Opportunities for Local Energy Supply in Norway: A Case Study of a University Campus Site

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1st Nordic ZEB+
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Outline

• Energy system at Campus Evenstad
• Monetary value of energy assets
• Investment analysis: «100 %» ZEN
• Conclusions
Campus Evenstad

Photo: Arne Nyaas, Fjellfolk Media
Campus Evenstad

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- Passive house w/ solar thermal collector (2015)
- Solar PV (2013)

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Campus Evenstad

- ZEB-COM (2016)
- Passive house w/ solar thermal collector (2015)
- Solar PV (2013)
- Battery (2018)
- Bio-based combined heat and power (2016)

Photo: Arne Nyaas, Fjellfolk Media
Energy system

- Bio boiler
- El. boiler
- HWS
- HWS
- Solar collectors
- Heat
- CAMPUS
- Electricity
- HWS
- Battery
- Meter
- Grid
- CHP
- Solar PV
- V2G
Monetary value of energy assets
Electricity bill

- Energy (27%)
- Grid (42%)
- Taxes & Levies (31%)
## Monetary value of local energy

<table>
<thead>
<tr>
<th>Measure</th>
<th>Calculation</th>
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<td>Reduced grid import (net metering)</td>
<td>$(0.39^a + 0.02 + 0.04 + 0.1658 + 0.02)(1.25)$</td>
<td>0.79 NOK/kWh</td>
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^a SSB (avg. spot price 1st quarter 2018). URL: [https://www.ssb.no/elkraftpris/](https://www.ssb.no/elkraftpris/)
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<td>Peak shaving (over 12 months)</td>
<td>$(432)(1.25)$</td>
<td>540 NOK/kWh/h</td>
</tr>
</tbody>
</table>

-57%  

*a SSB (avg. spot price 1st quarter 2018). URL: [https://www.ssb.no/elkraftpris/](https://www.ssb.no/elkraftpris/)
Investment analysis: «100 %» ZEN
Model: «ZENIT»

- Investment and operation
  - Lifetime investments
  - Hourly operations
  - Heat and electricity
- Cost minimization
- Ambitious emission target
«Zero Emission» target

\[ \sum_t (y_t^{imp} - y_t^{exp}) \cdot \alpha^{CO_2,el} + \sum_t \sum_f \alpha_f^{CO_2,fuel} \cdot q_{f,t} = 0 \]

- Index \( t \) represents hourly time steps over the representative year
- Index \( f \) represents fuel type (bio, gas etc.)
Instances

1. Asymmetric CO2-factor Annual balance
2. Symmetric CO2-factor Annual balance
3. Symmetric CO2-factor Annual balance 100 kW export limit
4. Symmetric CO2-factor Quarterly balance
Results

Investment in Production (kW)

Annual, Asymmetric Electricity CO2 Factors

Investment in Storage (kWh)
Results

Investment in Production (kW)

Investment in Storage (kWh)

1. Annual, Asymmetric Electricity CO2 Factors
2. Annual
3. Annual, Export Limit

- Solar thermal
- Bio boiler
- CHP
- Electric Boiler
- Heat pump
- PV
- Heat storage
- Battery
Results
Conclusion

- Most monetary value on increased self-consumption
- Dependent on emission factor assumptions
- Solar PV most cost-efficient emission compensation
Conclusion
Takk for oppmerksomheten!
# Electricity use at Campus Evenstad

KPIs for electricity at Campus Evenstad. Estimates are marked with *

<table>
<thead>
<tr>
<th></th>
<th>2015</th>
<th>2016</th>
<th>2017 (ex. Jan)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grid electricity (net) [kWh]</td>
<td>1,012,941</td>
<td>1,058,962</td>
<td>906,955</td>
</tr>
<tr>
<td>Max import [kWh/h]</td>
<td>436</td>
<td>479</td>
<td>468</td>
</tr>
<tr>
<td>Grid utilisation factor [%]</td>
<td>27</td>
<td>25</td>
<td>24</td>
</tr>
<tr>
<td>Average [kWh/h]</td>
<td>116</td>
<td>121</td>
<td>104</td>
</tr>
<tr>
<td>Export [kWh]</td>
<td>0</td>
<td>158</td>
<td>70</td>
</tr>
<tr>
<td>Delivered electricity PV [kWh]</td>
<td>62,454</td>
<td>61,960</td>
<td>62,000*</td>
</tr>
<tr>
<td>Delivered electricity CHP [kWh]</td>
<td>-</td>
<td>160,000*</td>
<td>160,000*</td>
</tr>
<tr>
<td>Self-consumption [%]</td>
<td>100</td>
<td>99.93</td>
<td>99.97</td>
</tr>
<tr>
<td>Self-generation [%]</td>
<td>6*</td>
<td>17*</td>
<td>20*</td>
</tr>
</tbody>
</table>
Emission factor of electricity

<table>
<thead>
<tr>
<th>Energy source</th>
<th>CO₂-eq</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity output [kg/MWh\text{out}]</td>
<td></td>
</tr>
<tr>
<td>Hard coal</td>
<td>660–1050</td>
</tr>
<tr>
<td>Lignite</td>
<td>800–1300</td>
</tr>
<tr>
<td>Natural gas</td>
<td>380–1000</td>
</tr>
<tr>
<td>Oil</td>
<td>530–900</td>
</tr>
<tr>
<td>Nuclear power</td>
<td>3–35</td>
</tr>
<tr>
<td>Biomass</td>
<td>8.5–130</td>
</tr>
<tr>
<td>Hydropower</td>
<td>2–20</td>
</tr>
<tr>
<td>Solar energy</td>
<td>13–190</td>
</tr>
<tr>
<td>Wind</td>
<td>3–41</td>
</tr>
</tbody>
</table>

Emission factor of electricity

Source:
Clauss et al. (2018): "A generic methodology to evaluate hourly CO2 factors of the electricity mix to deploy the energy flexibility potential of Norwegian buildings"