ECONOMIC FEASIBILITY OF ELECTRICAL BATTERIES FOR NZEB ROW HOUSES IN THE NETHERLANDS

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ABSTRACT

The total amount of renewable energy produced by a net zero energy building is equal or greater to the total amount of energy used on an annual basis. Net zero energy buildings rely on the energy grid to overcome the mismatch between energy production and energy use load patterns. In the Netherlands, this mismatch has currently no negative economic consequences, as there is a net metering agreement. However, this agreement has a close end date, end of 2022, what could make residential energy production and net zero energy buildings less attractive. The addition of a battery storage system to net zero energy buildings could allow to increase the percentage of renewable energy production self-consumption and therefore reduce the possible future energy costs. The aim of this research is to compare three possible future scenarios: (1) with a decreasing net metering agreement, (2) with no net metering agreement and (3) with no net metering agreement and variable wholesale energy market prices. The Matlab/Simulink model used to compare the scenarios has been fed with PV-meter data and smart-meter data of 17 net zero energy row houses located in the Netherlands. The model simulates an ideal battery with no losses. The results shows that with a decreasing net metering agreement, to add a battery will not be economically interesting until the year 2026, but in the case of stopping with the net metering agreement at once it will be immediately profitable and it will have a pay back-time of 7 years. In the case of no net metering agreement and variable wholesale electricity prices a battery will save some energy costs but without a battery charge and discharge control system the pay-back time would be too long to make it economically interesting, at least with the electricity prices of 2019.

Keywords: battery, nzeb, battery sizing, metering agreement, solar, PV system

INTRODUCTION

The goal of the Paris Agreement of 2015 is to keep the rise in global average temperature well below 2 degrees Celsius compared to pre-industrial levels by drastically reducing the emission of greenhouse gases. To reduce the emission of greenhouse gases, the world should stop burning fossil fuels. In the residential building sector this implies a switch from fossil fuel based heating systems to other heating systems such as heat pumps. This change therefore implies an increase on the demand for electric energy. To reduce the electric energy demand associated to the use of heat pumps and to increase the capacity of local renewable energy production the Dutch government has developed multiple programs to promote the increase of building insulation and the installation of PV- systems. The highest level of implementation of this strategy in the residential building sector is the new construction and renovation to net zero energy building (NZEB) level. A NZEB produces as much renewable energy as it consumes over the course of a year.

Too further encourage households to use PV-systems the Dutch government introduced the net metering agreement in 2004. With this metering agreement households can deliver energy into the grid. For pricing the amount of energy that is taken from the grid will be subtracted from the energy that is delivered to the grid at the end of the year. If there is a surplus of delivered energy to the grid this will be sold at a fix consumer electricity market price of €0.07/kWh [1]. If there is a surplus of taken energy from the grid the household has to pay at a fix consumer electricity market price of €0.22/kWh [1]. The problem with this agreement is that a certain amount of produced energy that is delivered to the grid is sold at the same price that it is bought. The difference is around €0.15 and it is paid by the government. Because of the high increase of PV- systems installed this incentive is becoming very costly for the Dutch government. Because of the price of this incentive, it is decided to change the metering agreement in 2023 [5]. This will have consequences for the energy bill of residential buildings that deliver renewable energy to the net. Specially for the NZEB.

To counter this negative financial effect, a solution to minimize energy import and maximize self-consumption of produced energy is desirable. This can be done by adding a battery to the system. The energy that is produced by the PV- system which cannot be consumed by the load demand of the household would normally be delivered to the grid. With a battery some of this energy can be stored. Later on when the household demands energy again, the energy that was stored by the battery can be used to meet this demand. The aim of this paper is to determine whether it is beneficial to add a battery to a NZEB. This will be done by comparing the economic performance of the battery on three different scenarios:

1) With a decreasing net metering agreement (as is the current government proposal).
2) Without net metering agreement and fix electricity market prices.
3) Without net metering agreement and variable wholesale electricity market prices.

Int the following section there is a description of the model, after that the results of the three scenarios simulations are presented and the paper ends with a discussion of the main findings of this research.

METHOD

The NZEB energy system generates electrical energy with a rooftop PV-system, the energy system is also connected to the electricity grid. In case the PV-system does not deliver enough power it is taken from the grid, and in case of surplus of power this is delivered to the grid. A diagram of this system can be seen in Fig. 1.

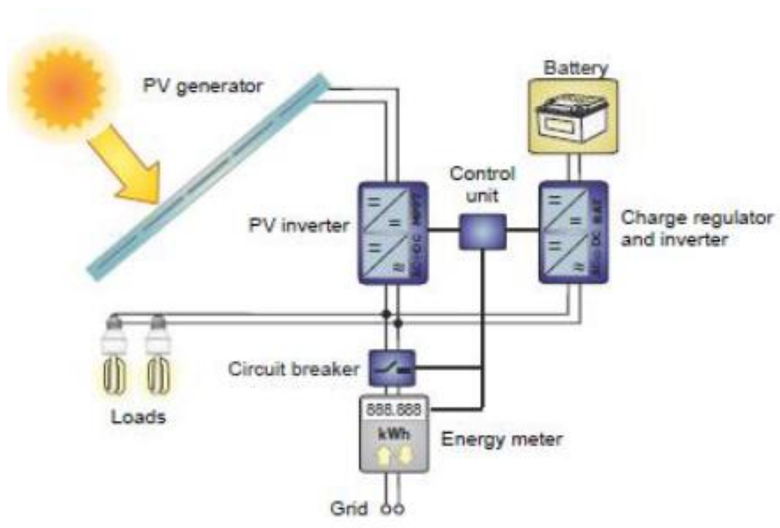

Figure 1. Schematic of energy system of NZEB

The data used in the model has been acquired from a group of 17 net zero energy row houses in Zoetermeer, the Netherlands. All the houses are from the same type, the only difference is that end of the row houses are equipped with a few more solar panels than in between houses. On average the yearly energy production is of 7551kWh and the energy use if of 5129 kWh. The houses are therefore energy positive. The average self-used energy production is of 1661,22 kWh. The average hourly energy import-export profile is presented in Figure 2.

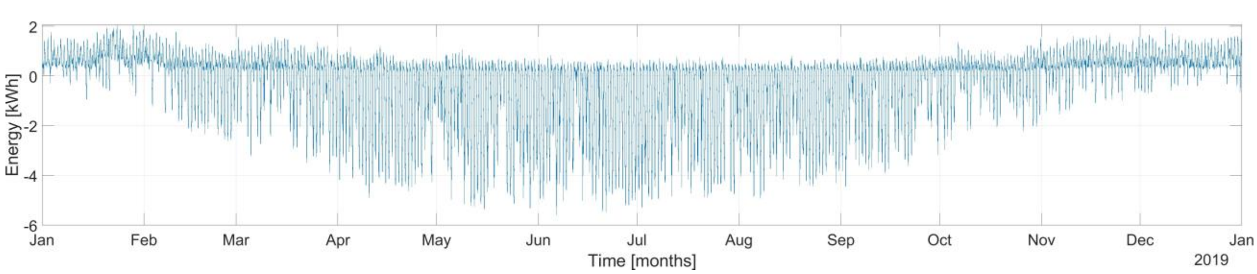

Figure 2: Mean energy balance of group NZEB houses

The data-set used in these paper contains information of energy generated by the rooftop PV-system [kWh] and smart meter import and export [kWh] at a five minute resolution of 17 households. All data used in this paper was recorded in 2019. The data has been reshaped to one hour resolution because variety in time-steps of the smart meter and PV-system meters. Although the mean of the time-steps was at a five minute resolution, the maximum variation between two time-steps was one hour and twenty minutes. Also the time-steps of various meters were not synchronized, reshaping the data made it easier to compare the data between houses. Reshaping was performed using the re-time nearest function of MATLAB.

To analyze the performance of the energy system a model has been created with Matlab/Simulink, in the following section there is a description of the model used.

Battery model description

In this model it is assumed that efficiency of PV inverter, charge regulator and inverter are 100%. It is also assumed that an ideal battery is in place, where there is no energy lost over time and it can deliver or take as much power as needed. This analysis does take the size of capacity of the battery into account.

Every household has its own smart meter which registers the energy that is taken from the grid E_{imp} and the energy that is delivered to the grid E_{exp}. The energy produced by the PV solar system is registered by the PV inverter meter E_{gen}. With the use of Eq. 1 and Eq. 2 is it possible to calculate the household energy use E_{load} and the energy directly used from the PV solar system $E_{edu.}$.

$E_{imp} = E_{load} - E_{du}$ [kWh] (Eq. 1)

$E_{exp} = E_{gen} - E_{du}$ [kWh] (Eq. 2)

The power is derived from the hourly energy measurements. The power shortage P_{short} (Eq. 3) and the power surplus P_{surpl} (Eq. 4) determines if the battery is charging or delivering energy to the household. If there is a momentary power surplus the power is delivered to the battery. If the maximum capacity of the battery is not reached the battery charges until the battery is fully charged. If there still a surplus after the battery is fully charged the power is delivered to the grid. If there is a momentary power shortage the power will be taken from the battery. If the battery is depleted, the power is taken from the grid.

$P_{short} = (P_{gen} - P_{load}) < 0$ [kW] (Eq. 3)

$P_{surp} = (P_{gen} - P_{load}) > 0$ [kW] (Eq. 4)

The capacity of the battery have been defined by looking to maximize the savings by adding a battery on scenario 2, without metering agreement. The optimal battery capacity in this scenario and with the battery cost calculation defined in the following section is of 8 kWh. Fig. 2.

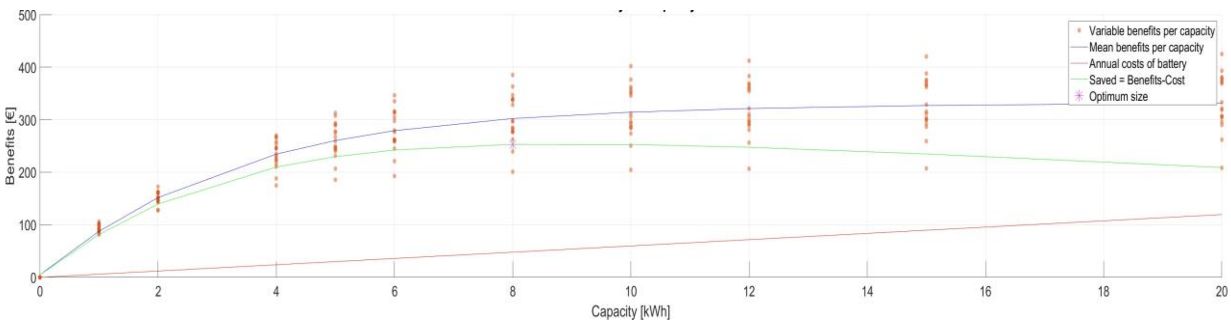

Figure 2: Savings and costs related to different battery sizes

Cost calculation

The parameters used to calculate the costs are presented in Table I, the same parameters have been used as in the research of Maik Naumann [3]. The battery investment costs $/kWh used are from the blog of renewable energy of the world [4], the price has been recalculated to euros. The variables used in this model are:

Table I: Cost calculation values

Parameter	Value
Lifetime battery	20 years
Investement cost battery	€122,71 * Capacity of battery
Maintenance cost battery	1.5% * investment cost every year
Installation rate	5.0% * investment cost
Consumer electricity buying price	0.22 €/kWh
Consumer electricity selling price	0.07 €/kWh

The wholesale variable energy prices that have been used in scenario three have been collected from the website ENTSO-E Transparency Platform [7]. The prices are different each hour and are defined one day ahead. The prices used for the simulation are from the year 2019, the same year as the energy measurements from the households. In the year 2019 the electricity prices ranged from negative €9 per MWh to positive €120 per MWh with an average of positive €40 per MWh.

The payback time t_{pb} has been calculated taking into account the total investment cost of the battery C_{inv}, the yearly energy cost savings S_{yBat} and the yearly maintenance costs C_m, Eq. 5. The total investment cost C_{inv} has been calculated taking into account the yearly investment cost C_{yInv}, the lifetime of the battery t_{bat} and the installations costs C_{inst}, Eq. 6. The yearly cost savings S_{yBat} has been calculated taking into account the energy discharged from the battery E_{dBat}, the grid energy buying price C_{gp} the yearly maintenance cost C_m and the yearly investment cost C_{yInv}, Eq. 7.

$$t_{pb} = \frac{C_{inv}}{S_{yBat} - C_m}$$ [years] (Eq. 5)

$$C_{inv} = \frac{C_{yInv} \times t_{bat}}{C_{inst}}$$ [€] (Eq. 6)

$$S_{yBat} = E_{dBat} \times C_{gp} - C_m - C_{yInv}$$ [kW] (Eq. 7)

Financial scenarios

Scenario 1, a decreasing net metering agreement. The current proposal of the Dutch government is to set in place a decreasing net metering agreement after 2022 that will run until 2031. The percentages of delivered energy that can be balanced with the imported energy of the grid will decrease every year [5]. The percentages of energy delivered to grid that can be balanced in relation to the imported energy from the grid are shown in table II.

Table II: Proposal net metering agreement from 2023 and on

Year	Percentage
2023	91%
2024	82%
2025	73%
2026	64%
2027	55%
2028	46%
2029	37%
2030	28%
2031	0%

Scenario 2, no metering agreement. In the second scenario there is no metering agreement, the energy that is delivered to the grid cannot be balanced with the energy that is imported from the grid. As a consequence all energy delivered to the grid is paid at €0.07 and all energy imported from the gird is paid at €0.22.

Scenario 3: no metering agreement and variable wholesale energy prices. The energy that is taken from or delivered to the grid is bought or sold at hourly day-ahead electricity prices. Currently there are no plans for letting consumers buy and sell electricity at variable wholesale prices. However, because of the great variance on the energy prices at the wholesale market new mechanism are being set in place to pass the effect of the price variability to the consumer market prices. Simulating this hypothetical scenario allows to anticipate what will happen if there was a direct relation between the two markets.

RESULTS

In scenario 1 in the first 4 years adding a battery will not save energy costs, Fig. 3. This is the case because in the first years it is still possible to balance a considerable amount of the delivered electricity to the grid with the imported electricity. With the consequent difference in costs. At the end of the decreasing net metering agreement program on average the savings are €205,- a year. If the battery was installed in 2021 the payback time for a 8 kWh battery would be of 16 years.

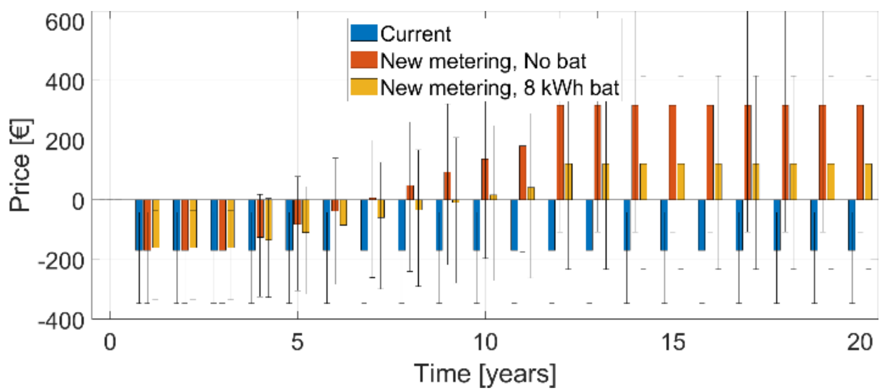

Figure 3: Energy price current metering agreement compared to new metering agreement

In scenario 2, without net metering agreement, NZEB households can deliver energy to the grid only at a selling price of €0.07kWh, what makes it economically interesting to add a battery immediately. Every year €205 will be saved on energy costs compared to the situation without a battery. In this scenario the payback time of the battery would be of 7 years.

In scenario 3 there is no net metering agreement and energy is sold and bought at day ahead wholesale prices. In this scenario it is not profitable to add a battery system to a NZEB household. With the wholesale prices of 2019 there is a yearly energy cost savings of €4. Therefore the payback time from the battery system is longer than the lifetime of the battery system.

However, it should be noted that wholesale electricity prices are considerable lower than consumer prices, in 2019 the average price for a kWh in the wholesale market was of €0.04. It should be also taken into account that the price variability and the average price in the wholesale electricity market has tripled in the last two years [8]. Lastly, the battery system simulated has not control system implemented, therefore, the battery charging and discharging periods are not cost optimized.

CONCLUSION

Until the end 2022 the current metering agreement will stay active, this results in high benefits for delivering energy back to the net. When the government will decrease the percentage of energy delivered to the grid that on a year basis can be balanced with the energy imported from the grid it will become more and more beneficial to add a battery. It is needed to take into consideration that all calculations have been done with an ideal battery. To create a more accurate model it would be necessary to add battery characteristics like:

- Batteries degrade over time and this is determined by the amount of power cycles.
- Batteries lose charge over time.
- Batteries can only be charged by a certain amount of power at the time.
- Batteries can only be discharged by a certain amount of power at the time.

These characteristics can make a difference to the outcome of how beneficial a battery system could be. Also the financial model should be further improved. Interest rates and later investment costs if battery reaches end of life should be included.

With the listed limitations taken into account the following can be concluded:
1) While the current metering agreement stays in place adding a battery to a NZEB energy system will not be profitable. Saving energy will cost more than delivering it back to the grid.
2) When the new metering agreement plan will be introduced adding a battery now to a NZEB energy system will be profitable if battery life can withstand for more than 16 years. Payback time of an 8 kWh will be 16 years.
3) When the metering agreement will be completely stopped it will become profitable right away to add a battery. With a battery capacity of 8 kWh the payback time will be of 7 years. If the trend of decreasing battery prices will go on, the payback time will be even shorter.
4) Scenario 3, no metering agreement and variable wholesale prices is not economically interesting if the battery system does not come equipped with a charge and discharge control system that allows to discharge the battery only on the most economically profitable periods of time.

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