ZERO EMISSION NEIGHBOURHOODS IN SMART CITIES

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

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The Research Centre on Zero Emission Neighbourhoods in Smart Cities (FME ZEN)

1st Nordic ZEB+

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ZERO EMISSION
NEIGHBOURHOODS
IN SMART CITIES

Outline

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

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Campus Evenstad

Photo: Arne Nyaas, Fjellfolk Media

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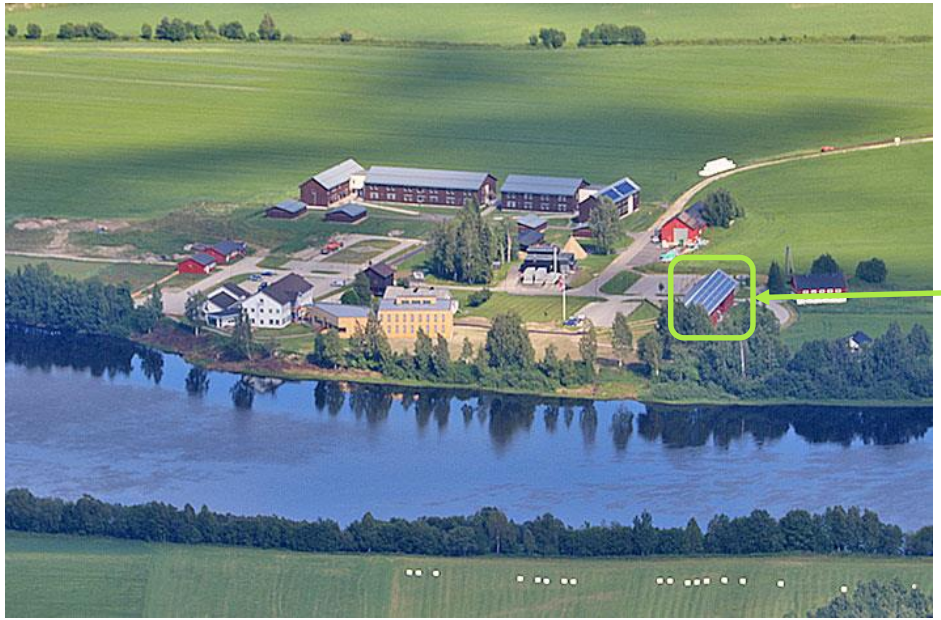
Campus Evenstad



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Campus Evenstad

Passive house
w/ solar thermal collector
(2015)

Solar PV
(2013)

Photo: Arne Nyaas, Fjellfolk Media

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Campus Evenstad

Passive house
w/ solar thermal collector
(2015)

ZEB-COM
(2016)

Bio-based combined heat and power
(2016)

Solar PV
(2013)

Photo: Arne Nyaas, Fjellfolk Media

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Campus Evenstad

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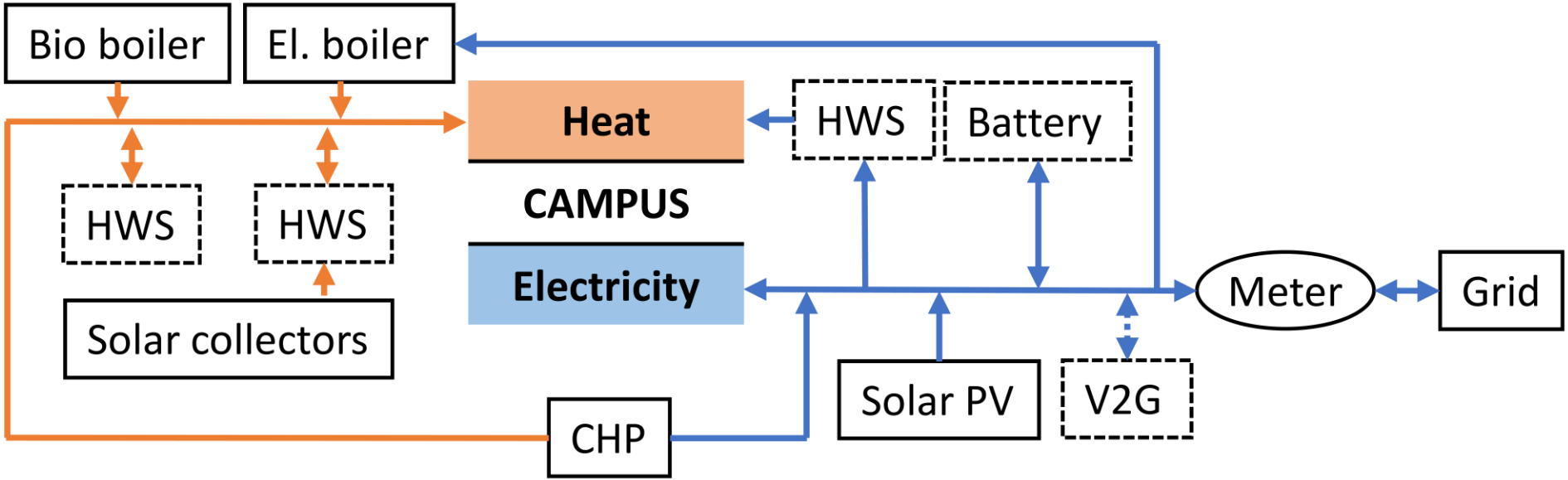
Energy system



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Monetary value of energy assets

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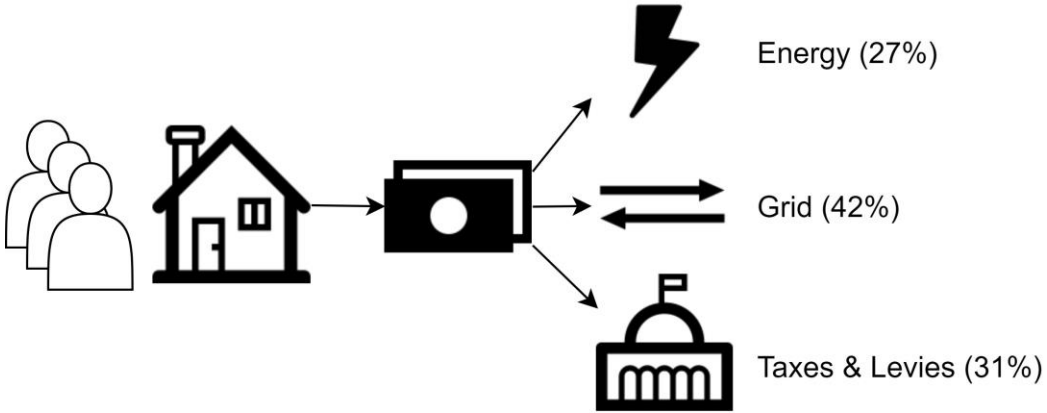
Electricity bill



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Monetary value of local energy

Measure	Calculation	Savings
Reduced grid import (net metering)	(0.39[a] + 0.02 + 0.04 + 0.1658 + 0.02)(1.25)	0.79 NOK/kWh

[a] *SSB (avg. spot price 1st quarter 2018). URL: https://www.ssb.no/elkraftpris/*

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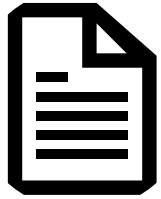
Monetary value of local energy



Measure	Calculation	Savings
Reduced grid import (net metering)	(0.39[a] + 0.02 + 0.04 + 0.1658 + 0.02)(1.25)	0.79 NOK/kWh
Grid export	(0.39[a] + 0.02 + 0.04)	0.45 NOK/kWh

-57%

[a] *SSB (avg. spot price 1st quarter 2018). URL: https://www.ssb.no/elkraftpris/*

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Monetary value of local energy

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Grid export	(0.39[a] + 0.02 + 0.04)	0.45 NOK/kWh
Peak shaving (over 12 months)	(432)(1.25)	540 NOK/kWh/h

-57%

[a] *SSB (avg. spot price 1st quarter 2018). URL: https://www.ssb.no/elkraftpris/*

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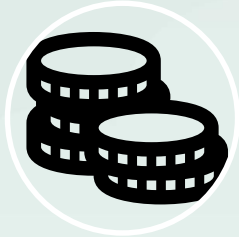

Investment analysis: «100 %» ZEN

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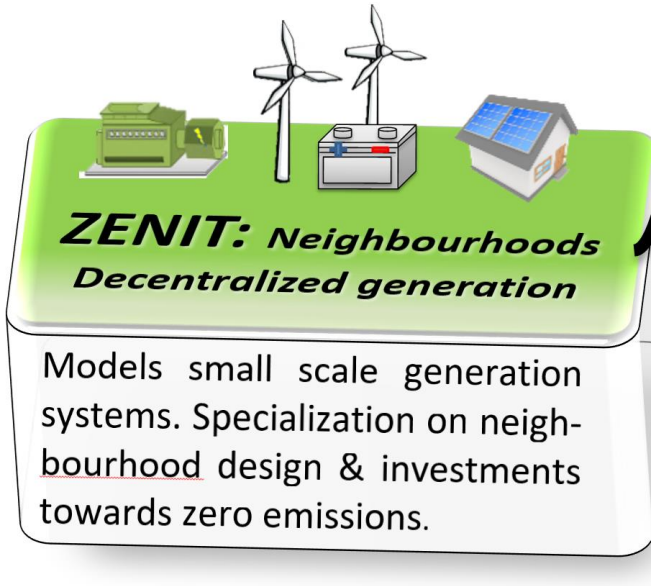
Model: «ZENIT»

- Investment and operation
  - Lifetime investments
  - Hourly operations
  - Heat and electricity
- Cost minimization
- Ambitious emission target



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«Zero Emission» target

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

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

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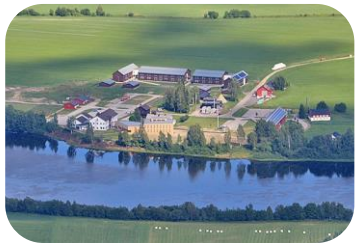
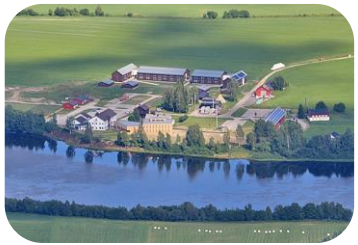
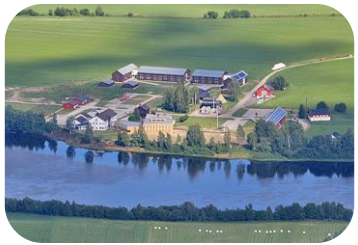
Instances

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

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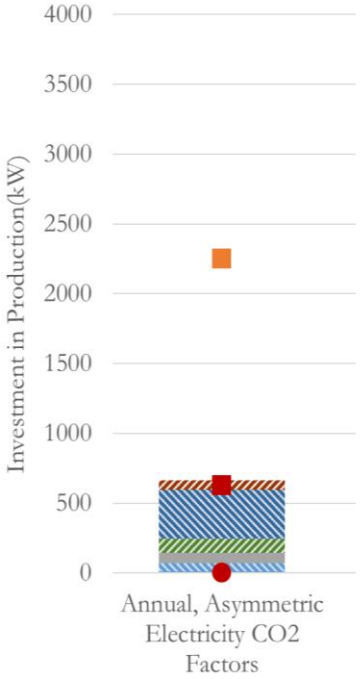
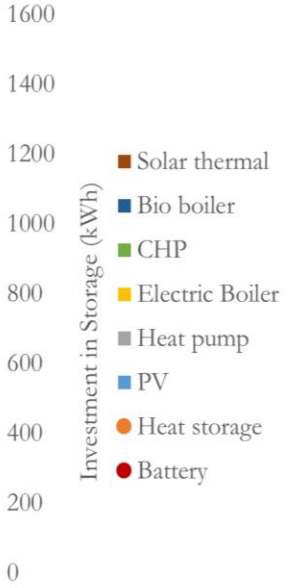
Results





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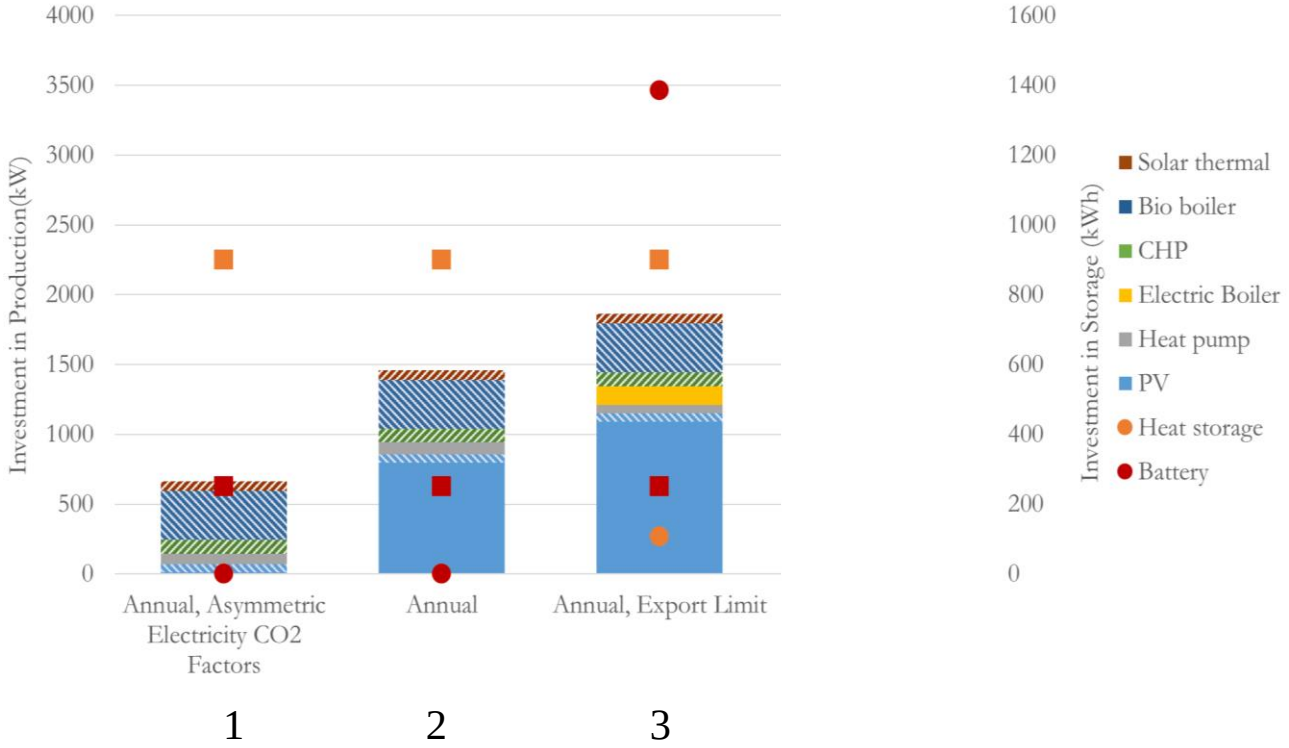
Results



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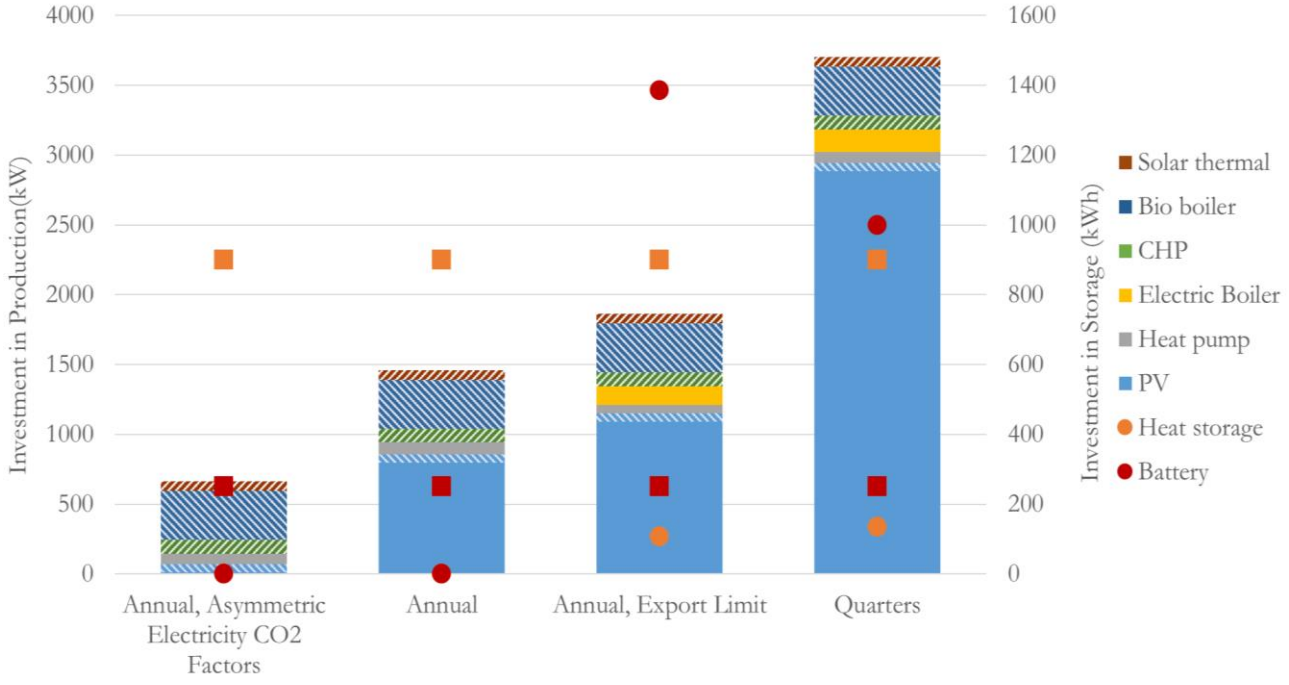
Results



1 2 3 4

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Conclusion

Most monetary value on increased self-consumption

Dependent on emission factor assumptions

Solar PV most cost-efficient emission compensation

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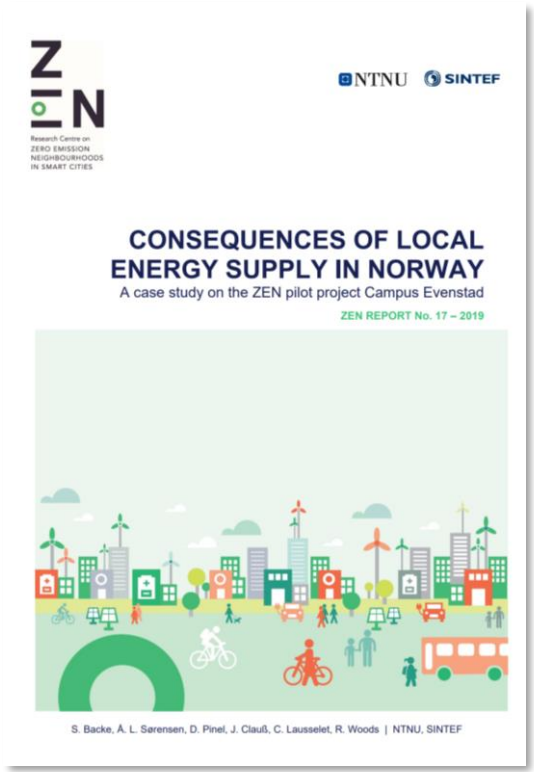
Conclusion



Takk for oppmerksomheten!

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Electricity use at Campus Evenstad

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

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

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Emission factor of electricity

Energy source	CO_2-eq
Electricity output [kg/MWh_{out}]	
Hard coal	660–1050
Lignite	800–1300
Natural gas	380–1000
Oil	530–900
Nuclear power	3–35
Biomass	8.5–130
Hydropower	2–20
Solar energy	13–190
Wind	3–41

Source:
Turconi, Roberto, Alessio Boldrin, and Thomas Astrup. "Life cycle assessment (LCA) of electricity generation technologies: Overview, comparability and limitations." *Renewable and sustainable energy reviews* 28 (2013): 555-565.

ZEB-factor: 132 gCO2eq/kWh

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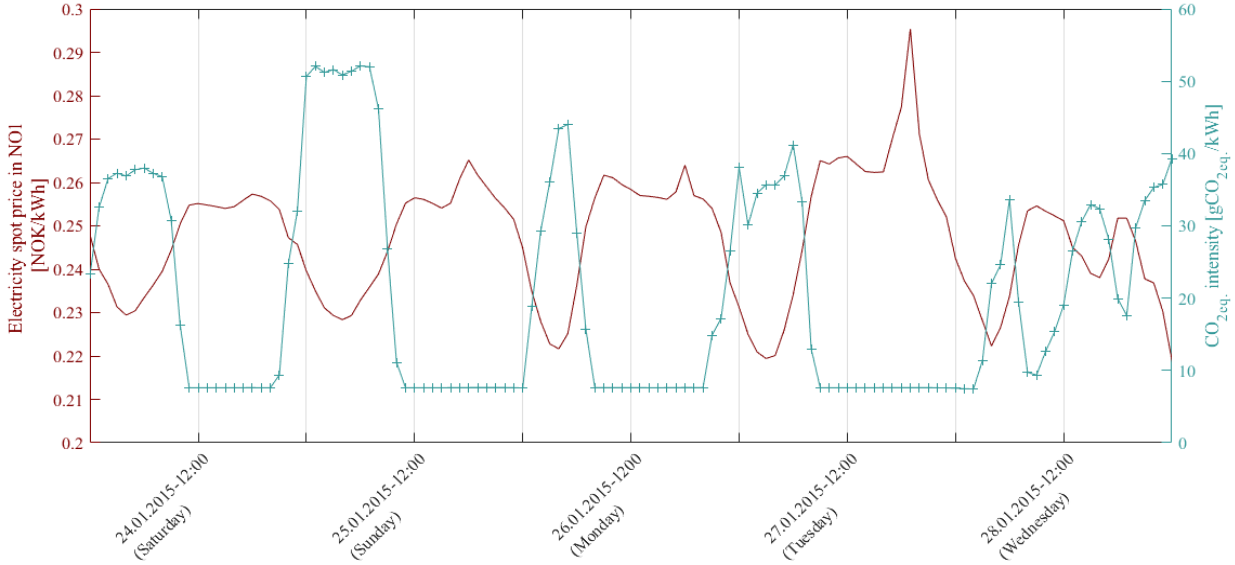
Emission factor of electricity



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"

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