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Zero energy at the neighbourhood scale: Regulatory challenges regarding billing practices in Norway

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Abstract. Buildings are becoming an increasingly active part of the power system due to the ongoing deployment of decentralized energy resources. To reap the added value that may be realized by zero emission neighbourhoods, it is important that the regulatory framework promotes an efficient development with buildings as an integrated and active part of the power system. When considering energy resources at the neighbourhood level and energy flows within neighbourhoods in Norway, the regulatory framework is challenged by innovative technical solutions. Therefore, it is necessary to explore how deployment of energy resources in neighbourhoods fit together with existing regulations and market mechanisms. Challenges concerning decentralized energy resources are identified based on discussions with stakeholders in Norway and a review of relevant literature in the scientific and regulatory domain. Key challenges for the deployment of energy resources in ZEN are identified, explained through examples, and related to ongoing projects in Norway. It is found that incentives regarding decentralized energy resources are highly dependent on the ownership structure, and therefore a distinction between two major classes of ZEN is made.

1. Introduction
The primary goal of the Norwegian energy law [1] is to ensure economic efficiency in the power system by creating a level playing field for competition in the power market. One major factor is the principle of individual metering to allow every consumer to decide on their electricity supplier, which increase the competition in the power market. The energy law was introduced in the 1990s, at a time where demand was viewed as fixed and the potential for cost reductions were on the supply side. However, there is an ongoing increase in energy-related measures including energy generation resources deployed at the building level. As we move from a goal of zero-energy on a building level towards the neighbourhood scale, it is essential that the regulatory framework continues to promote economic efficiency when buildings become an integrated and active part of the power system.

1.1. Zero-energy buildings
Buildings constitute about 40% of total primary energy consumption in Europe and the US [2]. To reduce the amount of energy required by buildings, the European Union (EU) has

set ambitious targets through the energy performance of buildings directives (EPBD), most recently in a 2018 revision [3]. Among other things, the EPBD promote development towards cost-effective nearly zero energy buildings (NZEBs) by 2020.

Although the exact definition of NZEB is not clearly defined, the development towards NZEBs in the building sector means that we move from focusing on reducing energy needs through passive buildings towards also generating energy at the distributed level to accommodate increasingly ambitious targets [4]. Due to the flexible definition of what a zero-energy building is, different interpretations exist in the scientific literature, and despite different interpretation for the 'zero' balance in the EU [5], national policy are driving the development of ZEB.

1.2. Zero-energy at the neighbourhood scale

The concept of zero energy can also be considered at other scales than individual buildings, for example, neighbourhood, district or city level. Marique and Reiter [6] articulate three main energy uses at the neighbourhood level: building energy consumption, the production of on-site renewable energy and transportation energy. When the scope of zero energy is extended beyond individual buildings, the system boundary change from individual buildings to groups of buildings. In the following, such groups of buildings of any size will be referred to as 'zero energy neighbourhoods' (ZEN).

In the following, we categorize ZEN into two different classes based on owner structure: S-ZEN, which is owned by a single entity, and M-ZEN, where multiple owners are present. To illustrate the difference, we provide two examples:

- Campus Evenstad (S-ZEN): A university campus, including student housing, offices and teaching facilities. It is developed, owned and operated by a single institution (Statsbygg).
- Verksbyen Fredrikstad (M-ZEN): One of the largest residential neighborhood development projects in Fredrikstad, Norway [7]. The project is developed by Arca Nova, and the area include several owners of the buildings.

By extending the system boundary to several buildings, it is possible to obtain additional benefits as compared to considering individual buildings separately. Benefits of considering the ZEN scale compared to ZEB include possibilities to build energy resources at the most favorable locations [8], decreased unit costs compared to smaller systems [9], and coordinated balancing of the energy needs of buildings to achieve a more flexible cumulative load profile [10]. In addition to improved conditions for deployment of energy resources, ZEN also facilitates investments that are not available for individual buildings, such as large-scale solar plants in [9].

Along with the benefits, ZEN also introduce challenges when compared to ZEB. Technically, an increased amount of buildings means more complex systems need to be designed and operated compared to the case of one individual building. Furthermore, when buildings become a more integrated and active part of the power system, regulations, taxes, and tariffs need to be designed in a way that facilitates decentralized decisions that are also system optimal.

1.3. Remuneration models for local energy generation

Investments in renewable energy generation assets is increasingly being made by non-utility type stakeholders, e.g. home owners and public institutions. Traditional consumers thus become *prosumers*: consumers that also generate energy. The growth of prosumers is partly a result of policies, and has been especially prominent for solar photovoltaic (PV) panels. For a prosumer, there are two common categories of remuneration models based on generation: (1) a net-metering policy based on (volumetric) energy [11] and (2) a Feed-in Tariff (FiT) [12].

The net-metering policy allows a prosumer to offset electricity consumption from the grid with local production defined over a measuring period (e.g. hourly, daily, monthly, yearly). The

longer the measuring period, the more likely the net-metering policy is to reduce the electricity bill of the prosumer. The FiT policy offers a fixed payment for prosumers and requires metering of the local generator. Prosumers subject to a FiT face no price risk except the future removal of the policy [12].

Net-metering policies are found to be financially bad for utilities and end-users without local generation as the lost revenue for utilities cannot be balanced by the saved costs from reduced power grid usage (referred to as the 'revenue erosion effect' [13]). Some fear this could lead to a utility 'death spiral' [14] where using the power grid becomes increasingly expensive as more end-users partly produce their own energy, which would lead more end-users to produce their own energy, and so on. Adjusting remuneration models to be partly based on peak demand will likely be a better measure to allocate costs among grid connected consumers and prevent the utility death spiral [11].

In Norway, the policy framework is favourable for S-ZEN. The prosumer policy ('plusskundeordningen') is a net-metering policy that applies to one meter per prosumer. The prosumer policy grants an exception from the conventional need for a regulatory concession to be an electricity producer in Norway, and it is subject to a requirement that the delivered power to the grid does not exceed 100 kW. The payment to prosumers for surplus energy is usually higher than wholesale electricity spot price, but can vary depending on the retailer contract. Prosumers can get additional remuneration from the joint certificate market [15] for Norway and Sweden if a production plant is commissioned before 2022. Since 2019, it is also more economically viable for small-scale producers (< 1 MW installed capacity) to apply for producer concession after a change in the producer tariff from being dependent on installed capacity to being dependent on net energy delivered to the grid [16].

1.4. Content of the paper

The feasibility of achieving a zero energy balance is dependent on rules and regulations for consumption, production, and pricing of energy. The present paper aims to provide an overview of current regulatory challenges concerning energy resources in ZEN with a particular focus on Norway. Topics covered include why ZEN poses challenges compared to ZEB, and how the concept of ZEN fits current regulations, tariffs, and incentives.

2. Regulatory challenges for ZEN

The following section describes two regulatory challenges that need to be addressed for consistent integration of ZEN in the Norwegian power system: (1) Balancing energy between buildings and (2) Sharing energy resources. These challenges have been identified based on discussions with stakeholders in Norway and a review of relevant literature both in the scientific and regulatory domain.

2.1. Balancing energy between buildings

Different types of buildings (residential buildings, schools, offices) may not have their peak energy usage at the same moment in time due to 'the coincidence factor' [17]. The coincidence factor means that the capacity connecting a neighbourhood to the rest of the power system generally is less than the sum of individual peaks in the neighbourhood. This cumulative load profile can be further improved by coordinating energy usage within a ZEN. Coordination of loads can potentially lead to cost reductions since the total amount of capacity connecting the ZEN to the rest of the power system can be reduced. The view that (a) the zero energy concept should be applied to a higher level and (b) energy should be shared between buildings is supported by e.g. [4, 18, 19, 20, 21]. In this context, [21] argue for an energy hub concept to extend the system boundary and realize a system with higher flexibility due to the availability of multiple energy sources and sharing of energy among various consumers and producers.

We now turn to the Norwegian context and the incentives towards consumers for sharing energy between buildings.

In the case of S-ZEN, all the energy resources and the demand are owned by the same stakeholder although they could be spread across several buildings. An example of this is Campus Evenstad which was described in Section 1.2. In S-ZEN projects, the energy usage within the ZEN can be efficiently balanced before the surplus or deficit is traded with the rest of the power system. Since grid charges and taxes are applied at the interface between the ZEN and the rest of the power system, the owner of S-ZENs has incentives to balance out their energy as much as possible before interacting with the grid since this is most economical.

The other class of ZEN, namely the M-ZEN, is more complicated than the S-ZEN when considering energy flows between buildings. The difference occurs because the energy needs to be transferred from one owner to another. Such transfer of energy requires some trading between the two owners, either directly or through a third party.

We use an illustrative example with two buildings as depicted in figure 1 to compare the case of the two classes of ZEN. For simplicity, we only consider electric energy and one hour of operation. During this hour, Building 1 has a surplus of 10 kWh, while Building 2 has a deficit of 10 kWh. Furthermore, we assume that the grid tariff and energy prices are both 0.50 NOK/kWh resulting in a total cost of 1 NOK/kWh for imports and an income of 0.50 NOK/kWh for exports, assuming the grid cost does not apply for exported energy.

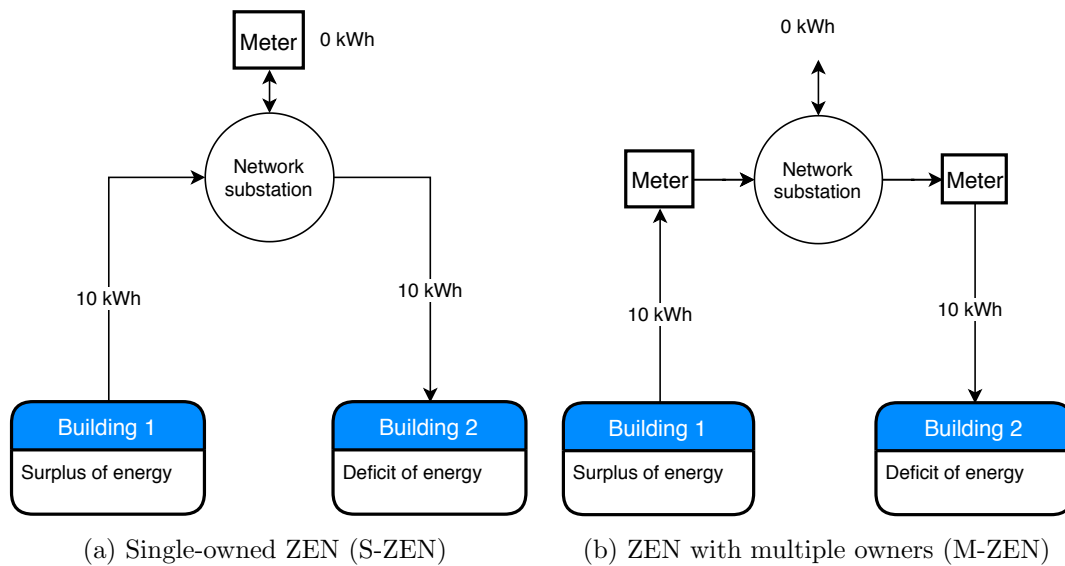(a) Single-owned ZEN (S-ZEN)   (b) ZEN with multiple owners (M-ZEN)

Figure 1: Illustrative example of energy sharing

In the case of S-ZEN, both buildings are owned by the same stakeholder, so these buildings are metered together at the interface to the rest of the power system (see figure 1a). Costs charged are zero as calculated in (1):

$$Cost^a = 1\frac{\text{NOK}}{\text{kWh}} * (10 - 10)\text{kWh} = 0 \text{ NOK} \tag{1}$$

Next, we consider the M-ZEN case where two different stakeholders own these two buildings. We now calculate the costs for each of the buildings separately since they are not metered together (see figure 1b). The result is a total cost of 5 NOK as calculated in (2):

$$Cost^b = 0.5\frac{\text{NOK}}{\text{kWh}} * (-10)\text{kWh} + 1\frac{\text{NOK}}{\text{kWh}} * 10\text{kWh} = 5 \text{ NOK} \tag{2}$$

Although our example is simplified, it can be observed that energy balancing between buildings in ZEN is not supported by the regulatory framework in the case of M-ZEN. The problem occurs as the individual owners do not have any incentives to cooperate in shifting their demand to balance the energy within the ZEN. The regulatory framework provide incentives to consume locally produced energy behind the meter, which in M-ZEN means avoiding surplus energy for single buildings. One might ask if it is possible for several owners located geographically close to each other to establish one common interface towards the rest of the power system, but this is prohibited by Norwegian regulations [22] requiring individual costumers to be metered separately. The current regulatory framework in Norway only allows trading of electricity between two consumers producing energy (prosumers) through a third party (an energy retailer and the local distribution system operator).

This is indeed a challenge for projects in Norway such as Verksbyen in Fredrikstad which will consist of multiple owners that could potentially be able to balance their energy usage locally, but lack incentives for doing so with the current regulatory framework. As an extension of this argument, [23] note that products and markets for demand response should be developed further in several EU countries.

2.2. Shared energy resources

The concept of ZEN facilitates several stakeholders pooling their financial resources together to be able to build larger power generating facilities. One typical example would be an apartment block in which the different apartment owners build a shared PV-plant on the roof or building facade.

So far, with the concept of ZEB, the distinction of on-site vs. off-site resources has been clear due to the well-defined system boundary. In the context of ZEB, [24] argue that if a generation system is behind the meter, it is on-site. Otherwise, it is off-site. This distinction is challenged by the concept of shared energy resources in a ZEN since the system boundary is not as well defined as for a single building. In some cases, it might be optimal to build larger shared plants within the ZEN, but located outside the meters of the individual households.

To illustrate the economics of shared energy resources, we will consider an illustrative example as depicted in figure 2. The example has been based on the business model of energy resources in Verksbyen Fredrikstad excluding the effect of a Feed-in Tariff (FiT). The reason for excluding FiT is that such policies represent an artificial market price and therefore inherent uncertainty regarding the development of future policies. In our example, we consider an operational hour in which a household and the shared consumption (e.g. EV-charging) requires 10 kWh while the shared generation facility generates 20 kWh.

We now look at this system in more detail. First, we consider the shared facilities in which both the consumption and the generation is behind the same metering point. Such a billing practice means that for any energy consumed directly, grid charges are avoided. A result of this is that it is possible to define a local energy price which is higher than the spot price and lower than the retail electricity price which include spot price added grid charges and taxes:

$$\text{spot price} \leq \text{LCOE} \leq \text{local energy price} \leq \text{retail electricity price} \qquad (3)$$

The levelized cost of energy (LCOE) is the lifetime costs divided by energy generation and therefore represent the minimum remuneration per unit of energy to pay back an investment in energy resources. The electricity spot price, e.g. at Nord Pool Spot [25] for nordic countries, is usually lower than the LCOE for distributed energy resources as stated in (3) so it is not profitable to invest in such resources solely to feed it into the electricity grid. Furthermore, (3) states that the LCOE can be lower than the retail electricity price. Therefore, if (3) holds, it is possible to define a local energy price which is larger than the LCOE for energy that is consumed directly. This means that even if distributed energy resources in ZEN are not competitive to
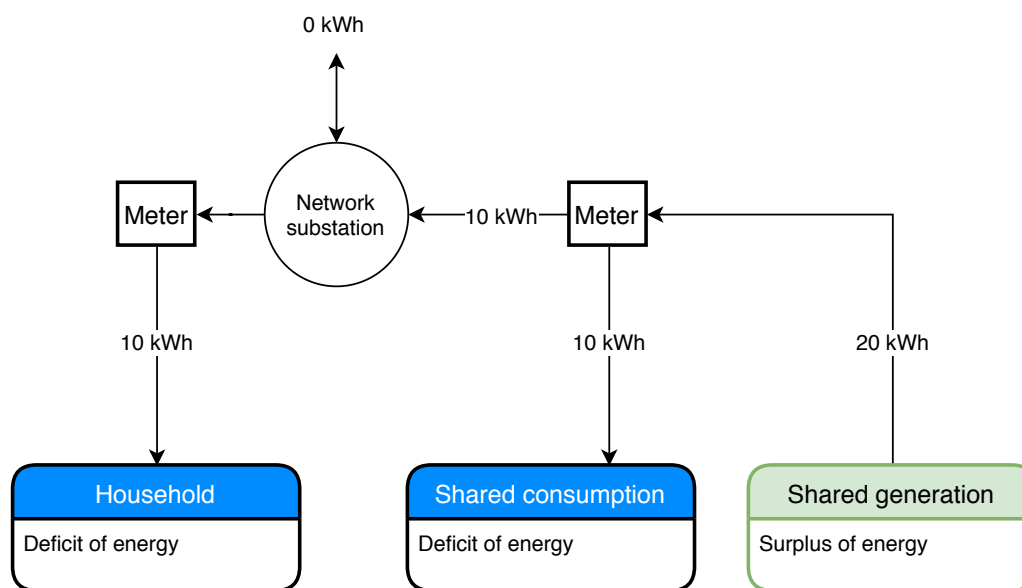
Figure 2: Illustrative example of shared energy resources

large-scale resources in the power market, they may have a place in the power system since they can provide a locational value due to the effect of reducing load as proposed in [26]. This is supported by e.g. [27] which argue that the payment received for exporting excess energy to the grid is insufficient. The underlying reason for this is that distributed generation in ZEN lack the economies of scale which reduce the LCOE for large-scale generation facilities.

We now look at the incentives of the household in this ZEN, which is not behind the same meter as the shared generation. It might be possible for these households to shift their load to some extent in order to match their consumption to the generation. However, due to the pricing policies, the households do not have any incentives for engaging in such behavior. This finding pose a problem since consumers are not incentivized to alleviate grid stress and defer grid investments since their local pricing information do not include the state of the local energy resources.

The issue of shared energy resources is highly relevant for Verksbyen which currently has a plus costumer scheme in place with with an agreement for 0.8 NOK/kWh for any surplus energy fed into the grid. However, the developer of the project consider this price to be highly uncertain since it can change on short notice while investments in energy resources have a long lifetime. Since the project needs to make their decisions subject to regulatory uncertainty, the net present value calculations are based on the assumption that no such agreement is in place since it is an artificial market price. This is in principle a robust optimization approach, and the result is that investments decisions in Verksbyen are based on current market prices and regulatory conditions as depicted in our example.

3. Discussion and conclusions

We have through examples and economic principles shown how current pricing policies in Norway do not offer proper incentives to align behavior by individual stakeholders in ZEN with multiple owners with efficient operation of the overall ZEN. We have demonstrated that when demand response and efficient sharing of energy resources is possible, the current Norwegian billing practices do not offer incentives for the activation of such potential. Furthermore, it should also be noted that grid companies will need to recover their sunk costs, but efficient pricing policies

to properly incentivize consumer behavior can activate the potential of local coordination and reduce the need of grid upgrades. The findings of this paper indicate that the current technical possibilities are ahead of the regulatory framework. Regulatory innovation to fill the gap of missing local incentives can take a multitude of forms, ranging from adapting the network tariffs to implementing other kinds of market mechanisms.

Incentives for energy balancing between buildings and sharing energy resources depends on the ownership structure of the ZEN. The critical distinction is between a single-owned ZEN (S-ZEN) and ZEN with multiple owners (M-ZEN). For S-ZEN, the owner has incentives for balancing the energy needs of the various buildings and generation facilities, while this is not the case for M-ZEN. The difference occurs because of billing practices since the interface to the rest of the power system is different for the two classes. In Norway, there is a lot of interest in local energy generation, but to deploy such assets efficiently for M-ZEN, it is necessary to design market mechanisms that enable utilization of such assets at the time of generation. In the case of M-ZEN, this raises the need for local energy trading between stakeholders within ZEN while also maintaining individual metering to facilitate economic efficiency in the overall power system. Therefore, it is worth considering how the locational value of energy can be exploited while maintaining economic efficiency in the overall power system.

The issues addressed in this paper is largely based on the premise that self-consumption is the most important factor to make decentralized energy resources profitable in Norway. However, the incentives vary across Europe as found in [28, 29] which compared support policies for decentralized photovoltaic systems. For instance, the Flemish policy differs from Norwegian billing practices and do not promote self-consumption since the electricity usage is netted out over a period of time. Germany employs on a Feed-in Tariff to guarantee a minimum selling price, which currently is lower than the electricity price resulting in incentives promoting self-consumption similarly as the situation in Norway. However, if the Feed-in tariff rate approaches the electricity retail price, such as in France, the incentives for self-consumption will disappear. Despite the varying incentives facing individual consumers in different countries, the issues concerning M-ZEN are relevant in a more general sense since there is currently no best practice regarding sharing of energy when multiple owners are present.

This article provides insight into how current pricing policies may need to evolve due to the on-going deployment of ZEN in the power system. Regarding policy development, a recent report from the Norwegian Water Resources and Energy Directorate (NVE) emphasize the need for a regulatory sandbox regime to allow testing of policies by providing temporary regulatory exceptions [30]. The findings in this article provide a starting point for further research on how we can design efficient market mechanisms and pricing policies to incentivize decentralized decisions that are also beneficial for the larger power system.

4. Acknowledgements

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