership

A commercial actor owns the solar panel infrastructure, which is then leased to the residents. However, the commercial actor is assumed to be responsible for the normal operating costs of the infrastructure.

As in scenario 1, it is assumed that the annual lease (including VAT) charged for the co-ownerships is equal to the annual value of the solar panel production under the private ownership structure. This assumption is made in order to explicitly calculate the return on investment for a commercial ownership structure. If the return on investment for the commercial actor is higher than that for the private co-ownership, there is room for transferring some of that increase to the households through lower leasing fees.

The main differences in input factors for the commercial ownership structure compared to the private ownership structure are that 1) the commercial investor gets a VAT refund on the initial investment, and must charge VAT on the annual lease, 2) the commercial investor is subject to corporate tax on any profits 3) the depreciation of assets reduces some of the tax burden, 4) an insurance cost is assumed.

A summary of the input factors for the NPV analysis can be seen below.

Scenario 3: All residential buildings in ZVB	
Installed capacity	4,037 kW(p)
Initial investment cost	48,444,000 NOK
Inverter reinvestment year 15	6,782,160 NOK
O&M cost for year 1	454,163 NOK
O&M escalation rate	0.25%
Annual insurance cost	151,388 NOK
Initial cost of green certificate registration	30,000 NOK
Initial Enova subsidy	0
Annual revenues from sale of green certificates for year 1	400,056 NOK
Annual revenues from local consumption and export of electricity for year 1	1,091,791 NOK/year
Solar panels' annual efficiency decline	0.4%
Discount rate	8%
Depreciation rate for tax accounting	5%
Depreciation period inverter	15 years
Depreciation period for panels and other equipment	30 years
Corporate tax rate	27%

Table 29: Input factors for NPV analysis for scenario 3, commercial ownership

7.3.3. Results

The results from the NPV analysis for scenario 3 can be seen in table 30 below.

NPV results for scenario 3 in NOK/kW(p)	
Private ownership	-12,144
Commercial ownership	-10,398

Table 30: NPV results for scenario 3

Both for the commercial and private ownership structures, the NPV is still negative under scenario 3 with an estimated loss of 10,398 NOK/kW(p) and 12,144 NOK/kW(p) respectively.

Compared with the average case for scenario 2, the results are marginally better. This is due to a slightly higher share of the solar panels' production being consumed locally in scenario 3.

The commercial ownership model performs better than the private ownership model, due to the refund of VAT on the initial investment. This outweighs the disadvantage of paying the annual insurance cost, and the reduced annual revenues due to the VAT charge. Since the investment is still a loss, and the depreciation of assets is larger than the annual revenues, no corporate tax applies for the commercial ownership structure.

7.4. Scenario 4

Under the fourth scenario, the same two ownership structures as under scenario 3 are considered. All parameters are the same, with the only difference being that the electricity consumption of the non-residential buildings is also considered as local consumption under the plus customer agreement.

The inclusion of the buildings without solar panels increases the share of local consumption to 42.66%. This results in an increase in the average value per kWh produced to 0.499 NOK/kWh. Further, the total annual value of production increases to 1,469,171 NOK in the first year (1,175,337 NOK for the commercial ownership structure). All other numbers relating to costs and incomes remain the same as under scenario 3.

7.4.1. Results

The results from the NPV analysis for scenario 4 can be seen in table 31 below.

NPV results for scenario 4 in NOK/kW(p)	
Private ownership	-11,863
Commercial ownership	-10,174

Table 31: NPV results for scenario 4

The NPV results for scenario 4 are still negative for both ownership structures, but with slightly better results than under scenario 3. This is due to the increased value of production caused by the inclusion of the electricity consumption of the non-residential buildings in the pooling.

The better performance of the commercial ownership structure is similar to scenario 3, for the same reasons.

7.5. Summary of NPV results

The results for scenarios 1-4 are presented in table 32 below.

Summary of NVP results in NOK/kW(p)								
	Scenario 1			**Scenario 2**			**Scenario 3**	**Scenario 4**
Ownership	**Low**	**Average**	**High**	**Low**	**Average**	**High**		
Private	-16,432	-14,260	-8,843	-13,245	-12,298	-11,375	-12,144	-11,863
Commercial	-15,217	-14,361	-13,116	-11,312	-10,542	-9,836	-10,398	-10,174

Table 32: Summary of NPV results in NOK/kW(p) for scenarios 1-4

On the basis of the assumptions used in the analysis, the solar panel investment results in a negative NPV for all scenarios and ownership structures, as can be seen in the table above. However, the results show a progressive improvement from scenario 1 through to scenario 4.

The effect of an increase in local consumption plays a minor role in decreasing the loss on investment. Compared to the overall loss, the change from scenario 2 to 4 is only -3.5%. This is caused by the pooling effect, as the consumption and production of all the co-ownerships are pooled in scenario 3, and as the buildings without solar panels are included in scenario 4.

Of greater importance is the shift from individual households to co-ownerships, where economies of scale in terms of installation and the profitability of registering for green certificates reduce the loss by 14% and 29% for the private and commercial ownership structures respectively.

In scenario 1, the two ownership structures perform similarly for the average case. However, the private ownership structure sees a far larger range of results due to the effect of the Enova subsidy, which covers a larger part of the investment cost for households with lower installed production capacity.

For scenarios 2, 3 and 4, the commercial ownership structure achieves a somewhat lower loss than the private investment structures. The main reason for this is that the benefits from the VAT refund on the upfront investment outweigh the reduced revenues caused by the necessity to pay VAT on the annual lease. In addition, the relatively small size of revenues compared to annual depreciation reduces the amount of tax paid on profits. Both these advantages are a consequence of the fact that there is a net loss on the investment. However, it will be illustrated in chapter 8 that as the relative performance of the two ownership structures change the input parameters are improved and the investment moves towards a positive return.

7.6. Effect of pooling

Under different scenarios, the share of electricity produced from solar panels used locally differs. This difference can be explained by the effect of pooling, whereby production and consumption are aggregated at different levels. The variation in local consumption also has an impact on the average value of electricity produced by the solar panels, and therefore on the NPV.

The difference between the average value per kWh produced and the share of production used locally for the four scenarios can be seen in table 33 below.

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Overall average share of production consumed locally	33.5%	34.4%	35.3%	42.6%
Share of production consumed locally (range)	7.4 % -74.5%	13.3% - 62.2%		
Overall average value per kWh produced	0.457 NOK/kWh	0.46 NOK/kWh	0.464 NOK/kWh	0.499 NOK/kWh
Average value per kWh produced (range)	0.33-0.65 NOK/kWh	0.36-0.59 NOK/kWh		
Overall average value of production in year 1	332.9 NOK/kW(p)	335.1 NOK/kW(p)	338.1 NOK/kW(p)	363.9 NOK/kW(p)
Value of production in year 1 (range)	234.4 – 476.3 NOK/kW(p)	254.5 – 433.3 NOK/kW(p)		
Value of ZVB production[47] in first year (NOK)	1,344,110 NOK	1,352,732 NOK	1,364,739 NOK	1,469,171 NOK

Table 33: Summary of results for different levels of pooling

The difference in the average value per kWh produced between scenarios 1, 2 and 3 is very limited. This can in part be attributed to the fact that a limited number of consumption profiles have been used to represent the 685 individual households in this analysis. In practice, the consumption patterns across households would probably vary more strongly, and consequently the effect of pooling would be higher.

Part of the reason why the share of electricity consumed locally is so low, is the large amount of installed capacity relative to consumption, which is a consequence of the ambition to achieve a near-zero emission building area. The share of electricity used locally, and hence the average value per kWh produced would increase significantly if the installed capacity were reduced.

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[47] Excluding revenues from green certificates

This suggests that combining a smaller amount of solar panels with a second renewable energy source (for example biogas), could have a positive impact on the renewable energy system in ZVB. See appendix I for a numerical illustration of the effect of decreasing the amount of installed capacity on the average value per kWh and the NPV/kW(p).

8. Sensitivity analyses

There is uncertainty regarding the value of several input factors used in the NPV analysis of the investment in solar panels in ZVB. This includes the future electricity price level, grid tariff structure, panel output, installation cost and subsidies. To cover this uncertainty quantitatively, two types of sensitivity analyses have been conducted. In the first, worst and best case scenarios have been developed around the base case, to produce a range of NPV results.

The second sensitivity analysis considers the effect on the NPV results from changes in three key parameters: the average wholesale electricity price, the initial installation cost per kW(p), and the discount rate. This analysis is performed in order to illustrate the necessary changes in these parameters to achieve a positive NPV.

8.1. Worst, base and best case sensitivity analysis

A worst and best case was constructed by respectively employing low and high assumptions for several input factors. The assumptions used in the sensitivity analysis are summed up in table 34, and explanations for the choice of assumptions are found below.

Parameter	Worst case	Best case
Electricity price	-5%	+100%
Panel efficiency	-5%	+15%
Grid tariffs	Variable tariff reduced by 0.09 NOK/kWh	No changes
Enova subsidy	No investment subsidies	No changes
Green certificates	Green certificates received only for surplus production	Green certificates received for entire period & production of project. Registration cost of 5,000 NOK for small-scale projects
Investment cost	Including and excluding VAT respectively the installation costs are assumed to be 21,250 and 17,000 NOK/kW(p) for medium-scale installations and 17,000 and 13,600 NOK/kW(p) for small-scale installations[48]	Including and excluding VAT respectively installation costs are assumed to be 12,500 and 10,000 NOK/kW(p) for medium-scale installations and 13,750 and 11,000 NOK/kW(p) for small-scale installations[49].

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[48] 85% of the maximum installation costs from the EIA national report from 2014 (Holm, 2014)

[49] Equal to low estimate from IEA national report from 2014 (Holm, 2014)

Table 34: Parameters used in the sensitivity analysis for worst and best cases.

Electricity prices: As discussed in section 4.2.10, there is considerable uncertainty regarding the long-term development of electricity prices in the Nordic market. Even though some analysts assume an increase in prices from 2020, it is still possible that in the future average electricity prices could move in either direction. To account for this possibility, a 5% reduction and a 100% increase in the wholesale electricity price is used for the worst case and the best case respectively.

Panel efficiency: Solar panel technology is continuously improving. For the best case, an efficiency gain of 15% is used. Due to uncertainty regarding climatic development, there is a risk that the actual output from the panels is lower than that anticipated in the analysis conducted by Multiconsult. Therefore, for the worst case, a reduction of annual production of 5% is assumed.

Grid tariffs: Costello and Hempkill (2014) describe how an end consumer with DG can impose an unfair burden on end consumers without DG, if the grid companies cover part of their fixed costs through volumetric tariffs (Costello & Hempkill, 2014). The Norwegian DSOs are currently operating in this manner. However, as documented in section 4.3.3.3, NVE is considering a move away from this tariff structure, towards a system of charging the end consumer only for the marginal cost of transporting electricity through volumetric tariffs.

In the worst case, it is assumed that BKK’s variable grid tariff reduces by 0.09 NOK/kWh to 0.255 NOK/kWh, as explained in section 4.3.3.3. This would decrease the value of electricity used locally, since the alternative cost of buying grid electricity is reduced.

Enova subsidies: At present there are very strict requirements for receiving Enova’s investment subsidy for solar panel installations. Even under scenario 1, it is not completely certain that the individual house owners will receive the investment subsidy. In the worst case, it is assumed that even individual owners do not receive the subsidy. For the best case, it is assumed that the support scheme stays the same as in the base case.

Green certificates: As discussed in section 4.3.2.2, NVE is proposing that in the future, plus customers will only receive green certificates on their surplus production. For the worst case, it is assumed that this regulation comes into force, and therefore the solar panel installations at ZVB will only receive green certificates for the part of the production that is exported to the grid.

Further, as explained in section 4.3.5, the high registration fee for entering the green certificate scheme is currently barring small-scale producers of renewable energy from benefitting from it. In the best case it is assumed that the fee for registering is reduced from 15,000 NOK to 5,000 NOK for the smallest category of customers (<100kW). In addition, it is assumed that the scheme is extended beyond 2020, so that the benefit of green certificates will be available over the entire lifetime of the project.

Solar panel investment cost: In the reports described in section 6.4, it is indicated that there is considerable uncertainty regarding the current and future cost of solar panel installations in Norway. In the worst case, 85% of the highest investment cost from the EIA national survey is used. In the best case, it is assumed that towards 2018 the market develops strongly and the price is assumed to be equal to the low estimate from the 2014 national survey for solar panels.

8.1.1. Results

The results from the sensitivity analysis described above can be seen in table 35 below.

NPV in NOK/kWh for Private Ownership Structures								
	Scenario 1			**Scenario 2**			**Scenario 3**	**Scenario 4**
	Low	**Average**	**High**	**Low**	**Average**	**High**		
Worst case	-20,846	-19,981	-18,735	-16,069	-15,290	-14,585	-15,148	-14,923
Base case	-16,458	-14,286	-8,868	-13,276	-12,329	-11,405	-12,175	-11,894
Best case	-7,471	-5,428	-2,026	-7,828	-6,607	-5,432	-6,454	-6,106
NPV in NOK/kWh for Commercial Ownership Structures								
	Scenario 1			**Scenario 2**			**Scenario 3**	**Scenario 4**
	Low	**Average**	**High**	**Low**	**Average**	**High**		
Worst case	-17,526	-16,295	-15,837	-13,669	-13,034	-12,503	-12,899	-12,719
Base case	-15,243	-14,861	-13,142	-11,343	-10,573	-9,867	-10,429	-10,204
Best case	-8,675	-7,638	-6,309	-7,095	-6,242	-5,576	-6,105	-5,881

Table 35: NPV results from case-based sensitivity analysis in NOK/kW(p)

As can be seen from the table, in all cases the NPV results are negative, but they vary strongly between the worst and best cases. For the average household in scenario 1 the range is -16,295 to -7,638 NOK/kW(p), for the average co-ownership in scenario 2 -13,034 to -6,242 NOK/kW(p), for scenario 3 -12,899 to -6,105 NOK/kW(p) and for scenario 4 -12,719 to -5,881 NOK/kW(p). This illustrates the significant uncertainty related to electricity prices, subsidies, investment cost, green certificates and other regulations.

8.2. Sensitivity analysis on key input parameters

The second sensitivity analysis has been performed on three input factors: the wholesale electricity price, the upfront investment cost and the discount rate. As discussed in sections 6.1, 6.4 and 6.5, these parameters are characterized by uncertainty, and each has an important impact on the NPV results. All other input parameters are the same as in the previous analysis.

Firstly, for investment cost, a range from the currently assumed level of 18,900 to 15,000 NOK/kW(p) for small and medium sized installation respectively, to 3,000 NOK/kW(p) was chosen.

Secondly, for the wholesale electricity price, an increase in the cost per kWh of 0% to 400% was used. This corresponds to a wholesale price range from 0.32 NOK/kWh to 1.60 NOK/kWh[50].

Thirdly, the effect of a change in the discount rate was explored by employing a range from the currently assumed 8% down to 0%.

The analysis was conducted both for the private and commercial ownership structures. Scenario 4 is used to illustrate the effect of changing the parameters. The results for scenario 1-3 can be found in appendices J-M.

8.2.1. Results

The results from the sensitivity analysis for private and commercial ownership structures are shown for scenario 4. In the sections 8.2.1.1-8.2.1.5, the discount rates 8%, 6%, 4%, 2% and 0% have been applied respectively. For each discount rate the effect of changes in the wholesale electricity price and investment cost on the NPV/kW(p) has been analyzed. A summary of the results is provided in section 8.2.1.6.

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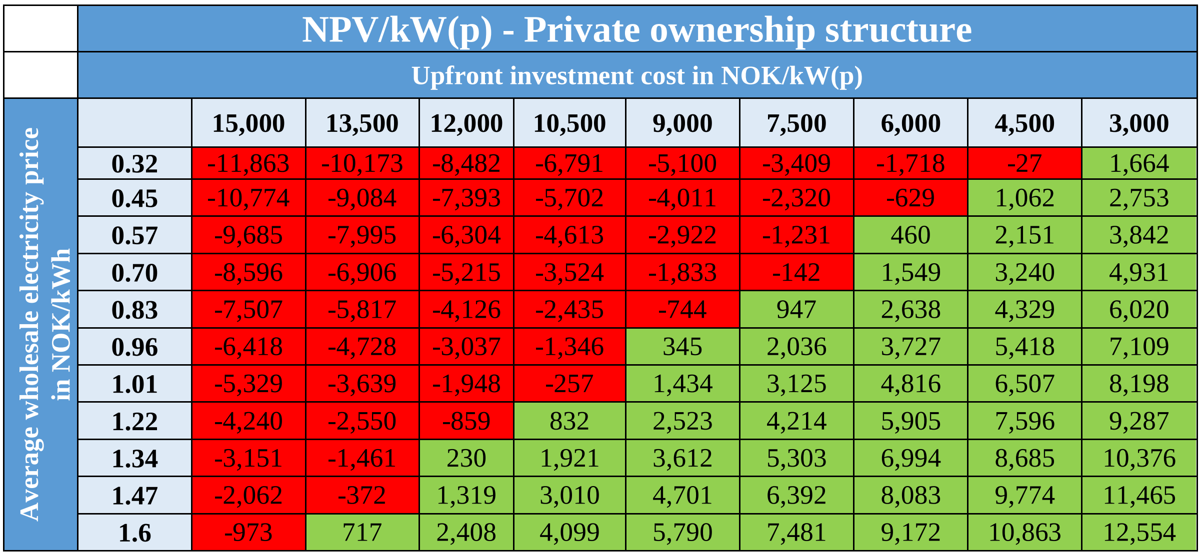
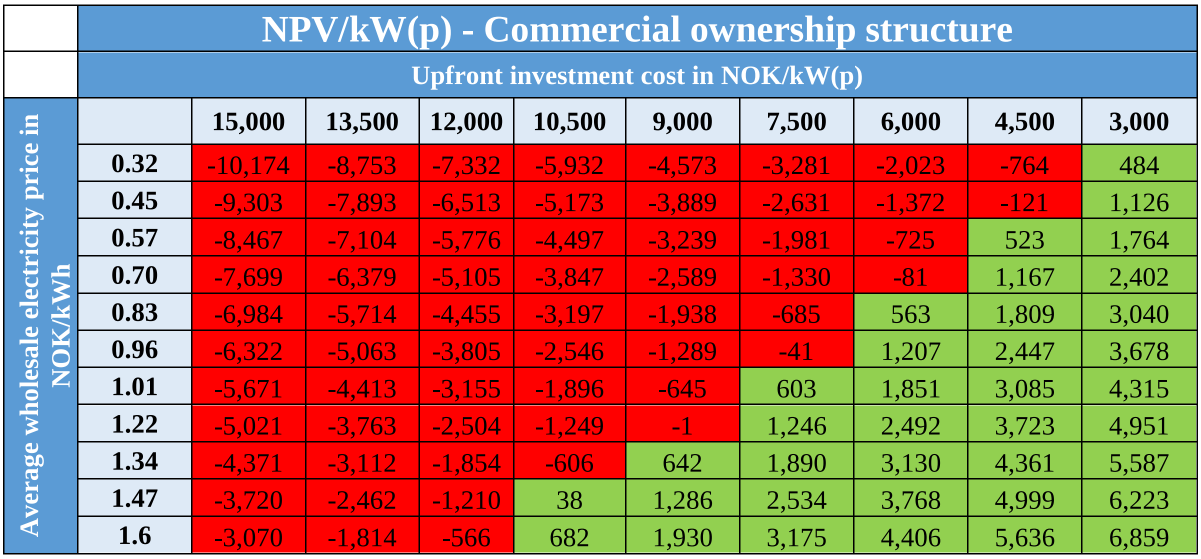
[50] For the relationship between the wholesale electricity price and the value of the solar panels' production, see section 7.1.1.1.1. The relationship is also illustrated for scenario 4 in appendix O.

8.2.1.1. Discount rate: 8 percent



	NPV/kW(p) - Private ownership structure									
	Upfront investment cost in NOK/kW(p)									
Average wholesale electricity price in NOK/kWh		15,000	13,500	12,000	10,500	9,000	7,500	6,000	4,500	3,000
	0.32	-11,863	-10,173	-8,482	-6,791	-5,100	-3,409	-1,718	-27	1,664
	0.45	-10,774	-9,084	-7,393	-5,702	-4,011	-2,320	-629	1,062	2,753
	0.57	-9,685	-7,995	-6,304	-4,613	-2,922	-1,231	460	2,151	3,842
	0.70	-8,596	-6,906	-5,215	-3,524	-1,833	-142	1,549	3,240	4,931
	0.83	-7,507	-5,817	-4,126	-2,435	-744	947	2,638	4,329	6,020
	0.96	-6,418	-4,728	-3,037	-1,346	345	2,036	3,727	5,418	7,109
	1.01	-5,329	-3,639	-1,948	-257	1,434	3,125	4,816	6,507	8,198
	1.22	-4,240	-2,550	-859	832	2,523	4,214	5,905	7,596	9,287
	1.34	-3,151	-1,461	230	1,921	3,612	5,303	6,994	8,685	10,376
	1.47	-2,062	-372	1,319	3,010	4,701	6,392	8,083	9,774	11,465
	1.6	-973	717	2,408	4,099	5,790	7,481	9,172	10,863	12,554

Figure 20: Results from sensitivity analysis of private ownership for scenario 4 assuming a discount rate of 8%



	NPV/kW(p) - Commercial ownership structure									
	Upfront investment cost in NOK/kW(p)									
Average wholesale electricity price in NOK/kWh		15,000	13,500	12,000	10,500	9,000	7,500	6,000	4,500	3,000
	0.32	-10,174	-8,753	-7,332	-5,932	-4,573	-3,281	-2,023	-764	484
	0.45	-9,303	-7,893	-6,513	-5,173	-3,889	-2,631	-1,372	-121	1,126
	0.57	-8,467	-7,104	-5,776	-4,497	-3,239	-1,981	-725	523	1,764
	0.70	-7,699	-6,379	-5,105	-3,847	-2,589	-1,330	-81	1,167	2,402
	0.83	-6,984	-5,714	-4,455	-3,197	-1,938	-685	563	1,809	3,040
	0.96	-6,322	-5,063	-3,805	-2,546	-1,289	-41	1,207	2,447	3,678
	1.01	-5,671	-4,413	-3,155	-1,896	-645	603	1,851	3,085	4,315
	1.22	-5,021	-3,763	-2,504	-1,249	-1	1,246	2,492	3,723	4,951
	1.34	-4,371	-3,112	-1,854	-606	642	1,890	3,130	4,361	5,587
	1.47	-3,720	-2,462	-1,210	38	1,286	2,534	3,768	4,999	6,223
	1.6	-3,070	-1,814	-566	682	1,930	3,175	4,406	5,636	6,859

Figure 21: Results from sensitivity analysis of commercial ownership for scenario 4 assuming a discount rate of 8%

With a discount rate of 8%, substantial changes are required in either the installation cost or the wholesale cost of electricity to achieve profitability. Given the current level of installation costs, the project remains unprofitable even at a wholesale electricity price of 1.60 NOK/kWh. Similarly, the investment cost must drop to less than a third of the current level if the wholesale price stays the same. It is clear that the private ownership structure reaches profitability at a lower wholesale electricity price and at higher investment cost than the commercial structure.

8.2.1.2. Discount rate: 6 percent

	NPV/kW(p) - Private ownership structure								
	Upfront investment cost in NOK/kW(p)								
Average wholesale electricity price in NOK/kWh	**15,000**	**13,500**	**12,000**	**10,500**	**9,000**	**7,500**	**6,000**	**4,500**	**3,000**
0.32	-11,351	-9,609	-7,868	-6,126	-4,385	-2,643	-901	840	2,582
0.45	-10,025	-8,284	-6,542	-4,801	-3,059	-1,317	424	2,166	3,907
0.57	-8,700	-6,958	-5,217	-3,475	-1,734	8	1,750	3,491	5,233
0.70	-7,375	-5,633	-3,891	-2,150	-408	1,333	3,075	4,817	6,558
0.83	-6,049	-4,308	-2,566	-824	917	2,659	4,400	6,142	7,884
0.96	-4,724	-2,982	-1,241	501	2,243	3,984	5,726	7,468	9,209
1.01	-3,398	-1,657	85	1,827	3,568	5,310	7,051	8,793	10,535
1.22	-2,073	-331	1,410	3,152	4,894	6,635	8,377	10,118	11,860
1.34	-747	994	2,736	4,477	6,219	7,961	9,702	11,444	13,185
1.47	578	2,320	4,061	5,803	7,544	9,286	11,028	12,769	14,511
1.6	1,904	3,645	5,387	7,128	8,870	10,612	12,353	14,095	15,836

Figure 22: Results from sensitivity analysis of private ownership for scenario 4 assuming a discount rate of 6%

	NPV/kW(p) - Commercial ownership structure								
	Upfront investment cost in NOK/kW(p)								
Average wholesale electricity price in NOK/kWh	**15,000**	**13,500**	**12,000**	**10,500**	**9,000**	**7,500**	**6,000**	**4,500**	**3,000**
0.32	-9,916	-8,440	-6,963	-5,514	-4,119	-2,798	-1,512	-226	1,046
0.45	-8,856	-7,396	-5,974	-4,602	-3,290	-2,004	-718	559	1,830
0.57	-7,847	-6,448	-5,089	-3,782	-2,496	-1,210	73	1,345	2,608
0.70	-6,926	-5,576	-4,274	-2,988	-1,702	-416	858	2,130	3,385
0.83	-6,064	-4,766	-3,480	-2,194	-908	371	1,643	2,913	4,162
0.96	-5,258	-3,972	-2,686	-1,400	-115	1,157	2,429	3,691	4,940
1.01	-4,464	-3,178	-1,892	-606	670	1,942	3,214	4,468	5,716
1.22	-3,670	-2,384	-1,098	183	1,456	2,728	3,996	5,245	6,490
1.34	-2,876	-1,590	-304	969	2,241	3,513	4,774	6,023	7,264
1.47	-2,082	-796	482	1,754	3,026	4,299	5,551	6,800	8,038
1.6	-1,288	-5	1,268	2,540	3,812	5,079	6,328	7,578	8,812

Figure 23: Results from sensitivity analysis of commercial ownership for scenario 4 assuming a discount rate of 6%

With a discount rate of 6%, the private ownership structure requires a 1.47 NOK/kWh wholesale electricity price, or a drop in the investment cost to around 6,000 NOK/kW(p). The NPV of the commercial ownership structure is still negative at a wholesale price of 1.60 NOK/kWh, and would require a drop in the investment cost to around 4,500 NOK/kWh to be positive.

8.2.1.3. Discount rate: 4 percent

		NPV/kW(p) - Private ownership structure								
		Upfront investment cost in NOK/kW(p)								
Average wholesale electricity price in NOK/kWh		**15,000**	**13,500**	**12,000**	**10,500**	**9,000**	**7,500**	**6,000**	**4,500**	**3,000**
	0.32	-10,657	-8,844	-7,032	-5,219	-3,407	-1,595	218	2,030	3,843
	0.45	-9,000	-7,188	-5,375	-3,563	-1,750	62	1,874	3,687	5,499
	0.57	-7,344	-5,531	-3,719	-1,906	-94	1,719	3,531	5,344	7,156
	0.70	-5,687	-3,874	-2,062	-250	1,563	3,375	5,188	7,000	8,813
	0.83	-4,030	-2,218	-405	1,407	3,219	5,032	6,844	8,657	10,469
	0.96	-2,374	-561	1,251	3,064	4,876	6,688	8,501	10,313	12,126
	1.01	-717	1,095	2,908	4,720	6,533	8,345	10,157	11,970	13,782
	1.22	940	2,752	4,564	6,377	8,189	10,002	11,814	13,627	15,439
	1.34	2,596	4,409	6,221	8,033	9,846	11,658	13,471	15,283	17,096
	1.47	4,253	6,065	7,878	9,690	11,502	13,315	15,127	16,940	18,752
	1.6	5,909	7,722	9,534	11,347	13,159	14,971	16,784	18,596	20,409

Figure 24: Results from sensitivity analysis of private ownership for scenario 4 assuming a discount rate of 4%

		NPV/kW(p) - Commercial ownership structure								
		Upfront investment cost in NOK/kW(p)								
Average wholesale electricity price in NOK/kWh		**15,000**	**13,500**	**12,000**	**10,500**	**9,000**	**7,500**	**6,000**	**4,500**	**3,000**
	0.32	-9,576	-8,021	-6,466	-4,950	-3,503	-2,141	-815	510	1,818
	0.45	-8,251	-6,721	-5,242	-3,825	-2,471	-1,145	180	1,495	2,800
	0.57	-7,001	-5,552	-4,149	-2,801	-1,476	-150	1,171	2,479	3,774
	0.70	-5,867	-4,474	-3,132	-1,806	-480	846	2,156	3,463	4,747
	0.83	-4,800	-3,462	-2,136	-810	516	1,833	3,140	4,444	5,721
	0.96	-3,792	-2,466	-1,140	186	1,509	2,817	4,124	5,418	6,694
	1.01	-2,796	-1,470	-145	1,181	2,494	3,801	5,109	6,391	7,665
	1.22	-1,800	-475	851	2,171	3,478	4,785	6,088	7,364	8,633
	1.34	-805	521	1,847	3,155	4,462	5,770	7,061	8,338	9,600
	1.47	191	1,517	2,832	4,139	5,447	6,754	8,035	9,311	10,568
	1.6	1,187	2,509	3,816	5,123	6,431	7,732	9,008	10 285	11,535

Figure 25: Results from sensitivity analysis of commercial ownership for scenario 4 assuming a discount rate of 4%

With a discount rate of 4%, the private ownership structure requires a wholesale price little over 1 NOK/kWh or a drop in the investment cost to around 6,750 NOK/kW(p). The commercial ownership sees profitability at around 1.35 NOK/kWh for the wholesale price, or a drop in the investment cost to around 6,000 NOK/kWh.

8.2.1.4. Discount rate: 2 percent

	NPV/kW(p) - Private ownership structure									
	Upfront investment cost in NOK/kW(p)									
Average wholesale electricity price in NOK/kWh		**15,000**	**13,500**	**12,000**	**10,500**	**9,000**	**7,500**	**6,000**	**4,500**	**3,000**
	0.32	-9,682	-7,769	-5,855	-3,942	-2,029	-115	1,798	3,711	5,625
	0.45	-7,548	-5,635	-3,722	-1,808	105	2,018	3,932	5,845	7,758
	0.57	-5,415	-3,501	-1,588	325	2,239	4,152	6,065	7,979	9,892
	0.70	-3,281	-1,368	546	2,459	4,372	6,286	8,199	10,112	12,026
	0.83	-1,147	766	2,679	4,593	6,506	8,419	10,333	12,246	14,159
	0.96	987	2,900	4,813	6,726	8,640	10,553	12,466	14,380	16,293
	1.01	3,120	5,034	6,947	8,860	10,774	12,687	14,600	16,513	18,427
	1.22	5,254	7,167	9,081	10,994	12,907	14,821	16,734	18,647	20,560
	1.34	7,388	9,301	11,214	13,128	15,041	16,954	18,868	20,781	22,694
	1.47	9,521	11,435	13,348	15,261	17,175	19,088	21,001	22,915	24,828
	1.6	11,655	13,568	15,482	17,395	19,308	21,222	23,135	25,048	26,962

Figure 26: Results from sensitivity analysis of private ownership for scenario 4 assuming a discount rate of 2%

	NPV/kW(p) - Commercial ownership structure									
	Upfront investment cost in NOK/kW(p)									
Average wholesale electricity price in NOK/kWh		**15,000**	**13,500**	**12,000**	**10,500**	**9,000**	**7,500**	**6,000**	**4,500**	**3,000**
	0.32	-9,108	-7,441	-5 775	-4,163	-2,642	-1,220	164	1,548	2,908
	0.45	-7,402	-5,772	-4 212	-2,730	-1,318	67	1,451	2,820	4,177
	0.57	-5,807	-4,287	-2 822	-1,415	-31	1,353	2,732	4,091	5,434
	0.70	-4,369	-2,914	-1 513	-128	1,256	2,640	4,003	5,363	6,691
	0.83	-3,008	-1,610	-226	1,158	2,543	3,915	5,275	6,630	7,947
	0.96	-1,708	-323	1 061	2,445	3,827	5,187	6,546	7,887	9,204
	1.01	-421	963	2 348	3,732	5,098	6,458	7,818	9,143	10,457
	1.22	866	2,250	3 634	5,010	6,370	7,730	9,083	10,400	11,703
	1.34	2,153	3,537	4 921	6,282	7,642	9,001	10,340	11,657	12,949
	1.47	3,439	4,824	6 194	7,553	8,913	10,273	11,596	12,914	14,195
	1.6	4,726	6,106	7 465	8,825	10,185	11,536	12,853	14,170	15,441

Figure 27: Results from sensitivity analysis of commercial ownership for scenario 4 assuming a discount rate of 2%

With a discount rate of 2%, the private ownership structure requires a wholesale price little over 0.90 NOK/kWh or a drop in the investment cost to around 7,500 NOK/kW(p). The commercial ownership structure becomes profitable at around 1 NOK/kWh for the wholesale price or with a drop in the investment cost to around 6,000 NOK/kWh.

8.2.1.5. Discount rate: 0 percent

		NPV/kW(p) - Private ownership structure								
		Upfront investment cost in NOK/kW(p)								
Average wholesale electricity price in NOK/kWh		**15,000**	**13,500**	**12,000**	**10,500**	**9,000**	**7,500**	**6,000**	**4,500**	**3,000**
	0.32	-8,260	-6,200	-4,140	-2,080	-20	2,040	4,100	6,160	8,220
	0.45	-5,419	-3,359	-1,299	761	2,821	4,881	6,941	9,001	11,061
	0.57	-2,578	-518	1,542	3,602	5,662	7,722	9,782	11,842	13,902
	0.70	263	2,323	4,384	6,444	8,504	10,564	12,624	14,684	16,744
	0.83	3,105	5,165	7,225	9,285	11,345	13,405	15,465	17,525	19,585
	0.96	5,946	8,006	10,066	12,126	14,186	16,246	18,306	20,366	22,426
	1.01	8,787	10,847	12,907	14,967	17,027	19,087	21,147	23,207	25,267
	1.22	11,629	13,689	15,749	17,809	19,869	21,929	23,989	26,049	28,109
	1.34	14,470	16,530	18,590	20,650	22,710	24,770	26,830	28,890	30,950
	1.47	17,311	19,371	21,431	23,491	25,551	27,611	29,671	31,731	33,791
	1.6	20,152	22,212	24,272	26,332	28,392	30,452	32,512	34,572	36,632

Figure 28: Results from sensitivity analysis of private ownership for scenario 4 assuming a discount rate of 0%

		NPV/kW(p) - Commercial ownership structure								
		Upfront investment cost in NOK/kW(p)								
Average wholesale electricity price in NOK/kWh		**15,000**	**13,500**	**12,000**	**10,500**	**9,000**	**7,500**	**6,000**	**4,500**	**3,000**
	0.32	-8,435	-6,604	-4,774	-3,024	-1,396	114	1,586	3,057	4,496
	0.45	-6,164	-4,391	-2,715	-1,139	362	1,834	3,305	4,756	6,191
	0.57	-4,063	-2,442	-884	610	2,082	3,553	5,016	6,455	7,870
	0.70	-2,176	-631	858	2,329	3,801	5,273	6,715	8,154	9,549
	0.83	-380	1,106	2,577	4,049	5,521	6,976	8,414	9,847	11,227
	0.96	1,354	2,825	4,297	5,768	7,236	8,675	10,113	11,526	12,906
	1.01	3,073	4,545	6,016	7,488	8,935	10,374	11,812	13,204	14,577
	1.22	4,793	6,264	7,736	9,196	10,634	12,073	13,502	14,883	16,237
	1.34	6,512	7,984	9,455	10,895	12,333	13,772	15,181	16,561	17,896
	1.47	8,232	9,703	11,155	12,594	14,032	15,471	16,860	18,240	19,555
	1.6	9,951	11,416	12,854	14,293	15,731	17,158	18,538	19,918	21,215

Figure 29: Results from sensitivity analysis of commercial ownership for scenario 4 assuming a discount rate of 0%

Assuming zero percent discount rate, the private ownership structure becomes profitable at an average wholesale electricity price of 0.70 NOK/kWh or a drop in the investment cost to around 9,000 NOK/kW(p). The commercial ownership is profitable at around 0.85 NOK/kWh for the wholesale price or following a drop in the investment cost to around 7,500 NOK/kWh.

8.2.1.6. Summary

Comparing the results in sections 8.2.1.1- 8.2.1.5, it is clear that the discount rate chosen for the investment has an important impact on its profitability. Thus, the potential difference in the discount rate between the two ownership structures discussed in section 6.5 may have a large influence on their relative performance.

Further, the analysis demonstrated that a substantial reduction in either one of the three input factors, or in a combination of them, is necessary to reach a positive NPV for the solar panel installations in ZVB.

With the assumptions employed in this thesis, the private ownership structure reaches a break-even faster than the commercial ownership structure due to the requirement of VAT and taxes payable for the latter, as well as the avoidance of insurance cost for the former.

This suggests that unless the commercial investor is able to undertake the investment at a lower cost of capital, or achieves lower costs of investment or operation, it would be preferable to use a private ownership structure for the project reaches a positive NPV.

9. Risk Analysis

This chapter presents the distribution of risks discussed in section 5.2. The level of risk exposure under different ownership structures could be an important criterion in potential investors' decisions. The distribution of risks will not vary with different scenarios, and the risk analysis will therefore be presented only for the two different ownership structures considered in this thesis.

9.1. Private ownership

Under the private ownership structures, households/co-ownerships will carry all the risk related to the solar panel investment. The regulator is more inclined towards the individual household ownership structures, and there is less ambiguity regarding the regulations and support schemes. Therefore, the household ownership structure will have lower regulatory risk compared to other structures.

The household ownership structure is more prone to financial risks due to lack of diversification in the investment compared to a commercial investor.

Households may also be less well-equipped than companies to tackle the technical and O&M risks. However, the households can handle some O&M activities themselves, such as cleaning the panels, thereby reducing the risk of cost escalation.

In addition, it will be more difficult for households to hedge their risks using hybrid financial products. This will primarily be on account of lack of expertise leading to additional requirement of time and efforts to understand and manage the position for hedging.

Finally, if households wanted to sell the house, they would have to look for a potential buyer who would also be willing to buy the solar infrastructure. This likely reduces the choice of potential buyers, and could make it more difficult to sell the house. In a worst-case scenario, the households might have to sell the house without receiving any compensation for their investment in the solar panel infrastructure.

9.2. Commercial ownership

Under commercial ownership structure, the distribution of risks will be governed by the terms of the leasing agreement. The agreement can be structured in numerous ways depending on the risk preferences of the involved parties. This section will cover the risk distribution under the basic leasing model used in this thesis.

The leasing arrangement discussed in this thesis involves the residents leasing the solar panel infrastructure from the commercial owner. The commercial owner is responsible for the O&M, and hence will be exposed to the O&M-associated risks. Furthermore, the commercial owner will also carry most of the technical risks, and will have to ensure the minimum level of performance by the solar panels to the lessees.

Both the residents and the commercial owner will be exposed to regulatory risks. However, given the flexibility of having different arrangements under the leasing models, it may be comparatively easier for stakeholders to adjust the models to make them suitable for any changes in the regulatory framework.

The commercial owner will be exposed to the component of risk linked with the initial investment. However, the residents will carry the risk of any changes in the electricity prices and grid tariffs. That said, the residents can also reduce part of their risk by entering into a long-term lease at a fixed price to supply some of their electricity. This would act as an indirect hedge against any future rise in electricity prices.

Finally, the residents will carry most of the climate-associated risks such as lower electricity production due to lower degree of solar irradiation. The commercial owner will carry the other components of the climate risk of damage to the infrastructure due to storms or bad weather. However, as discussed under section 5.2.4, such risks are generally covered under insurance.

Based on the above analysis, there is large variation in a stakeholder's risk exposure under different ownership structures. Therefore, the risk preference of the individuals or entities involved can play a material role in selecting a particular ownership structure.

10. Conclusions

This thesis examined the expected return on investment in solar panel systems that aims to enable a residential area in Western Norway to achieve a near-zero emission status, under different regulatory scenarios and ownership structures, using ZVB as a case study.

Two potential ownership structures were found to be possible within the regulatory framework for distributed generation in Norway today: a private ownership structure, where the end users of the electricity own the solar panels, and a commercial ownership structure, where a commercial investor owns the solar panels and leases them to the electricity end users for an annual fee.

Four regulatory scenarios, differentiated by the level of pooling of electricity production and consumption allowed under the plus customer agreement, were analyzed.

The NPV analysis found that the planned investment in solar panels in ZVB would not achieve a positive return, under any of the regulatory scenarios or ownership structures considered in this thesis. However, the analysis demonstrated that there are substantial variations in the NPV between scenarios, ownership structures, and entities (households/co-ownerships).

The NPV findings demonstrate that under scenario 1, there is a loss of around 14,300 NOK/kW(p) for private ownership and 14,400 NOK/kW(p) for commercial ownership and leasing structures. However, the NPV differs strongly between individual households, due to the substantial variation in the installed capacity per household, different electricity consumption patterns, different solar panel capacity factors between buildings, and effect of the Enova investment subsidy, which varies with the installation size.

Under scenario 2, the loss is around 12,300 NOK/kW(p) and 10,550 NOK/kW(p) for private co-ownerships and commercial ownership structures respectively. The variation in losses across co-ownerships is considerably smaller when compared to scenario 1, due to the pooling of different household categories as well as the fact that co-ownerships are not eligible for the Enova subsidy.

When comparing results from these two scenarios, the analysis found that the NPV is generally higher under scenario 2 than under scenario 1. There are two main reasons for this: first, the larger installations reduce the investment cost due to economies of scale; secondly, the larger scale of the solar panels makes it profitable to register for the green certificate scheme, which provides an additional source of revenue. There is also a small improvement resulting from the pooling of production and consumption of all the households in a co-ownership, which leads to a 1.2% increase in the value of annual production from scenario 1 to scenario 2 on average for the entire solar panel system in ZVB.

Under scenarios 3 and 4 respectively, the losses are around 12,150 and 11,860 NOK/kW(p) for private ownership structures, and 10,450 and 10,170 NOK/kW(p) for commercial ownership structures.

The small improvements in NPV from scenario 2 to 3 and from 3 to 4 are due to the effect of pooling electricity production and consumption. For scenarios 1 to 4, the average value per kWh produced for the ZVB as a whole was found to be 0.45, 0.46, 0.465 and 0.49 NOK/kWh respectively[51]. The respective share of production used locally was 33.5%, 34.4%, 35.3% and 42.6%. Thus, the effect of pooling translates into a limited financial improvement of only 31.6 NOK/kW(p) in annual revenues from scenario 1 to scenario 4.

The sensitivity analyses showed that the NPV results could vary considerably, because of uncertainty within the input factors. For example, there remains substantial uncertainty around installation costs, electricity price development, subsidies, green certificates, installation costs and other regulations. However, even under the best case scenario developed in this thesis, the solar panel investment in ZVB incurs a loss.

The sensitivity analysis on discount rate, installation cost and wholesale electricity price demonstrated that, for the investment to be profitable, with all other factors held equal, 1) even a 0% discount rate would not be sufficient; 2) the installation cost per kW(p) would have to be reduced by a factor of 3 to 5; or 3) the wholesale electricity price would have to be more than 1.60 NOK/kWh. However, if improvements in all these three factors were to happen simultaneously, the required improvement in each would be smaller.

The NPV analysis showed similar results between the two ownership structures in scenario 1, and a lower loss for the commercial ownership structure under scenarios 2, 3 and 4. However, the better performance of the commercial structure is caused by the VAT refund on the upfront investment, and because low revenues relative to depreciation significantly reduce the tax on net profits.

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[51] Excluding the value of green certificates.

However, as demonstrated by the sensitivity analysis, as the input parameters for the investment are improved, private ownership structures reach a positive return on investment faster than the commercial ownership structures. This is due to the necessity under the commercial ownership structures of adding VAT on the annual lease[52], paying tax on profits, and paying insurance costs.

As a consequence, under conditions where the investment reaches a positive NPV, a private ownership structure is preferable. For the commercial ownership structure to achieve a better result it would have to perform substantially better than the private on costs of investment, operation or capital. However, the specifics of this performance are outside the scope of this thesis and would need further research.

In addition to these findings, three important elements relating to the share of electricity production consumed locally became apparent. First, due to the nature of the plus customer agreement, there is a substantial difference in the value of a kWh consumed locally and when exported. Therefore, given that the share of electricity used locally in the fourth scenario is just above 40% for ZVB as a whole, there may be business opportunities for technological measures that can shift demand or store electricity locally in order to better fit consumption with production. This would naturally have to be weighed against the cost of such measures.

Secondly, the relative size of electricity production to consumption affects the share of electricity consumed locally and exported to the grid. This in turn has an impact on the total value realized per unit of electricity produced. In the ZVB context, as the project aims to achieve near-zero emission status, solar panels are projected to cover a substantial part of the total electricity consumption of ZVB. Therefore, a way to potentially increase the value of panels would be to reduce the installed capacity and to combine it with another source of low-emission energy (biogas, for example), which can be used when the panels are not producing electricity.

Thirdly, as discussed in section 6.2.2, the production from solar panels better matches the consumption patterns of the commercial sector rather than the residential sector. Regulators can use this to prioritize support for solar panels used by commercial buildings.

Norway’s regulatory framework currently places limitations on the scenarios and ownership structures considered in this thesis. Within the current regulations relating to the plus customer agreement, only scenario 1 is allowed. However, it is possible that scenario 2 will be allowed

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[52] As explained in section 7.1.2.

in the future plus customer agreement. There is so far no indication from NVE that scenarios 3 and 4 would be allowed.

Other factors of importance which emerged through the analysis relate to the possible ownership structures under the current regulatory framework, and risk considerations of potential investors. Under the current regulatory framework, private ownership will be allowed for individual households under scenario 1. Private ownership is also likely to be allowed for co-ownerships under scenario 2, 3 and 4, if the regulatory framework were to allow these levels of pooling under the plus customer agreement in the future. The current regulatory framework does not explicitly allow or rule out commercial ownership structures with leasing of panels to end users, but it is likely to be allowed in the same scenarios as the private ownership structures.

Risk preferences are also a factor in choosing an ownership structure. Under private ownership structures, the households/co-ownerships would be exposed to all the risks. However, in the case of a commercial ownership and leasing of the solar panels, the risks can be distributed between the private and commercial actors, thus enabling a range of different arrangements based on risk sharing schemes.

This thesis ascertained that the business case for rooftop solar panels in Norway is substantially improved when moving from small panels linked to individual households, to larger installations shared by several households or co-ownerships. Therefore, if regulators believe that rooftop solar panels should receive support as a means of reducing the environmental impact of buildings, they should financially and practically encourage and facilitate the sharing of solar panels over several households or co-ownerships.

Finally, this thesis demonstrates that, unless there are substantial improvements in key project parameters, for solar panel systems to be economically viable in achieving a near-zero emission status for residential areas either residents would have to pay a premium, or the government would have to provide financial support.

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12. Appendix

A. Cost of electricity in Norway in 2014 and 2035

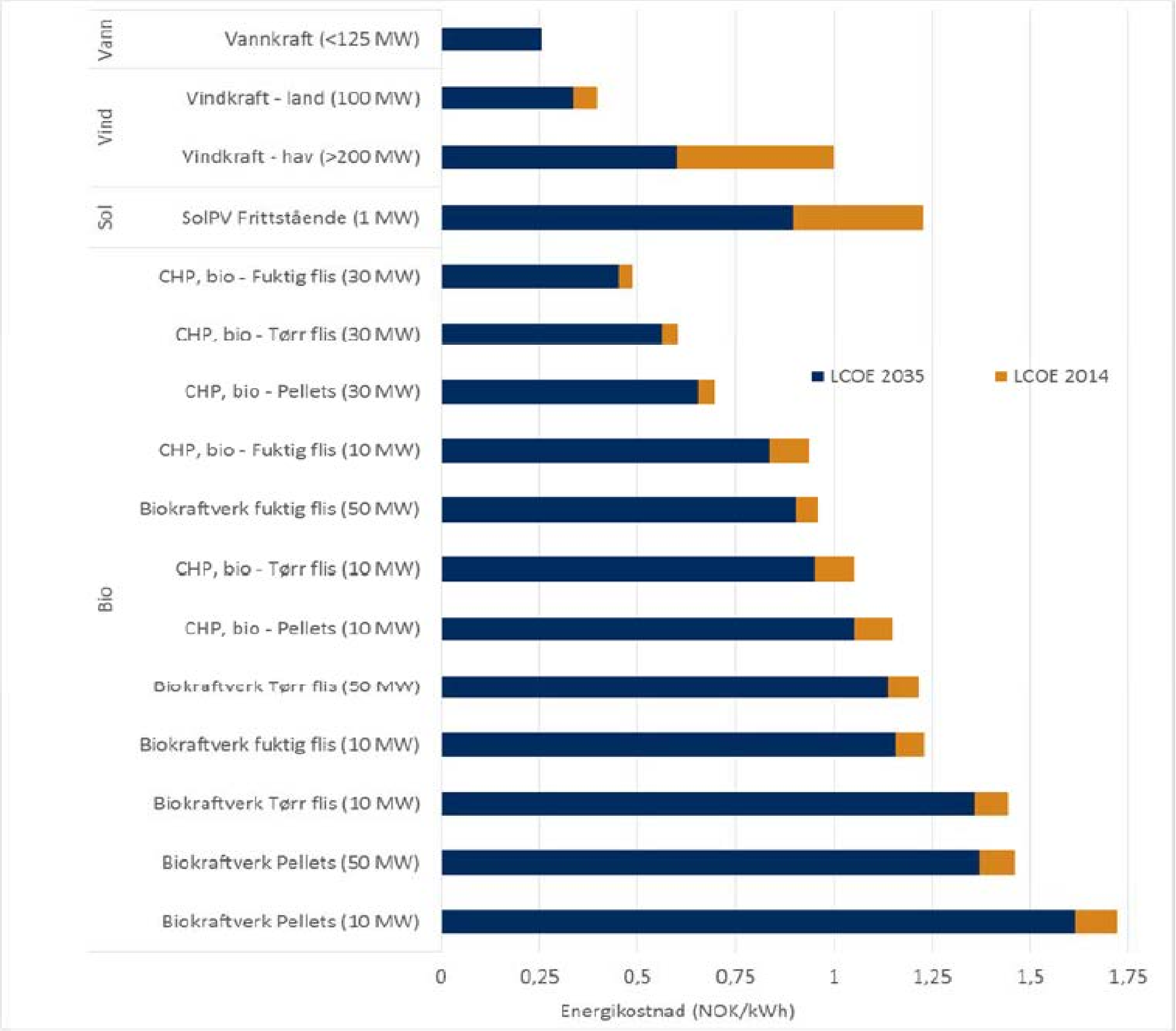

Figure 30. Cost of electricity in Norway in 2014 and 2035 (NVE, 2015f).

B. Capacity factors of the solar panels across co-ownerships in ZVB

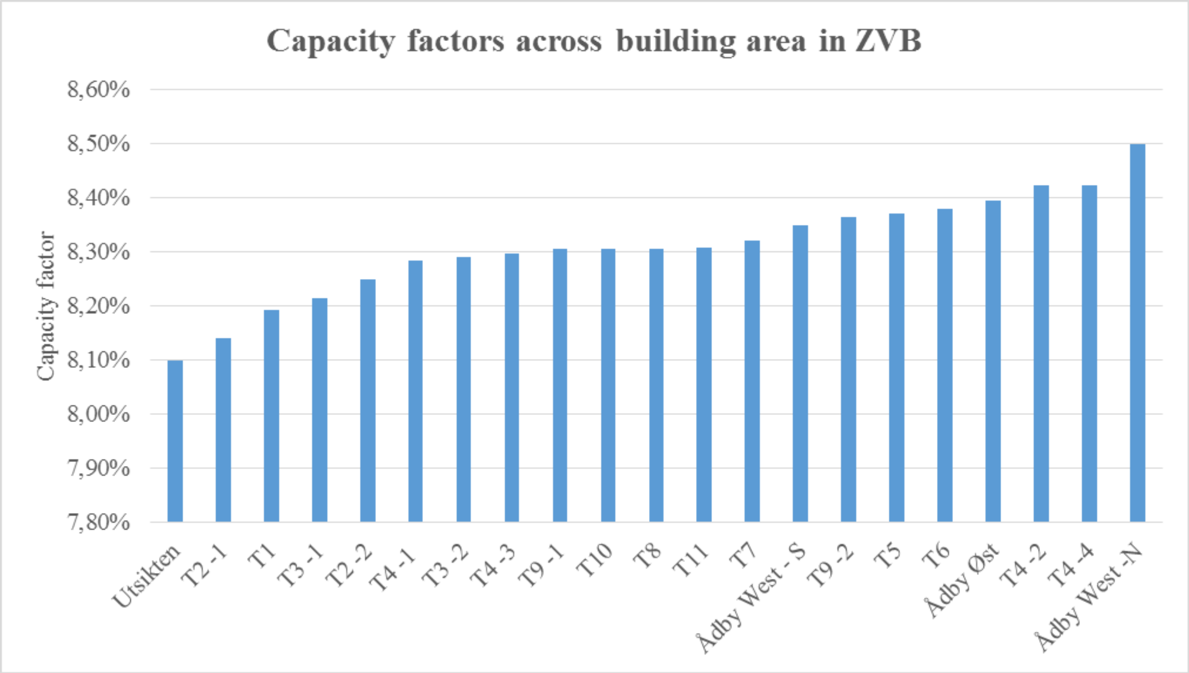

Figure 31: Capacity factors for the solar systems across building areas in ZVB (Multiconsult AS, 2015a)

C. Adjustments made to time series data from Nord Pool Spot

In Table 36, the adjustments made to the wholesale electricity price data from Nord Pool Spot's Elspot database for the NO5 regions for the years 2004-2014 can be seen. In total 24 days corresponding to 0.6% of the total data was removed.

Year	Adjustments
2014	No changes
2013	All other data moved forward one day. 01.01 deleted. Missing values for 31.12 because of moving the data forward by one day
2012	All data moved three days forward. 01.01 to 03.01 deleted. Missing values 29.12 - 31.12 because of moving the data forward by three days. Data for 29.02 deleted
2011	All data moved three days back. 31.12 - 29.12 deleted. Missing values 01.01 - 03.01 because of moving the data back by two days.
2010	All data moved two days back. 30.12 to 31.12 deleted. Missing values 01.01 - 02.01 because of moving data back by two days
2009	All data moved one day back. 31.12 deleted. Missing values 01.01 because of moving the data back by one day.
2008	All data moved forward one day. 01.01 deleted. Missing values for 31.12 because of moving the data forward by one day. Data for 29.02 deleted
2007	All data moved forward two days. 01.01-02.01 deleted. Missing values for 30.12 - 31.12 because of moving the data forward by two days.

2006	All data moved forward three days. 01.01-03.01 deleted. Missing values for 29.12 - 31.12 because of moving the forward back by two days.
2005	All data moved three days back. 29.12-31-12 deleted. Missing values for 01.01 - 03.01 because of moving the data back by three days.
2004	All data moved one day back. 31.12 deleted. Missing value for 01.01 because of moving the data back by one day. Data for 29.02 deleted.

Table 36: Adjustments made to wholesale electricity price data from Nord Pool Spot AS

D. Assumed distribution of household categories ZVB

Household category	Percentage
Single person 26-64 years old	11.6%
V2 Single person 26-64 years old	11.6%
Couple without Children, 26-64 years old	11.6%
V2 Couple without Children, 26-64 years old	11.6%
Couple without Children, 64 years old and above	3.95%
V2 Couple without Children, 64 years old and above	3.95%
Family, 26-64 years old	22.9%
V2 Family, 26-64 years old	22.9%
Total	**100.0%**

Table 37: Assumed percentage distribution of household categories in ZVB

E. Distribution of household categories of the 21 residential building areas in the ZVB

Building area	V2 Family	Family	V2 Couple (26-64)	Couple (26-64)	V2 Couple (64+)	Couple (64+)	V2 Single Person	Single Person	Total number of households
Åd V - S	16	16	8	8	3	3	8	8	**70**
Åd Ø	20	21	10	11	3	4	10	11	**90**
Åd V - N	16	16	8	8	3	3	8	8	**70**
T4 - 4	3	3	1	2	0	1	1	2	**13**
T1	7	8	3	4	1	2	3	3	**31**
T6	9	10	5	5	1	2	5	5	**42**
T11	8	7	4	4	1	1	3	4	**32**
T9 - 1	7	7	4	4	1	1	4	3	**31**
T7	9	9	5	5	1	2	4	5	**40**
T3	3	4	2	2	0	1	2	2	**16**
T4 -1	4	5	2	2	1	1	2	2	**19**
T3 - 2	9	8	4	5	1	2	4	5	**38**
T4 -2	2	3	1	2	0	1	1	2	**12**
T10	8	8	4	4	1	2	4	4	**35**
T5	9	8	4	4	2	1	4	5	**37**
T8	9	8	4	4	1	2	4	4	**36**
T2 - 1	3	2	1	1	0	1	2	1	**11**
T9 - 2	5	5	3	2	1	1	3	2	**22**
T2 - 2	3	2	2	1	0	1	1	1	**11**
T4 - 3	5	4	2	2	1	1	2	2	**19**
Utsikten	2	2	1	1	1	1	1	1	**10**
Total	**157**	**156**	**78**	**81**	**23**	**34**	**76**	**80**	**685**

Table 38: Assumed distribution of household categories of the 21 building areas in the ZVB

F. Share of electricity used locally, average value per kWh produced and total annual value of electricity production across individual households in ZVB

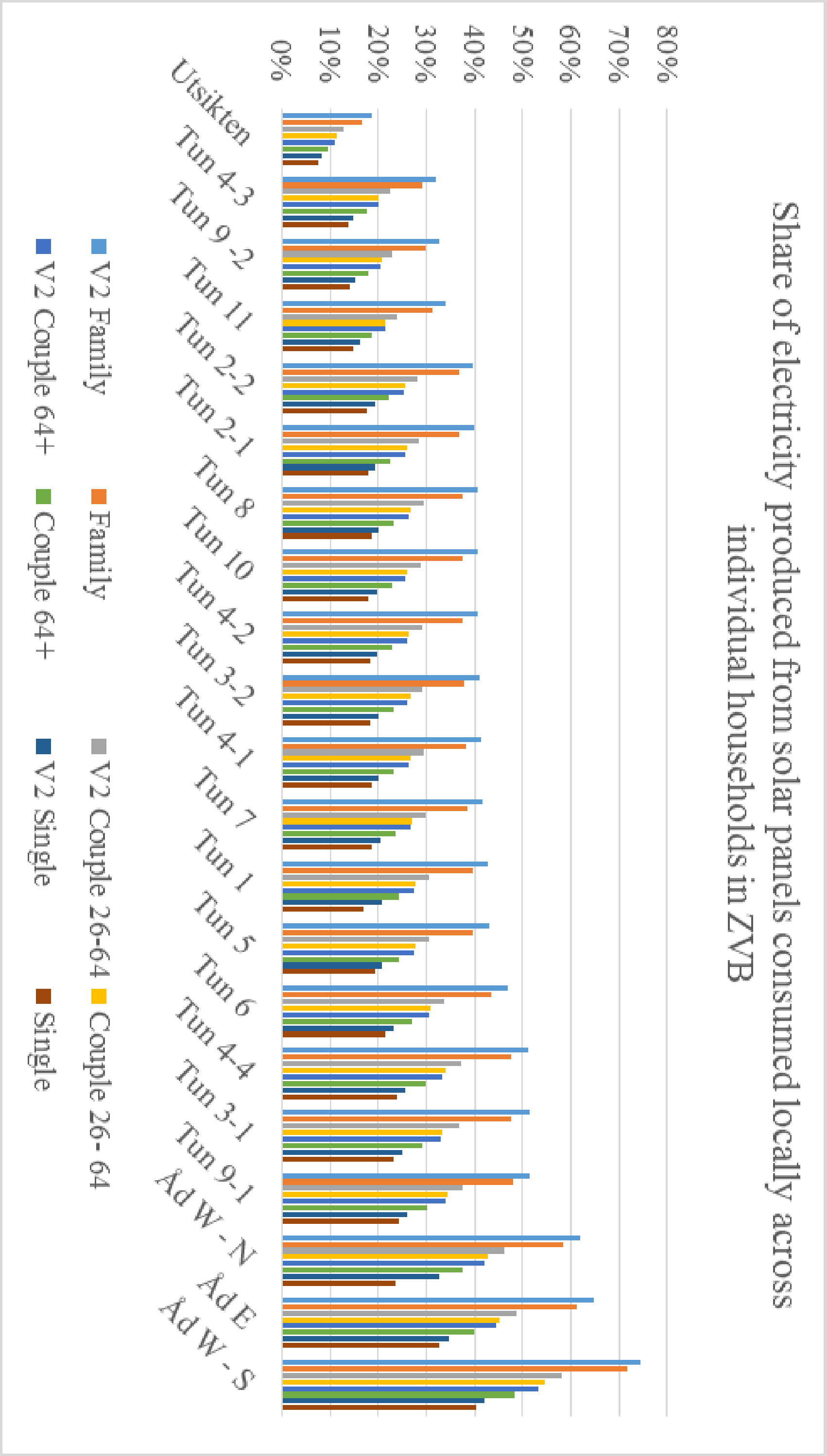

Figure 32: Share of electricity produced from solar panels consumed locally across individual households in ZVB

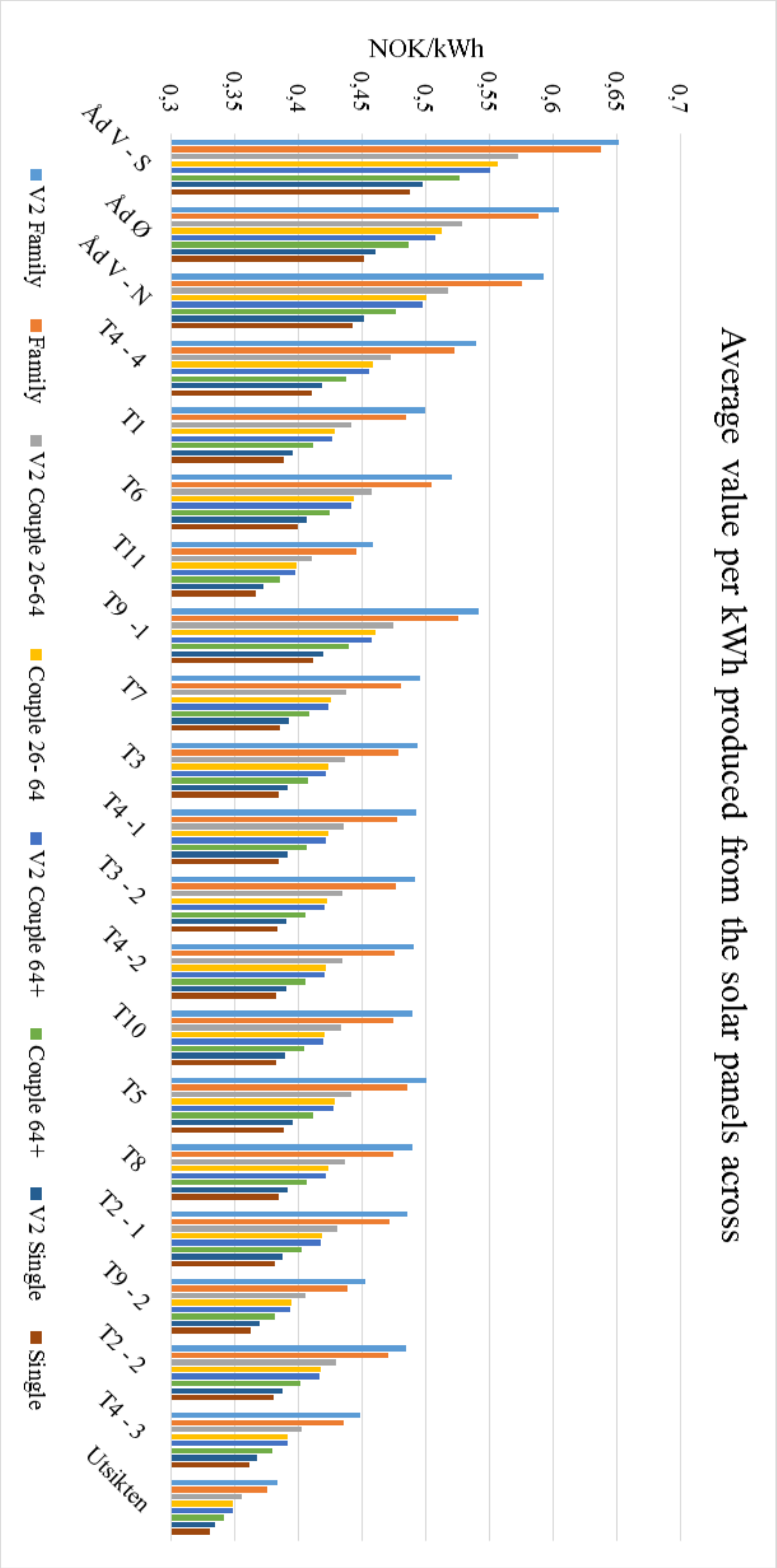

Figure 33: Average value in NOK/kWh of electricity produced from solar panels across individual households in ZVB (Exculding revenues from green certificates)

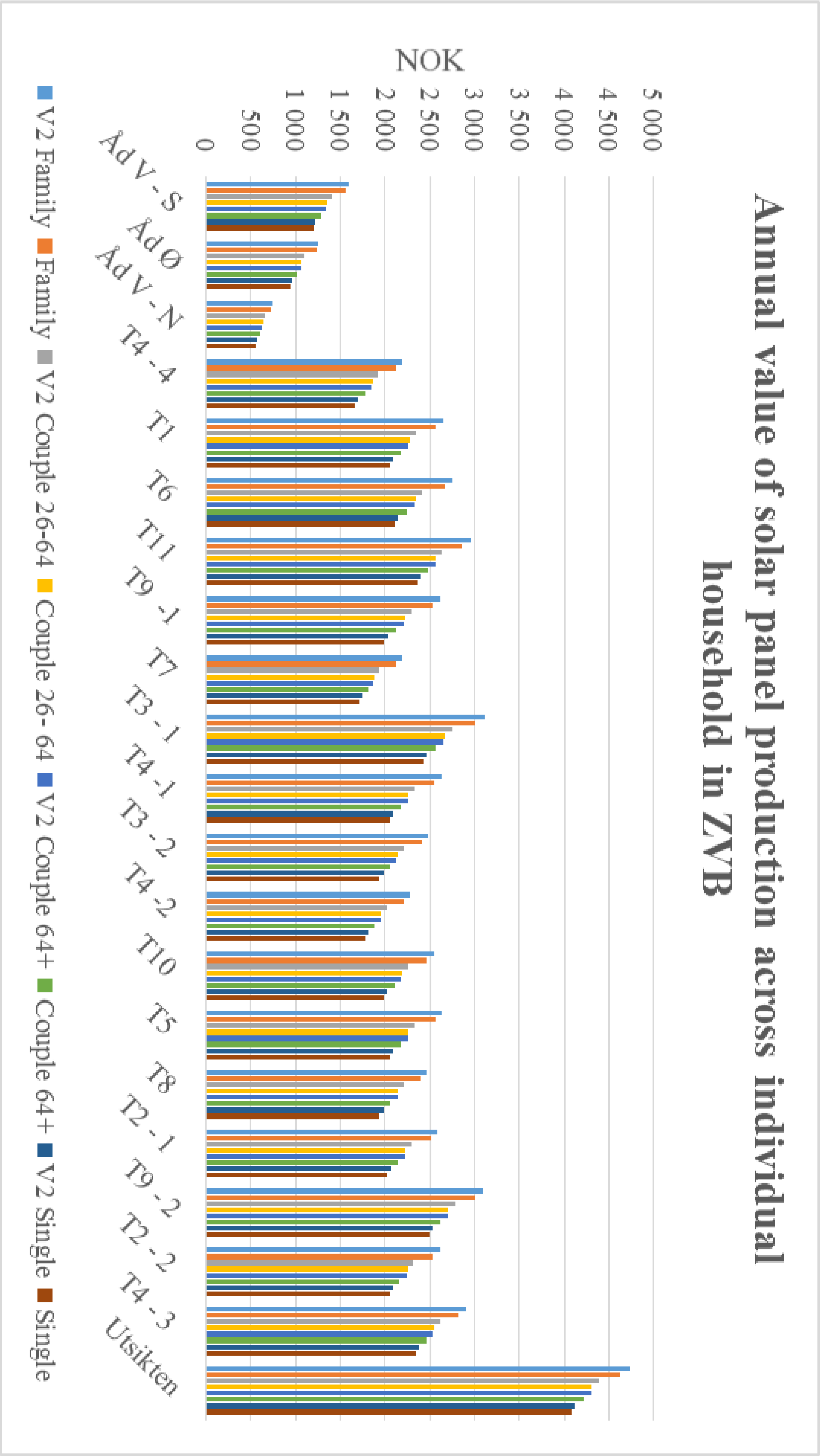

Figure 34: Total annual value electricity production from solar panels across individual households in ZVB (Excluding revenues from green certificates)

G. Share of electricity used locally, average value per kWh produced and total annual value of electricity production across co-ownership in ZVB

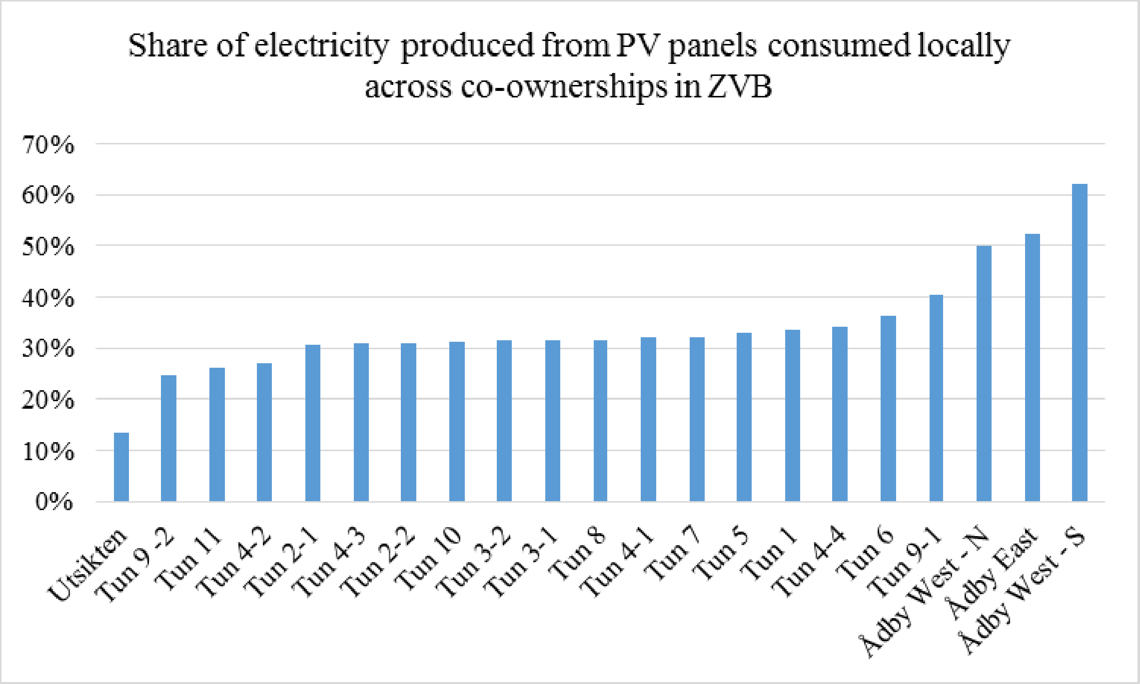

Figure 35: Share of electricity produced by solar panels consumed locally across co-ownership in ZVB

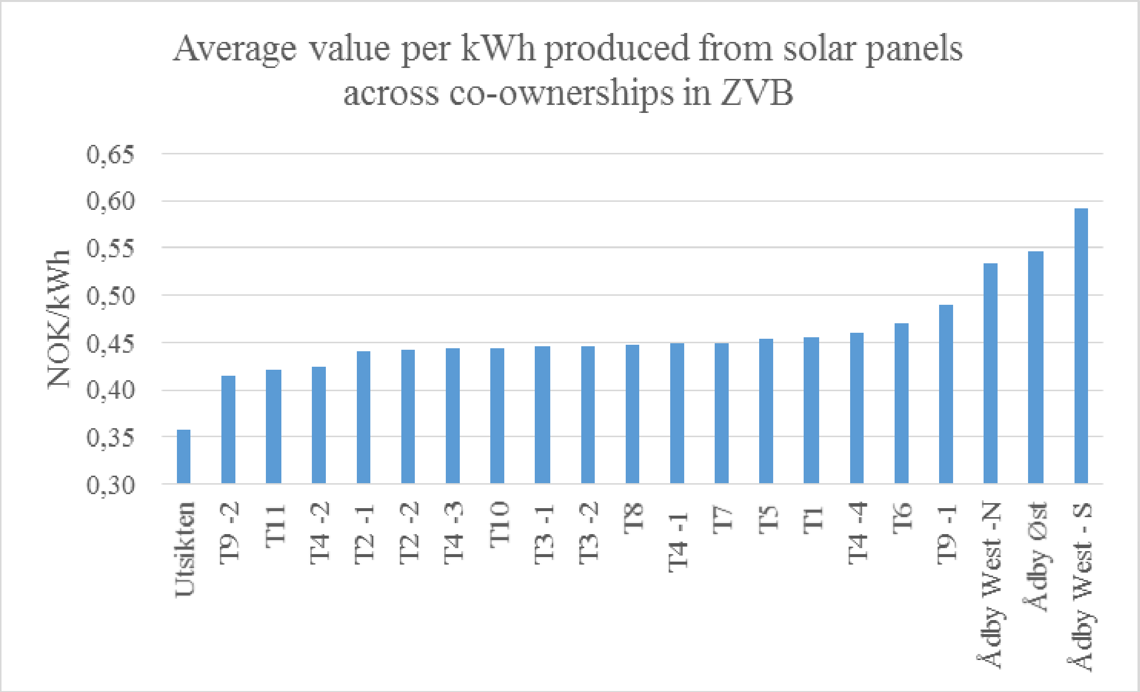

Figure 36: Average value per kWh produced from solar panels across co-ownership in ZVB, excluding revenues from green certificates

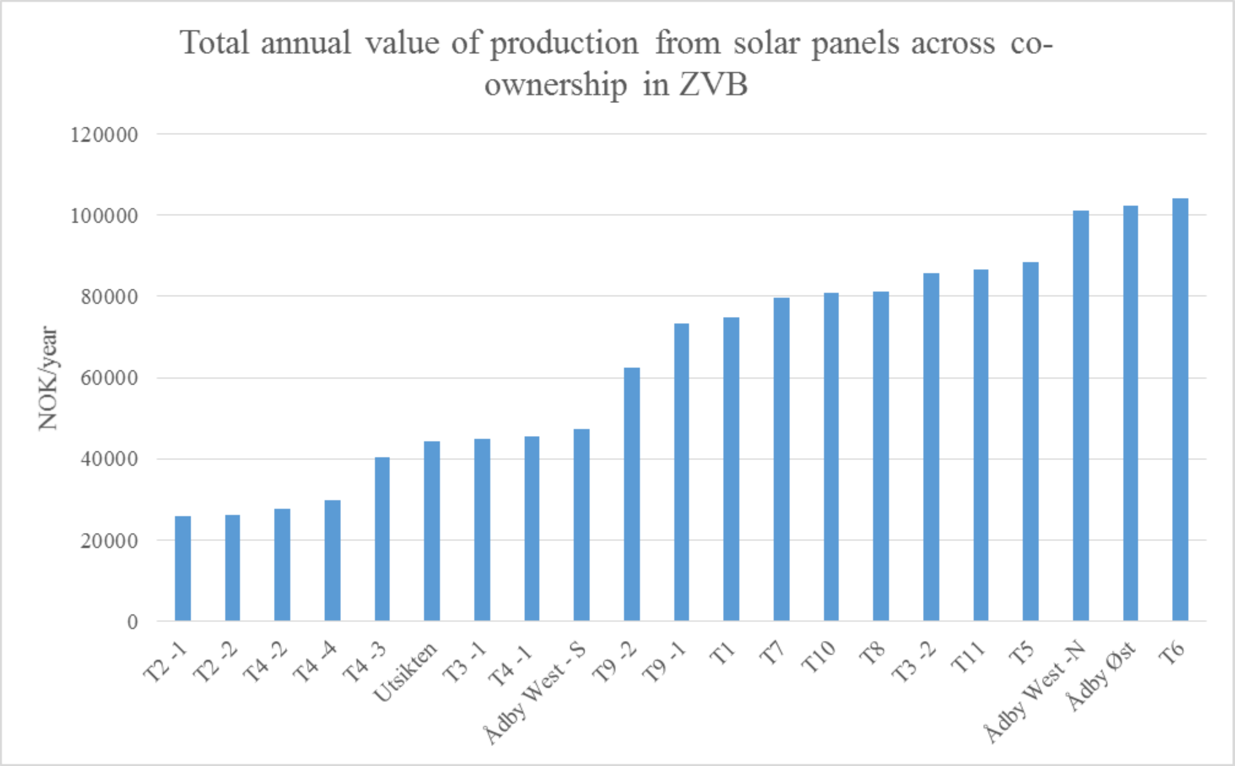

Figure 37: Total annual value of electricity production from solar panels across co-ownerships in ZVB, excluding revenues from green certificates

H. LCOE calculations

Levelized cost of Energy (LCOE) is a widely used concept to calculate and compare the cost of energy generation across technologies and markets. The formula condenses the lifetime costs and production of a given energy generation method into monetary units per energy unit, in our case NOK/kWh.

LCOE of an energy investment project can be calculated using the following formula (Multiconsult AS, 2013):

$$LCOE = \frac{CAPEX + \sum_{t=1}^{T} \frac{AC}{(1+r)^t}}{\sum_{t=1}^{T} \frac{AEP * (1-Lf)^t}{(1+r)^t}}$$

The explanation of the different parameters can be seen in Table 39:

Nomenclature	Description
CAPEX	Initial capital investments
T	Year

AC	Annual cost of energy production
AEP	Annual Energy Production
LF	Annual loss factor
R	Discount rate
T	Project lifetime in years

Table 39: Nomenclature for different parameters used for LCOE

In order to calculate the LCOE for the electricity production from the solar panels in ZVB over the lifetime of the project, only information regarding the costs of production and the size of production is needed. A real discount rate of 4% is chosen to easily compare the LCOE with NVE's LCOE estimates for other technologies and measures.

The capacity factor, which determines the size of production in the first year, varies between a minimum of 8.10% in Utsikten and a maximum of 8.50%[53] in Ådlandsbyen West -S. For scenario 1, the investment cost is higher per kW(p) than for the other scenarios, thus considering the LCOE for a household in Utsikten under scenario 1 constitute a low extreme. Contrary, the LCOE for Ådlandsbyen West – S under scenario 4 constitute a high extreme.

LCOE is therefore calculated for these two cases in order to illustrate the range in LCOE between the different building areas in ZVB. The solar panels are assumed to have a 0.40% decline in production per year, and the panels are assumed to have lifetime of 30 years.

A summary of the input factors used can be found in table 40.

Description	Scenario 1 - Utsikten	Scenario 2 – Ådby West – N
Investment cost	15,120 NOK/kW(p)[54]	12,000 NOK/kW(p)[55]
Total project lifetime	30 years	30 years
O&M cost as % of investment cost	0.75%	0.75%
Insurance cost as % of investment cost	0.25%	0.25%
Inverter reinvestment as % of investment cost	14%	11.6%
Capacity factor	8.10%	8.50%
Annual loss factor	0.40%	0.40%
Discount rate	4.0%	4.0%

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[53] For details regarding the capacity factors for different buildings areas in ZVB, see appendix B.

[54] Investment cost for small scale solar panel system (<10 kW(p)) without VAT: 18,900 NOK/kW(p) /1.25 = 15,120 NOK/ kW(p).

[55] Investment cost for medium-scale solar panel system (10-100 kW(p) without VAT: 15,000 NOK/kW(p)/ 1.25 = 12,000 NOK/kW(p).

Table 40: Input factors for LCOE calculations for solar panels in ZVB for different scenarios

The calculations demonstrate an LCOE of 1.23 NOK/kWh for Ådlandsbyen West –S under scenario 4 and 1.60 NOK/kWh for Utsikten under scenario 1. Thus, the LCOE range for ZVB is 1.23- 1.60 NOK/kWh using the same 4% discount rate as the NVE report. Using a discount rate of 8%, the same numbers are 1.85- 2.4 NOK/kWh.

I. Effect of reducing the installed capacity in ZVB on average value per kWh

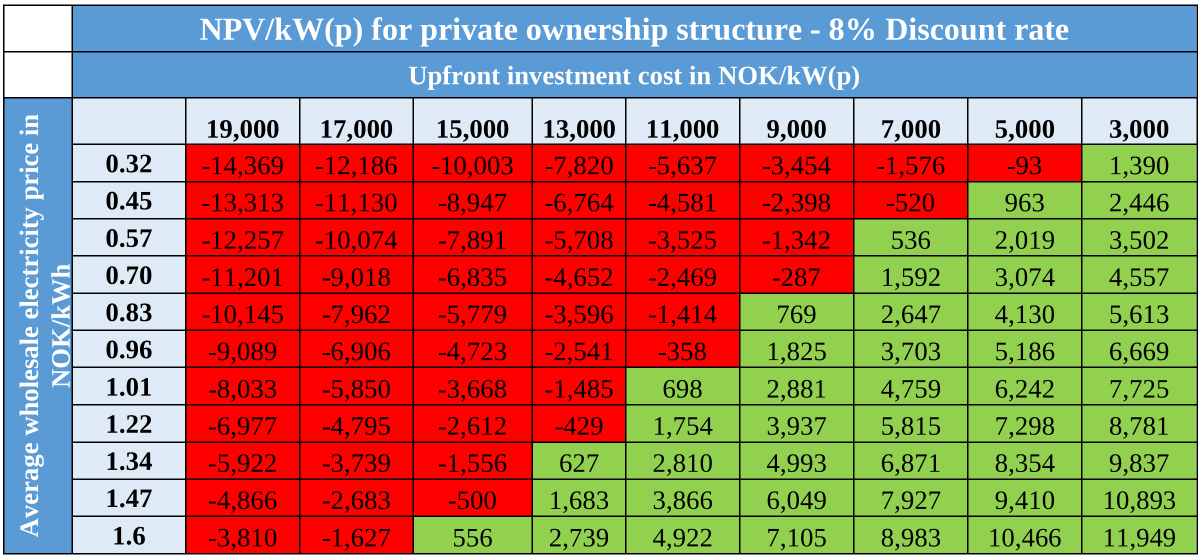
The effect of reducing the amount of installed capacity in ZVB on the average value per kWh produced from the solar panels can be seen in figure 38 below. The value pf green certificates have not been taken into account. Reducing the installed capacity to 50% for all buildings in ZVB would lead to an increase in the average value per kWh produced, of about 0.10 NOK for all scenarios. Reducing capacity further to 25% increases the average value by another 0.11 NOK/kWh. At 10% of the planned installed capacity, the average value per kWh for all scenarios is approaching the average cost of buying electricity from the grid of 0.79 NOK/kWh.

Effect of reducing the installed capacity of solar panels in ZVB on the average value per kWh produced from the solar panels and the share used locally

	Share consumed locally (scenario 4)	**NOK/kWh Scenario 4**	**NOK/kWh Scenario 3**	**NOK/kWh Scenario 2**	**NOK/kWh Scenario 1**
100 %	42.6%	0.499	0.464	0.460	0.457
75 %	51.8%	0.543	0.502	0.496	0.492
50 %	66.17%	0.611	0.563	0.555	0.547
25 %	90.17%	0.726	0.680	0.664	0.651
10 %	100%	0.772	0.772	0.760	0.748

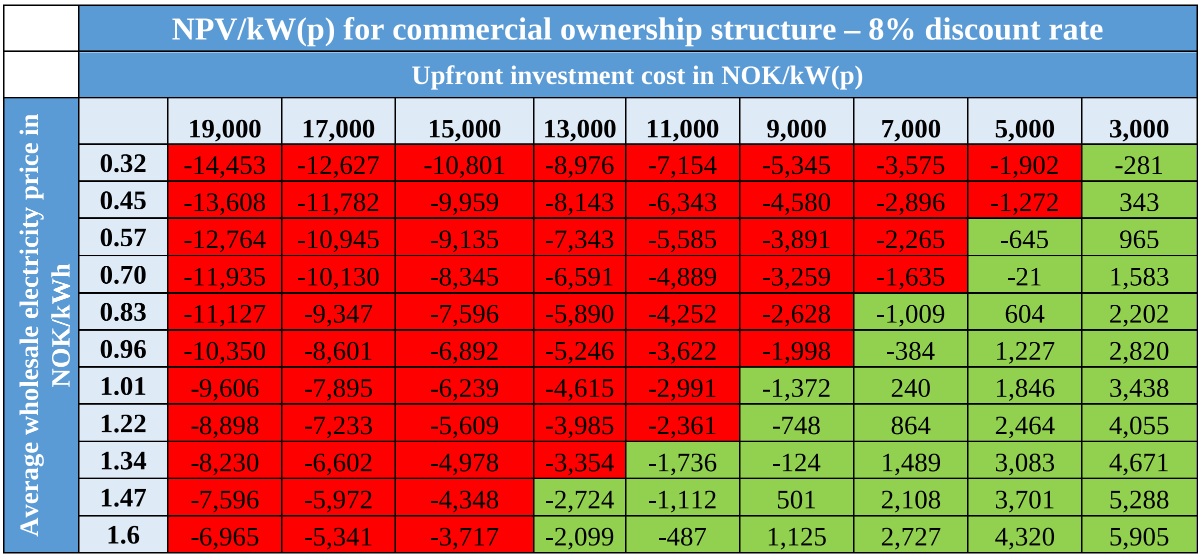
Figure 38: Effect of reducing the amount of installed capacity of solar panels in ZVB on the average value per kWh produced

J. Results from sensitivity analysis for scenario 1



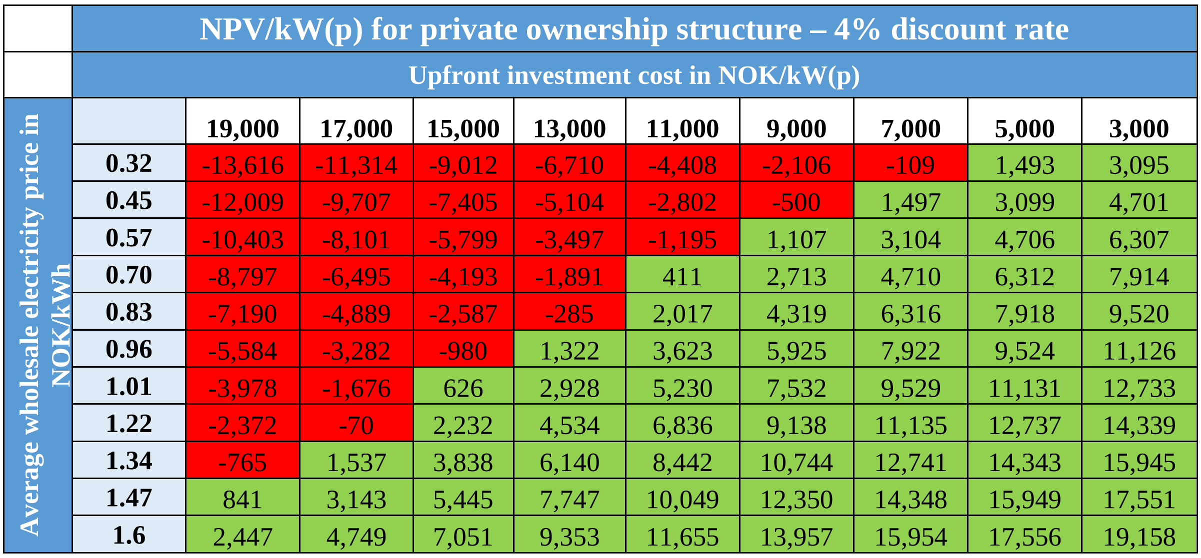
	NPV/kW(p) for private ownership structure - 8% Discount rate								
	Upfront investment cost in NOK/kW(p)								
Average wholesale electricity price in NOK/kWh	19,000	17,000	15,000	13,000	11,000	9,000	7,000	5,000	3,000
0.32	-14,369	-12,186	-10,003	-7,820	-5,637	-3,454	-1,576	-93	1,390
0.45	-13,313	-11,130	-8,947	-6,764	-4,581	-2,398	-520	963	2,446
0.57	-12,257	-10,074	-7,891	-5,708	-3,525	-1,342	536	2,019	3,502
0.70	-11,201	-9,018	-6,835	-4,652	-2,469	-287	1,592	3,074	4,557
0.83	-10,145	-7,962	-5,779	-3,596	-1,414	769	2,647	4,130	5,613
0.96	-9,089	-6,906	-4,723	-2,541	-358	1,825	3,703	5,186	6,669
1.01	-8,033	-5,850	-3,668	-1,485	698	2,881	4,759	6,242	7,725
1.22	-6,977	-4,795	-2,612	-429	1,754	3,937	5,815	7,298	8,781
1.34	-5,922	-3,739	-1,556	627	2,810	4,993	6,871	8,354	9,837
1.47	-4,866	-2,683	-500	1,683	3,866	6,049	7,927	9,410	10,893
1.6	-3,810	-1,627	556	2,739	4,922	7,105	8,983	10,466	11,949

Figure 39: Results from sensitivity analysis of private ownership for scenario 1 assuming a discount rate of 8%



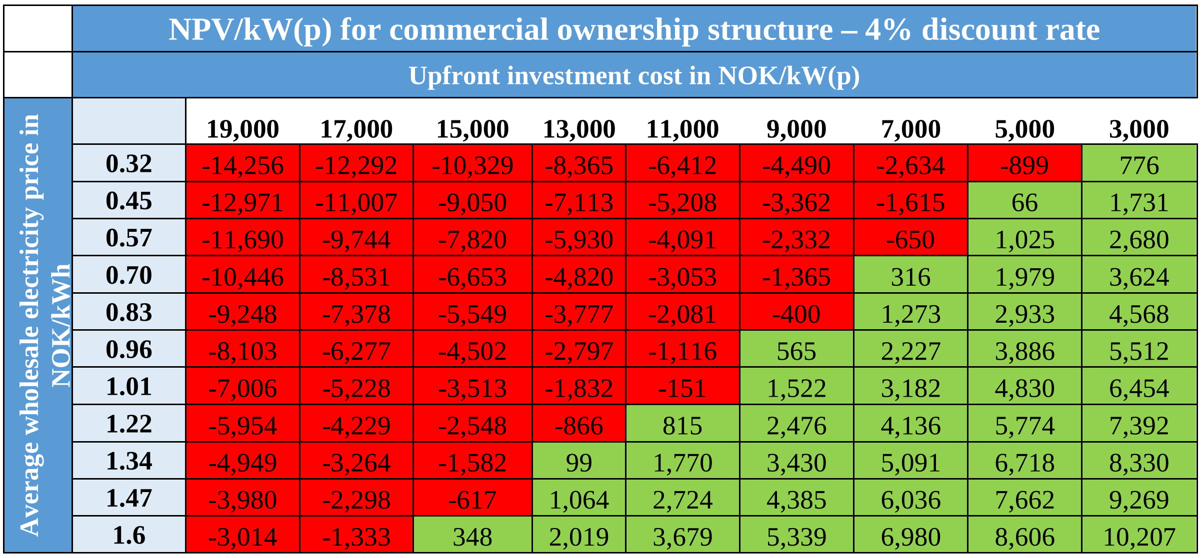
	NPV/kW(p) for commercial ownership structure – 8% discount rate								
	Upfront investment cost in NOK/kW(p)								
Average wholesale electricity price in NOK/kWh	19,000	17,000	15,000	13,000	11,000	9,000	7,000	5,000	3,000
0.32	-14,453	-12,627	-10,801	-8,976	-7,154	-5,345	-3,575	-1,902	-281
0.45	-13,608	-11,782	-9,959	-8,143	-6,343	-4,580	-2,896	-1,272	343
0.57	-12,764	-10,945	-9,135	-7,343	-5,585	-3,891	-2,265	-645	965
0.70	-11,935	-10,130	-8,345	-6,591	-4,889	-3,259	-1,635	-21	1,583
0.83	-11,127	-9,347	-7,596	-5,890	-4,252	-2,628	-1,009	604	2,202
0.96	-10,350	-8,601	-6,892	-5,246	-3,622	-1,998	-384	1,227	2,820
1.01	-9,606	-7,895	-6,239	-4,615	-2,991	-1,372	240	1,846	3,438
1.22	-8,898	-7,233	-5,609	-3,985	-2,361	-748	864	2,464	4,055
1.34	-8,230	-6,602	-4,978	-3,354	-1,736	-124	1,489	3,083	4,671
1.47	-7,596	-5,972	-4,348	-2,724	-1,112	501	2,108	3,701	5,288
1.6	-6,965	-5,341	-3,717	-2,099	-487	1,125	2,727	4,320	5,905

Figure 40: Results from sensitivity analysis of commercial ownership for scenario 1 assuming a discount rate of 8%



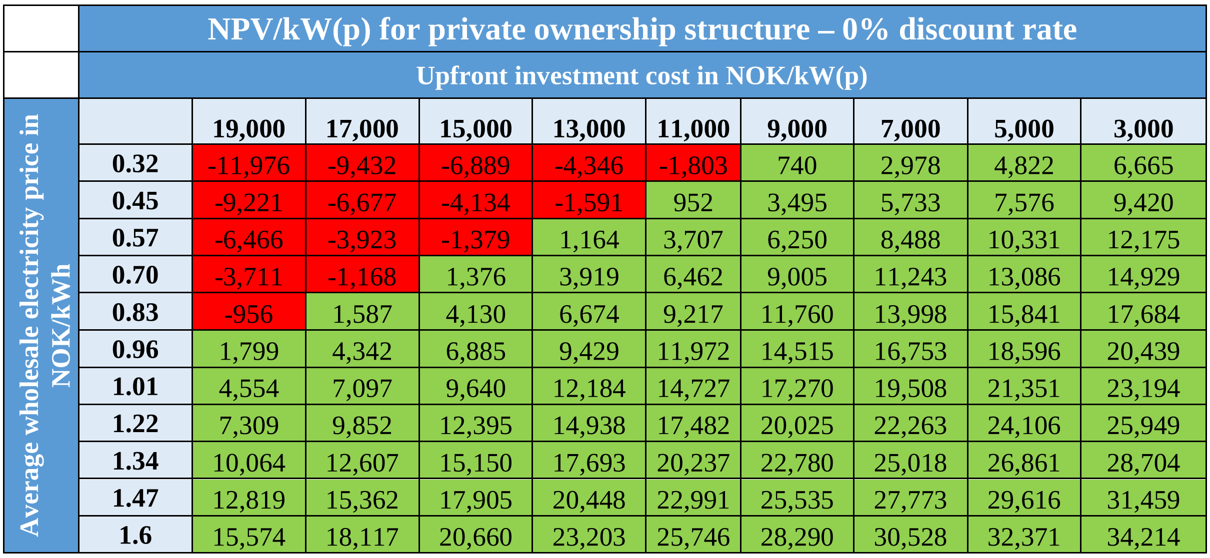
		NPV/kW(p) for private ownership structure – 4% discount rate								
		Upfront investment cost in NOK/kW(p)								
Average wholesale electricity price in NOK/kWh		**19,000**	**17,000**	**15,000**	**13,000**	**11,000**	**9,000**	**7,000**	**5,000**	**3,000**
	0.32	-13,616	-11,314	-9,012	-6,710	-4,408	-2,106	-109	1,493	3,095
	0.45	-12,009	-9,707	-7,405	-5,104	-2,802	-500	1,497	3,099	4,701
	0.57	-10,403	-8,101	-5,799	-3,497	-1,195	1,107	3,104	4,706	6,307
	0.70	-8,797	-6,495	-4,193	-1,891	411	2,713	4,710	6,312	7,914
	0.83	-7,190	-4,889	-2,587	-285	2,017	4,319	6,316	7,918	9,520
	0.96	-5,584	-3,282	-980	1,322	3,623	5,925	7,922	9,524	11,126
	1.01	-3,978	-1,676	626	2,928	5,230	7,532	9,529	11,131	12,733
	1.22	-2,372	-70	2,232	4,534	6,836	9,138	11,135	12,737	14,339
	1.34	-765	1,537	3,838	6,140	8,442	10,744	12,741	14,343	15,945
	1.47	841	3,143	5,445	7,747	10,049	12,350	14,348	15,949	17,551
	1.6	2,447	4,749	7,051	9,353	11,655	13,957	15,954	17,556	19,158

Figure 41: Results from sensitivity analysis of private ownership for scenario 1 assuming a discount rate of 4%



		NPV/kW(p) for commercial ownership structure – 4% discount rate								
		Upfront investment cost in NOK/kW(p)								
Average wholesale electricity price in NOK/kWh		**19,000**	**17,000**	**15,000**	**13,000**	**11,000**	**9,000**	**7,000**	**5,000**	**3,000**
	0.32	-14,256	-12,292	-10,329	-8,365	-6,412	-4,490	-2,634	-899	776
	0.45	-12,971	-11,007	-9,050	-7,113	-5,208	-3,362	-1,615	66	1,731
	0.57	-11,690	-9,744	-7,820	-5,930	-4,091	-2,332	-650	1,025	2,680
	0.70	-10,446	-8,531	-6,653	-4,820	-3,053	-1,365	316	1,979	3,624
	0.83	-9,248	-7,378	-5,549	-3,777	-2,081	-400	1,273	2,933	4,568
	0.96	-8,103	-6,277	-4,502	-2,797	-1,116	565	2,227	3,886	5,512
	1.01	-7,006	-5,228	-3,513	-1,832	-151	1,522	3,182	4,830	6,454
	1.22	-5,954	-4,229	-2,548	-866	815	2,476	4,136	5,774	7,392
	1.34	-4,949	-3,264	-1,582	99	1,770	3,430	5,091	6,718	8,330
	1.47	-3,980	-2,298	-617	1,064	2,724	4,385	6,036	7,662	9,269
	1.6	-3,014	-1,333	348	2,019	3,679	5,339	6,980	8,606	10,207

Figure 42: Results from sensitivity analysis of commercial ownership for scenario 1 assuming a discount rate of 4%



		NPV/kW(p) for private ownership structure – 0% discount rate								
		Upfront investment cost in NOK/kW(p)								
Average wholesale electricity price in NOK/kWh		**19,000**	**17,000**	**15,000**	**13,000**	**11,000**	**9,000**	**7,000**	**5,000**	**3,000**
	0.32	-11,976	-9,432	-6,889	-4,346	-1,803	740	2,978	4,822	6,665
	0.45	-9,221	-6,677	-4,134	-1,591	952	3,495	5,733	7,576	9,420
	0.57	-6,466	-3,923	-1,379	1,164	3,707	6,250	8,488	10,331	12,175
	0.70	-3,711	-1,168	1,376	3,919	6,462	9,005	11,243	13,086	14,929
	0.83	-956	1,587	4,130	6,674	9,217	11,760	13,998	15,841	17,684
	0.96	1,799	4,342	6,885	9,429	11,972	14,515	16,753	18,596	20,439
	1.01	4,554	7,097	9,640	12,184	14,727	17,270	19,508	21,351	23,194
	1.22	7,309	9,852	12,395	14,938	17,482	20,025	22,263	24,106	25,949
	1.34	10,064	12,607	15,150	17,693	20,237	22,780	25,018	26,861	28,704
	1.47	12,819	15,362	17,905	20,448	22,991	25,535	27,773	29,616	31,459
	1.6	15,574	18,117	20,660	23,203	25,746	28,290	30,528	32,371	34,214

Figure 43: Results from sensitivity analysis of private ownership for scenario 1 assuming a discount rate of 0%

	NPV/kW(p) for commercial ownership structure – 0% discount rate									
	Upfront investment cost in NOK/kW(p)									
Average wholesale electricity price		19,000	17,000	15,000	13,000	11,000	9,000	7,000	5,000	3,000
	0.32	-13,800	-11,554	-9,307	-7,060	-4,844	-2,705	-682	1,185	2,983
	0.45	-11,597	-9,350	-7,121	-4,947	-2,844	-837	1,044	2,852	4,630
	0.57	-9,404	-7,209	-5,065	-2,989	-993	901	2,711	4,507	6,268
	0.70	-7,314	-5,192	-3,136	-1,148	755	2,570	4,378	6,154	7,896
	0.83	-5,328	-3,285	-1,303	605	2,429	4,237	6,031	7,801	9,524
	0.96	-3,437	-1,458	454	2,287	4,096	5,904	7,678	9,446	11,151
	1.01	-1,614	302	2,146	3,955	5,763	7,555	9,326	11,074	12,775
	1.22	150	2,005	3,813	5,622	7,430	9,202	10,973	12,701	14,384
	1.34	1,860	3,672	5,481	7,289	9,079	10,850	12,620	14,329	15,993
	1.47	3,531	5,339	7,148	8,956	10,727	12,497	14,252	15,957	17,602
	1.6	5,198	7,007	8,815	10,603	12,374	14,145	15,879	17,584	19,211

Figure 44: Results from sensitivity analysis of commercial ownership for scenario 1 assuming discount rate of 8%

K. Results from sensitivity analysis for scenario 2

	NPV/kW(p) for private ownership structure – 8% discount rate									
	Upfront investment cost in NOK/kW(p)									
Average wholesale electricity price in NOK/kWh		15,000	13,500	12,000	10,500	9,000	7,500	6,000	4,500	3,000
	0.32	-12,298	-10,607	-8,916	-7,225	-5,534	-3,843	-2,153	-462	1,229
	0.45	-11,236	-9,545	-7,854	-6,164	-4,473	-2,782	-1,091	600	2,291
	0.57	-10,175	-8,484	-6,793	-5,102	-3,411	-1,720	-29	1,662	3,353
	0.70	-9,113	-7,422	-5,731	-4,040	-2,349	-658	1,033	2,724	4,415
	0.83	-8,051	-6,360	-4,669	-2,978	-1,287	404	2,094	3,785	5,476
	0.96	-6,989	-5,298	-3,607	-1,916	-226	1,465	3,156	4,847	6,538
	1.01	-5,927	-4,237	-2,546	-855	836	2,527	4,218	5,909	7,600
	1.22	-4,866	-3,175	-1,484	207	1,898	3,589	5,280	6,971	8,662
	1.34	-3,804	-2,113	-422	1,269	2,960	4,651	6,342	8,032	9,723
	1.47	-2,742	-1,051	640	2,331	4,021	5,712	7,403	9,094	10,785
	1.6	-1,680	10	1,701	3,392	5,083	6,774	8,465	10,156	11,847

Figure 45: Results from sensitivity analysis of private ownership for scenario 2 assuming a discount rate of 8%

	NPV/kW(p) for commercial ownership structure – 8% discount rate									
	Upfront investment cost in NOK/kW(p)									
Average wholesale electricity price in NOK/kWh		15,000	13,500	12,000	10,500	9,000	7,500	6,000	4,500	3,000
	0.32	-10,542	-9,121	-7,701	-6,286	-4,905	-3,585	-2,325	-1,066	184
	0.45	-9,693	-8,274	-6,877	-5,517	-4,209	-2,949	-1,691	-437	811
	0.57	-8,859	-7,478	-6,133	-4,832	-3,573	-2,315	-1,057	191	1,434
	0.70	-8,088	-6,751	-5,456	-4,198	-2,939	-1,681	-429	819	2,056
	0.83	-7,371	-6,081	-4,822	-3,564	-2,305	-1,049	199	1,447	2,678
	0.96	-6,705	-5,447	-4,188	-2,930	-1,671	-422	826	2,069	3,300
	1.01	-6,071	-4,812	-3,554	-2,296	-1,042	206	1,454	2,691	3,922
	1.22	-5,437	-4,178	-2,920	-1,662	-414	834	2,082	3,313	4,542
	1.34	-4,803	-3,544	-2,286	-1,034	214	1,462	2,704	3,935	5,162
	1.47	-4,169	-2,910	-1,655	-407	841	2,089	3,326	4,557	5,782
	1.6	-3,535	-2,276	-1,027	221	1,469	2,717	3,948	5,179	6,402

Figure 46: Results from sensitivity analysis of commercial ownership for scenario 2 assuming a discount rate of 8%

	NPV/kW(p) for private ownership structure – 4% discount rate									
	Upfront investment cost in NOK/kW(p)									
Average wholesale electricity price in NOK/kWh		15,000	13,500	12,000	10,500	9,000	7,500	6,000	4,500	3,000
	0.32	-11,264	-9,452	-7,639	-5,827	-4,014	-2,202	-390	1,423	3,235
	0.45	-9,649	-7,837	-6,024	-4,212	-2,399	-587	1,226	3,038	4,850
	0.57	-8,034	-6,221	-4,409	-2,597	-784	1,028	2,841	4,653	6,466
	0.70	-6,419	-4,606	-2,794	-981	831	2,644	4,456	6,268	8,081
	0.83	-4,803	-2,991	-1,179	634	2,446	4,259	6,071	7,884	9,696
	0.96	-3,188	-1,376	437	2,249	4,061	5,874	7,686	9,499	11,311
	1.01	-1,573	239	2,052	3,864	5,677	7,489	9,301	11,114	12,926
	1.22	42	1,854	3,667	5,479	7,292	9,104	10,917	12,729	14,541
	1.34	1,657	3,470	5,282	7,094	8,907	10,719	12,532	14,344	16,157
	1.47	3,272	5,085	6,897	8,710	10,522	12,334	14,147	15,959	17,772
	1.6	4,887	6,700	8,512	10,325	12,137	13,950	15,762	17,574	19,387

Figure 47: Results from sensitivity analysis of private ownership for scenario 2 assuming a discount rate of 4%

	NPV/kW(p) for commercial ownership structure – 4% discount rate									
	Upfront investment cost in NOK/kW(p)									
Average wholesale electricity price in NOK/kWh		15,000	13,500	12,000	10,500	9,000	7,500	6,000	4,500	3,000
	0.32	-10,083	-8,528	-6,973	-5,430	-3,946	-2,551	-1,222	103	1,414
	0.45	-8,791	-7,240	-5,732	-4,284	-2,905	-1,577	-252	1,066	2,374
	0.57	-7,532	-6,055	-4,630	-3,259	-1,933	-607	718	2,026	3,325
	0.70	-6,391	-4,978	-3,613	-2,288	-962	364	1,678	2,986	4,274
	0.83	-5,328	-3,968	-2,643	-1,317	9	1,330	2,638	3,945	5,223
	0.96	-4,323	-2,998	-1,672	-346	980	2,290	3,597	4,895	6,172
	1.01	-3,353	-2,027	-701	625	1,942	3,250	4,557	5,844	7,121
	1.22	-2,382	-1,056	270	1,595	2,902	4,209	5,517	6,794	8,065
	1.34	-1,411	-85	1,240	2,554	3,862	5,169	6,466	7,743	9,008
	1.47	-440	885	2,206	3,514	4,821	6,129	7,415	8,692	9,951
	1.6	530	1,856	3,166	4,474	5,781	7,088	8,364	9,641	10,894

Figure 48: Results from sensitivity analysis of commercial ownership for scenario 2 assuming a discount rate of 4%

	NPV/kW(p) for private ownership structure – 0% discount rate									
	Upfront investment cost in NOK/kW(p)									
Average wholesale electricity price in NOK/kWh		15,000	13,500	12,000	10,500	9,000	7,500	6,000	4,500	3,000
	0.32	-9,230	-7,170	-5,110	-3,050	-990	1,070	3,130	5,190	7,250
	0.45	-6,460	-4,400	-2,340	-279	1,781	3,841	5,901	7,961	10,021
	0.57	-3,689	-1,629	431	2,491	4,551	6,611	8,671	10,731	12,791
	0.70	-919	1,141	3,201	5,261	7,321	9,381	11,441	13,501	15,561
	0.83	1,851	3,911	5,971	8,031	10,091	12,151	14,211	16,271	18,331
	0.96	4,621	6,681	8,741	10,801	12,861	14,921	16,981	19,041	21,101
	1.01	7,391	9,451	11,511	13,571	15,631	17,691	19,752	21,812	23,872
	1.22	10,162	12,222	14,282	16,342	18,402	20,462	22,522	24,582	26,642
	1.34	12,932	14,992	17,052	19,112	21,172	23,232	25,292	27,352	29,412
	1.47	15,702	17,762	19,822	21,882	23,942	26,002	28,062	30,122	32,182
	1.6	18,472	20,532	22,592	24,652	26,712	28,772	30,832	32,892	34,952

Figure 49: Results from sensitivity analysis of private ownership for scenario 2 assuming a discount rate of 0%

		NPV/kW(p) for commercial ownership structure – 0% discount rate								
		Upfront investment cost in NOK/kW(p)								
Average wholesale electricity price in NOK/kWh		**15,000**	**13,500**	**12,000**	**10,500**	**9,000**	**7,500**	**6,000**	**4,500**	**3,000**
	0.32	-9,231	-7,401	-5,570	-3,762	-2,069	-516	958	2,429	3,874
	0.45	-7,015	-5,195	-3,464	-1,841	-311	1,162	2,634	4,091	5,530
	0.57	-4,881	-3,211	-1,626	-105	1,367	2,839	4,309	5,748	7,170
	0.70	-2,983	-1,413	101	1,572	3,044	4,515	5,966	7,404	8,807
	0.83	-1,202	305	1,777	3,249	4,720	6,184	7,622	9,061	10,443
	0.96	510	1,982	3,454	4,925	6,397	7,840	9,279	10,700	12,080
	1.01	2,187	3,658	5,130	6,602	8,058	9,497	10,935	12,336	13,717
	1.22	3,863	5,335	6,806	8,276	9,715	11,153	12,592	13,973	15,336
	1.34	5,540	7,011	8,483	9,933	11,371	12,810	14,229	15,609	16,954
	1.47	7,216	8,688	10,151	11,589	13,028	14,466	15,866	17,246	18,572
	1.6	8,893	10,364	11,807	13,246	14,684	16,122	17,502	18,883	20,190

Figure 50: Results from sensitivity analysis of commercial ownership for scenario 2 assuming a discount rate of 0%

M. Results from sensitivity analysis for scenario 3

		NPV/kW(p) for private ownership structure – 8% discount rate								
		Upfront investment cost in NOK/kW(p)								
Average wholesale electricity price in NOK/kWh		**15,000**	**13,500**	**12,000**	**10,500**	**9,000**	**7,500**	**6,000**	**4,500**	**3,000**
	0.32	-12,144	-10,453	-8,762	-7,072	-5,381	-3,690	-1,999	-308	1,383
	0.45	-11,082	-9,391	-7,700	-6,009	-4,319	-2,628	-937	754	2,445
	0.57	-10,020	-8,329	-6,638	-4,947	-3,256	-1,566	125	1,816	3,507
	0.70	-8,958	-7,267	-5,576	-3,885	-2,194	-503	1,187	2,878	4,569
	0.83	-7,896	-6,205	-4,514	-2,823	-1,132	559	2,250	3,941	5,631
	0.96	-6,834	-5,143	-3,452	-1,761	-70	1,621	3,312	5,003	6,694
	1.01	-5,772	-4,081	-2,390	-699	992	2,683	4,374	6,065	7,756
	1.22	-4,710	-3,019	-1,328	363	2,054	3,745	5,436	7,127	8,818
	1.34	-3,647	-1,956	-266	1,425	3,116	4,807	6,498	8,189	9,880
	1.47	-2,585	-894	797	2,487	4,178	5,869	7,560	9,251	10,942
	1.6	-1,523	168	1,859	3,550	5,240	6,931	8,622	10,313	12,004

Figure 51: Results from sensitivity analysis of private ownership for scenario 3 assuming a discount rate of 8%

		NPV/kW(p) for commercial ownership structure – 8% discount rate								
		Upfront investment cost in NOK/kW(p)								
Average wholesale electricity price in NOK/kWh		**15,000**	**13,500**	**12,000**	**10,500**	**9,000**	**7,500**	**6,000**	**4,500**	**3,000**
	0.32	-10,542	-9,121	-7,701	-6,286	-4,905	-3,585	-2,325	-1,066	184
	0.45	-9,693	-8,274	-6,877	-5,517	-4,209	-2,949	-1,691	-437	811
	0.57	-8,859	-7,478	-6,133	-4,832	-3,573	-2,315	-1,057	191	1,434
	0.70	-8,088	-6,751	-5,456	-4,198	-2,939	-1,681	-429	819	2,056
	0.83	-7,371	-6,081	-4,822	-3,564	-2,305	-1,049	199	1,447	2,678
	0.96	-6,705	-5,447	-4,188	-2,930	-1,671	-422	826	2,069	3,300
	1.01	-6,071	-4,812	-3,554	-2,296	-1,042	206	1,454	2,691	3,922
	1.22	-5,437	-4,178	-2,920	-1,662	-414	834	2,082	3,313	4,542
	1.34	-4,803	-3,544	-2,286	-1,034	214	1,462	2,704	3,935	5,162
	1.47	-4,169	-2,910	-1,655	-407	841	2,089	3,326	4,557	5,782
	1.6	-3,070	-1,814	-566	682	1,930	3,175	4,406	5,636	6,859

Figure 52: Results from sensitivity analysis of commercial ownership for scenario 3 assuming a discount rate of 8%

		NPV/kW(p) for private ownership structure – 4% discount rate								
		Upfront investment cost in NOK/kW(p)								
Average wholesale electricity price in NOK/kWh		**15,000**	**13,500**	**12,000**	**10,500**	**9,000**	**7,500**	**6,000**	**4,500**	**3,000**
	0.32	-11,084	-9,271	-7,459	-5,647	-3,834	-2,022	-209	1,603	3,416
	0.45	-9,468	-7,656	-5,843	-4,031	-2,218	-406	1,406	3,219	5,031
	0.57	-7,852	-6,040	-4,228	-2,415	-603	1,210	3,022	4,835	6,647
	0.70	-6,237	-4,424	-2,612	-799	1,013	2,825	4,638	6,450	8,263
	0.83	-4,621	-2,809	-996	816	2,629	4,441	6,253	8,066	9,878
	0.96	-3,005	-1,193	619	2,432	4,244	6,057	7,869	9,682	11,494
	1.01	-1,390	423	2,235	4,048	5,860	7,672	9,485	11,297	13,110
	1.22	226	2,038	3,851	5,663	7,476	9,288	11,101	12,913	14,725
	1.34	1,842	3,654	5,467	7,279	9,091	10,904	12,716	14,529	16,341
	1.47	3,457	5,270	7,082	8,895	10,707	12,520	14,332	16,144	17,957
	1.6	5,073	6,886	8,698	10,510	12,323	14,135	15,948	17,760	19,573

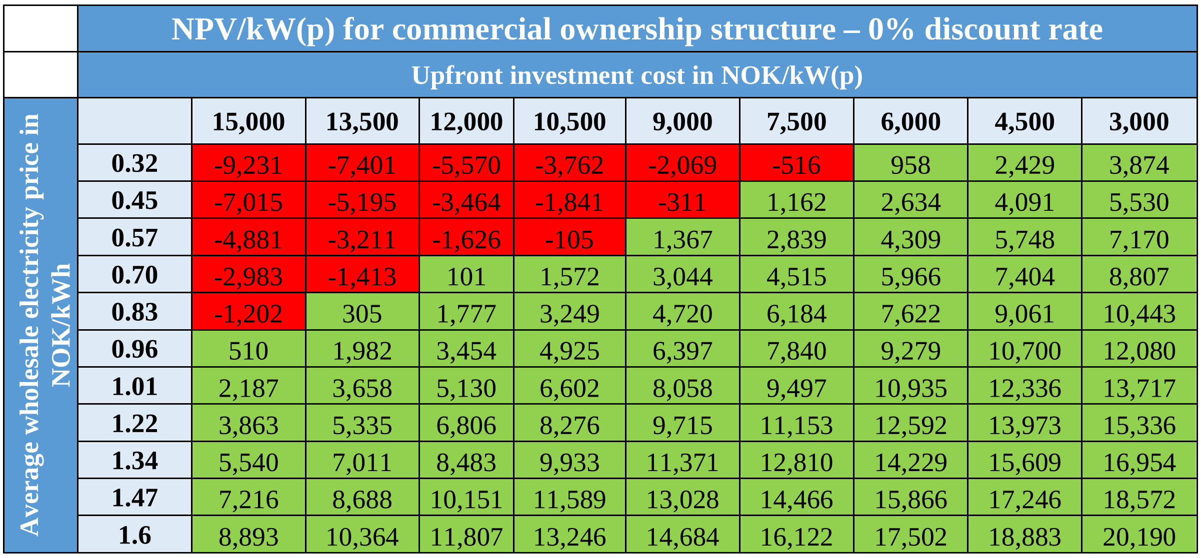
Figure 53: Results from sensitivity analysis of private ownership for scenario 3 assuming a discount rate of 4%

		NPV/kW(p) for commercial ownership structure – 4% discount rate								
		Upfront investment cost in NOK/kW(p)								
Average wholesale electricity price in NOK/kWh		**15,000**	**13,500**	**12,000**	**10,500**	**9,000**	**7,500**	**6,000**	**4,500**	**3,000**
	0.32	-10,083	-8,528	-6,973	-5,430	-3,946	-2,551	-1,222	103	1,414
	0.45	-8,791	-7,240	-5,732	-4,284	-2,905	-1,577	-252	1,066	2,374
	0.57	-7,532	-6,055	-4,630	-3,259	-1,933	-607	718	2,026	3,325
	0.70	-6,391	-4,978	-3,613	-2,288	-962	364	1,678	2,986	4,274
	0.83	-5,328	-3,968	-2,643	-1,317	9	1,330	2,638	3,945	5,223
	0.96	-4,323	-2,998	-1,672	-346	980	2,290	3,597	4,895	6,172
	1.01	-3,353	-2,027	-701	625	1,942	3,250	4,557	5,844	7,121
	1.22	-2,382	-1,056	270	1,595	2,902	4,209	5,517	6,794	8,065
	1.34	-1,411	-85	1,240	2,554	3,862	5,169	6,466	7,743	9,008
	1.47	-440	885	2,206	3,514	4,821	6,129	7,415	8,692	9,951
	1.6	530	1,856	3,166	4,474	5,781	7,088	8,364	9,641	10,894

Figure 54: Results from sensitivity analysis of commercial ownership for scenario 3 assuming a discount rate of 4%

		NPV/kW(p) for private ownership structure – 0% discount rate								
		Upfront investment cost in NOK/kW(p)								
Average wholesale electricity price in NOK/kWh		**15,000**	**13,500**	**12,000**	**10,500**	**9,000**	**7,500**	**6,000**	**4,500**	**3,000**
	0.32	-8,993	-6,933	-4,873	-2,813	-753	1,307	3,367	5,427	7,487
	0.45	-6,222	-4,162	-2,102	-42	2,018	4,078	6,138	8,198	10,258
	0.57	-3,451	-1,391	669	2,729	4,789	6,849	8,909	10,969	13,029
	0.70	-680	1,380	3,440	5,500	7,560	9,620	11,680	13,741	15,801
	0.83	2,091	4,151	6,212	8,272	10,332	12,392	14,452	16,512	18,572
	0.96	4,863	6,923	8,983	11,043	13,103	15,163	17,223	19,283	21,343
	1.01	7,634	9,694	11,754	13,814	15,874	17,934	19,994	22,054	24,114
	1.22	10,405	12,465	14,525	16,585	18,645	20,705	22,765	24,825	26,885
	1.34	13,176	15,236	17,296	19,356	21,416	23,476	25,536	27,596	29,656
	1.47	15,947	18,007	20,067	22,127	24,187	26,247	28,307	30,367	32,427
	1.6	18,718	20,778	22,838	24,898	26,958	29,018	31,078	33,138	35,198

Figure 55: Results from sensitivity analysis of private ownership for scenario 3 assuming a discount rate of 0%



NPV/kW(p) for commercial ownership structure – 0% discount rate

Upfront investment cost in NOK/kW(p)

Average wholesale electricity price in NOK/kWh	15,000	13,500	12,000	10,500	9,000	7,500	6,000	4,500	3,000
0.32	-9,231	-7,401	-5,570	-3,762	-2,069	-516	958	2,429	3,874
0.45	-7,015	-5,195	-3,464	-1,841	-311	1,162	2,634	4,091	5,530
0.57	-4,881	-3,211	-1,626	-105	1,367	2,839	4,309	5,748	7,170
0.70	-2,983	-1,413	101	1,572	3,044	4,515	5,966	7,404	8,807
0.83	-1,202	305	1,777	3,249	4,720	6,184	7,622	9,061	10,443
0.96	510	1,982	3,454	4,925	6,397	7,840	9,279	10,700	12,080
1.01	2,187	3,658	5,130	6,602	8,058	9,497	10,935	12,336	13,717
1.22	3,863	5,335	6,806	8,276	9,715	11,153	12,592	13,973	15,336
1.34	5,540	7,011	8,483	9,933	11,371	12,810	14,229	15,609	16,954
1.47	7,216	8,688	10,151	11,589	13,028	14,466	15,866	17,246	18,572
1.6	8,893	10,364	11,807	13,246	14,684	16,122	17,502	18,883	20,190

Figure 56: Results from sensitivity analysis of commercial ownership for scenario 3 assuming a discount rate of 0%

O. Relationship between average wholesale electricity price and average value per kWh produced from the solar panels in scenario 4

Percentage increase in the average wholesale electricity price	Average wholesale electricity price	Average value per kWh produced from solar panels in scenario 4
0%	0.32 NOK/kWh	0.49 NOK/kWh
40%	0.45 NOK/kWh	0.64 NOK/kWh
80%	0.57 NOK/kWh	0.77 NOK/kWh
120%	0.70 NOK/kWh	0.91 NOK/kWh
160%	0.83 NOK/kWh	1.05 NOK/kWh
200%	0.96 NOK/kWh	1.19 NOK/kWh
240%	1.01 NOK/kWh	1.33 NOK/kWh
280%	1.22 NOK/kWh	1.46 NOK/kWh
320%	1.34 NOK/kWh	1.60 NOK/kWh
360%	1.47 NOK/kWh	1.74 NOK/kWh
400%	1.60 NOK/kWh	1.88 NOK/kWh

Table 41: Relationship between the average wholesale electricity price and the average value per kWh produced from the solar panels under scenario 4, excluding the value of green certificates.