Optimal integration of net Zero Energy Buildings in the Scandinavian energy system

71TH SEMI-ANNUAL ETSAP MEETING
Maryland, USA 10.07.2017

Pernille Seljom (pernille.seljom@ife.no),
Karen Byskov Lindberg (kli@nve.no) &
Asgeir Tomasgard (asgeir.tomasgard@ntnu.no)

Motivation

- **net Zero Energy Building (ZEB)**
  - Low energy demand and renewable energy generation
  - Energy generation = energy demand
  - PV is a suitable energy generation technology
- **EU’s Energy Performance of Buildings Directive (EPBD)**
  - All new buildings shall be nearly ZEB from 2020
  - The definition of a “nearly” and Primary Energy factors are member specific
- **Scandinavia; Denmark, Norway & Sweden**
  - Solar irradiation is high in summer when electricity demand is low
  - ZEBs with PV require electricity trade with the electricity grid

Research questions

- If all new and rehabilitated buildings are ZEB with PV
  - How will this change the cost-optimal development of energy system towards 2050 ?
  - What is the optimal heat design in buildings ?
  - Is it possible to integrate substantial PV production in Scandinavia ?
  - What is the future role of the flexible hydropower ?

Methodology

- **Scandinavian TIMES model**
  - Model period 2010 - 2050
  - 48 time-slices
    - 4 seasons
    - 12 daily periods
  - End-use sectors
    - Buildings
    - Transport
    - Industry
  - Perfect foresight investments

Methodology

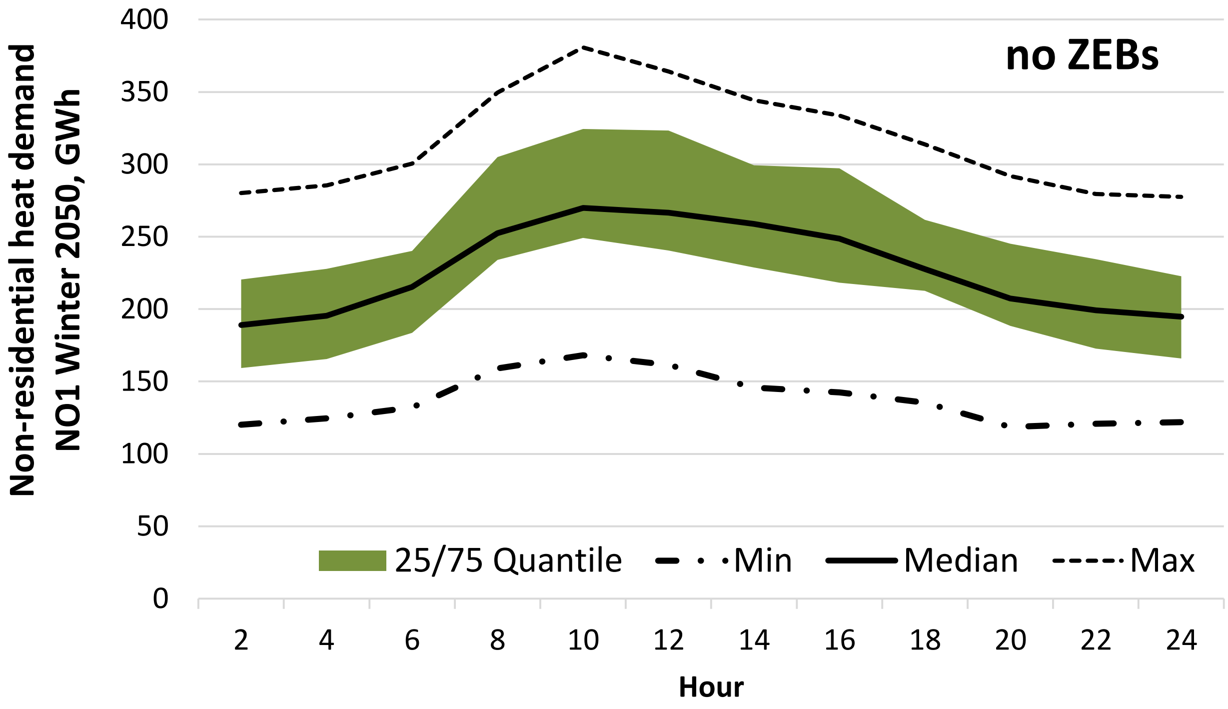
- **ZEB definition**
  - All new and rehabilitated buildings have a passive house standard with on-site PV. In 2050:
    - 50 % of the Scandinavian building stock is ZEBs
    - Expected heat demand is reduced from 192 TWh to 157 TWh
  - PV production = Electric specific consumption on an annual basis
    - 2030: 25 TWh
    - 2050: 53 TWh
- No use of local energy storage

Methodology

- Stochastic Programming is used to consider short-term uncertainty and to value flexibility
- Investments are made with respect to the short-term uncertainty of
  - PV production
  - Wind power production
  - Hydropower production
  - Heat demand in buildings
  - Electricity prices outside Scandinavia
- Grid interaction with ZEBs is particular dependent on PV production & heat demand

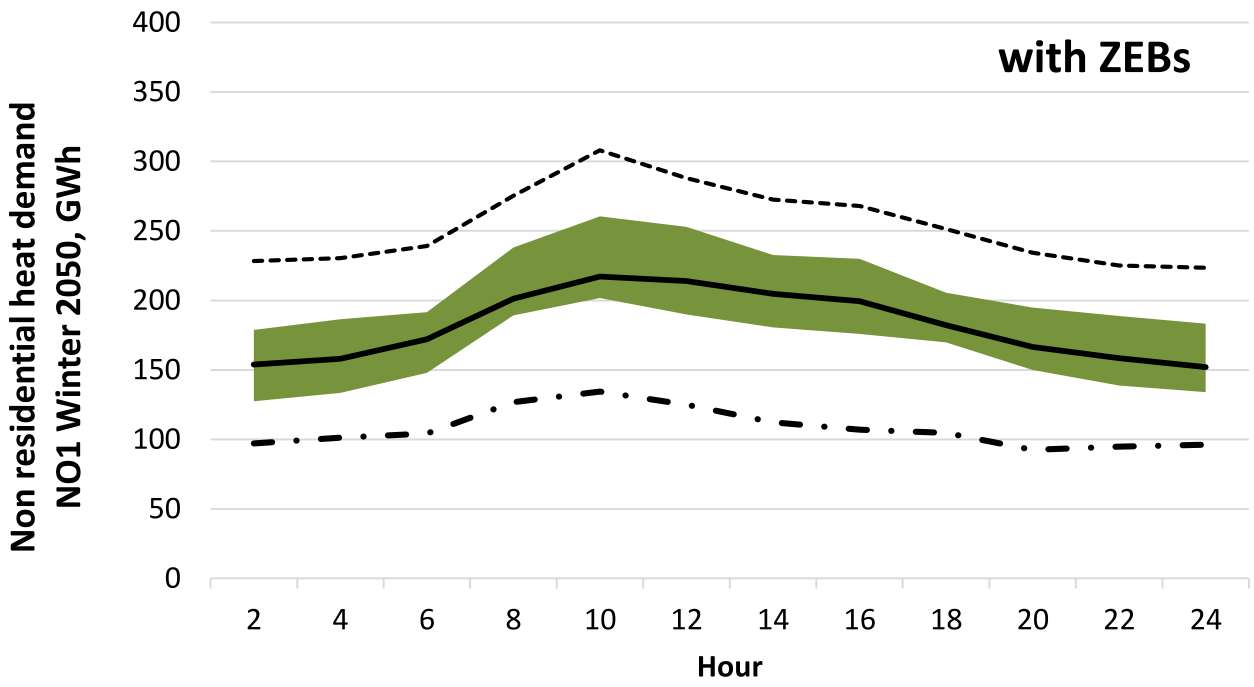
Methodology

- Model input on non-residential heat demand without ZEBs
  - 21 stochastic scenarios



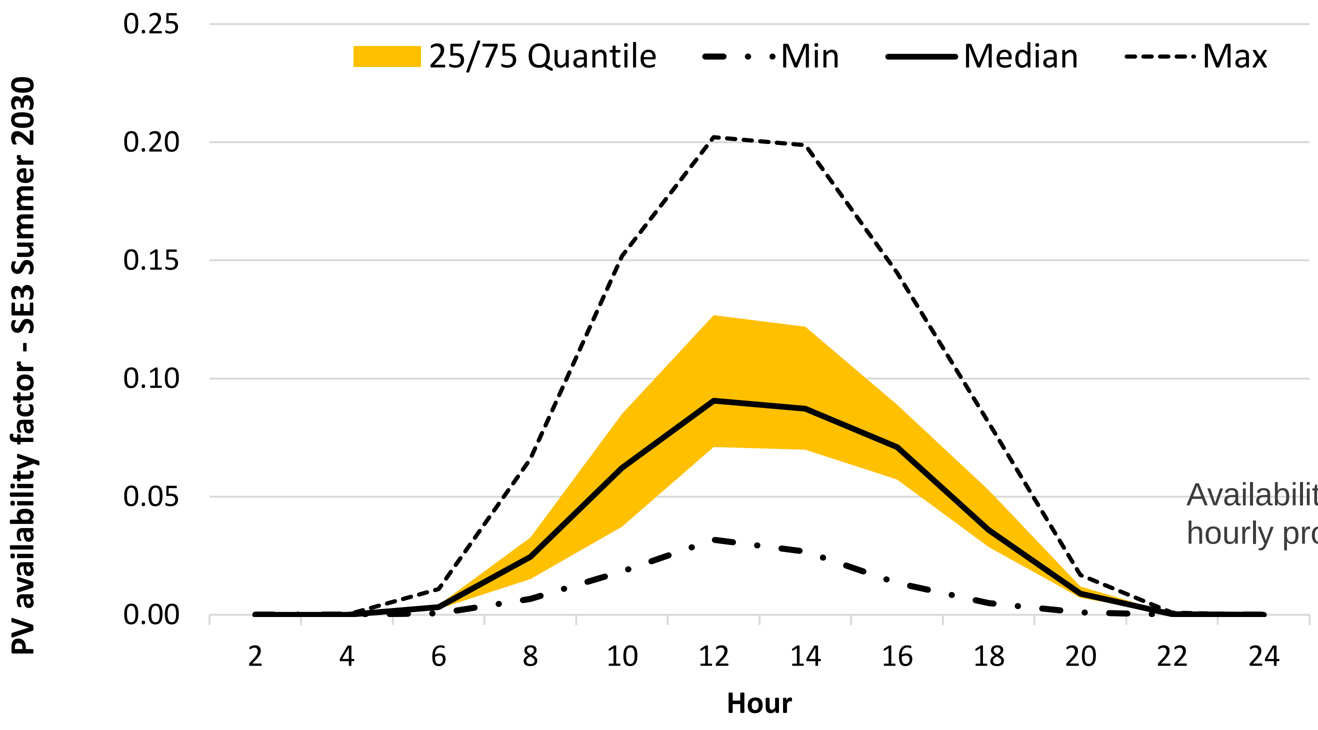
Methodology

- Model input on non-residential heat demand with ZEBs
  - 21 stochastic scenarios



Methodology

- Model input on PV production
  - 21 stochastic scenarios



Availability factor = hourly production/ capacity

Results

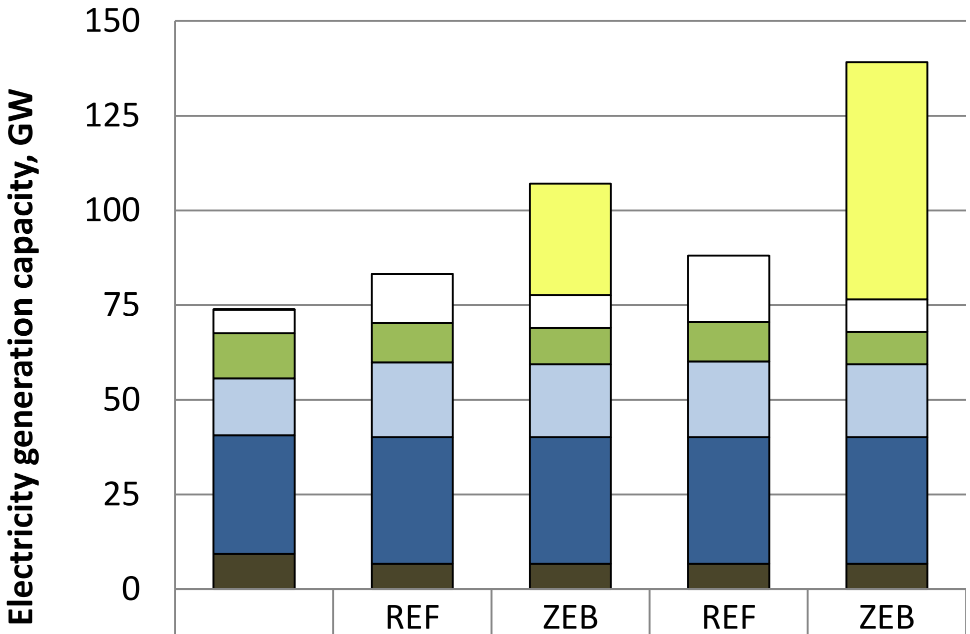
- Two different case assumptions on new and rehabilitated buildings

Case	Passive building standard	Building integrated PV
REF	No	No
ZEB	Yes	Yes

- Heat demand (TWh/y) 2030 2050
  - REF 177/**194**/222 179/**192**/224
  - ZEB 162/**178**/203 145/**157**/183

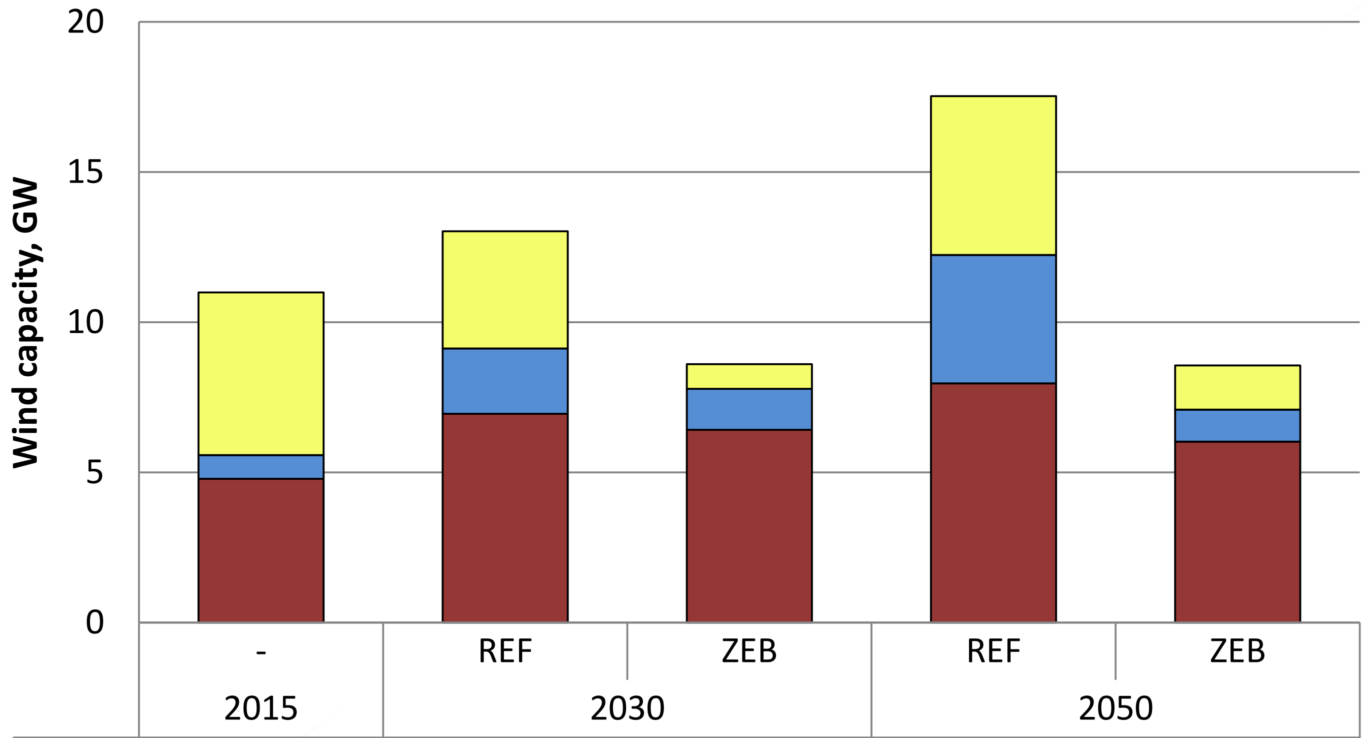
- PV production in ZEB
  - 2030 25 TWh
  - 2050 53 TWh

Electricity generation capacity



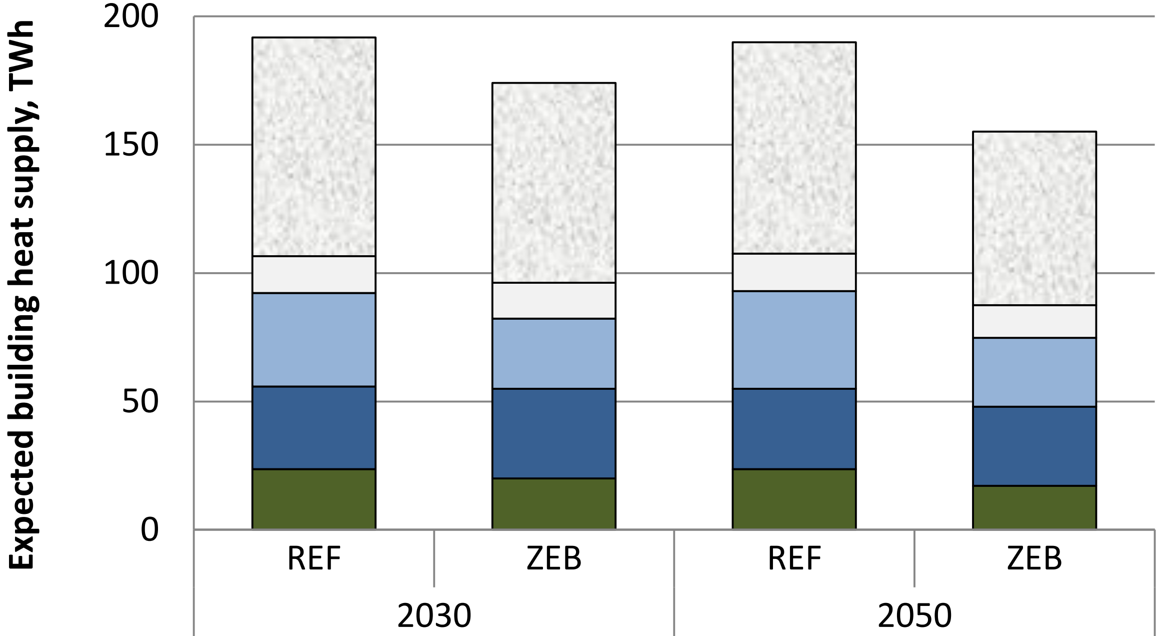
	2010	2030 REF	2030 ZEB	2050 REF	2050 ZEB	
Total	73.8	83.3	107.0	88.0	139.1	
PV	0.0	0.0	29.4	0.0	62.6	
Wind	6.3	13.0	8.6	17.5	8.6	- 51 %
CHP	11.9	10.4	9.6	10.4	8.6	- 17 %
Non-flexible hydro	15.0	19.8	19.2	20.0	19.2	- 4 %
Flexible hydro	31.4	33.4	33.4	33.4	33.4	0 %
Nuclear	9.3	6.7	6.7	6.7	6.7	0 %

Wind power capacity



	2015	2030 REF	2030 ZEB	2050 REF	2050 ZEB
Total	11.0	13.0	8.6	17.5	8.6
SE	5.4	3.9	0.8	5.3	1.5
NO	0.8	2.2	1.4	4.3	1.1
DK	4.8	7.0	6.4	8.0	6.0

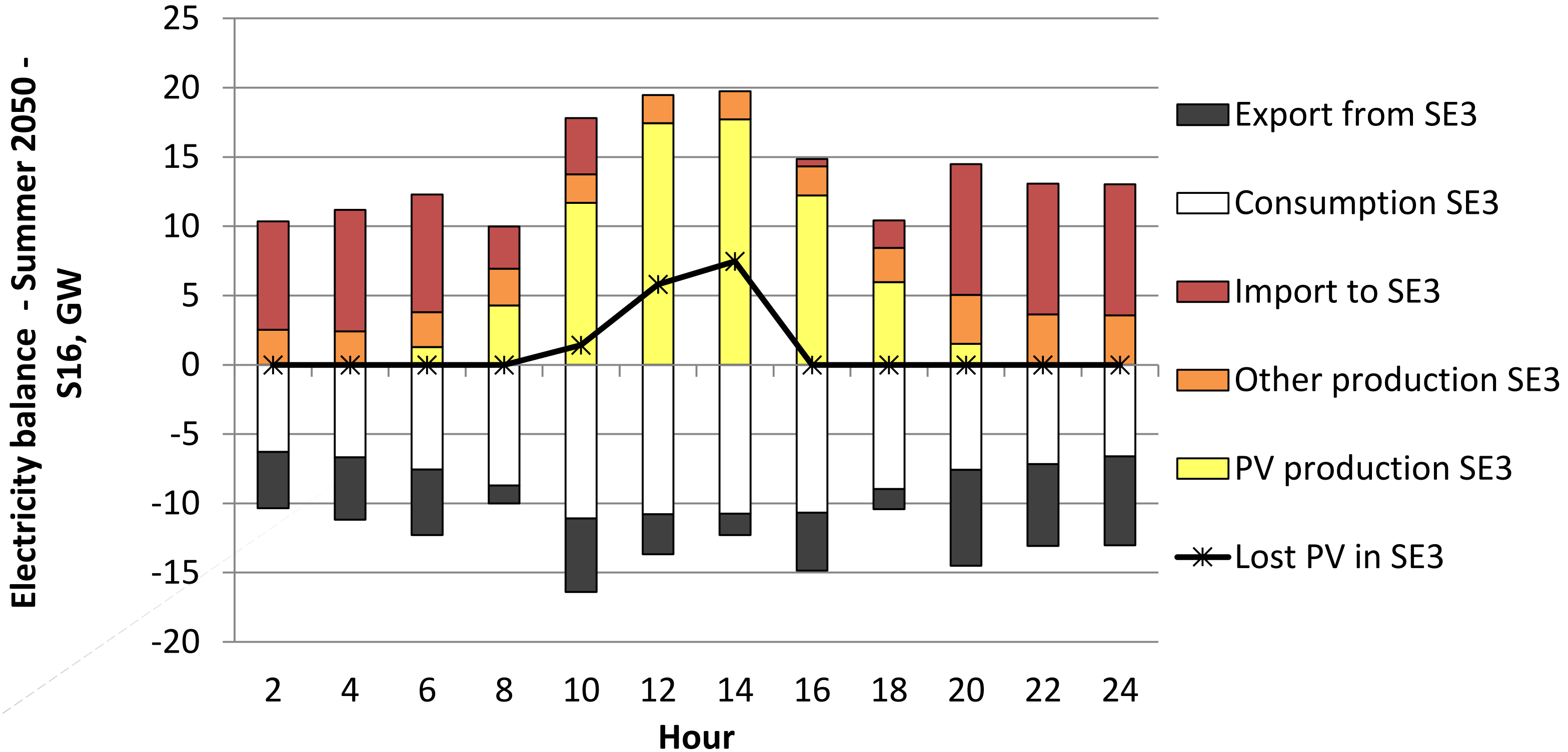
Building heat supply



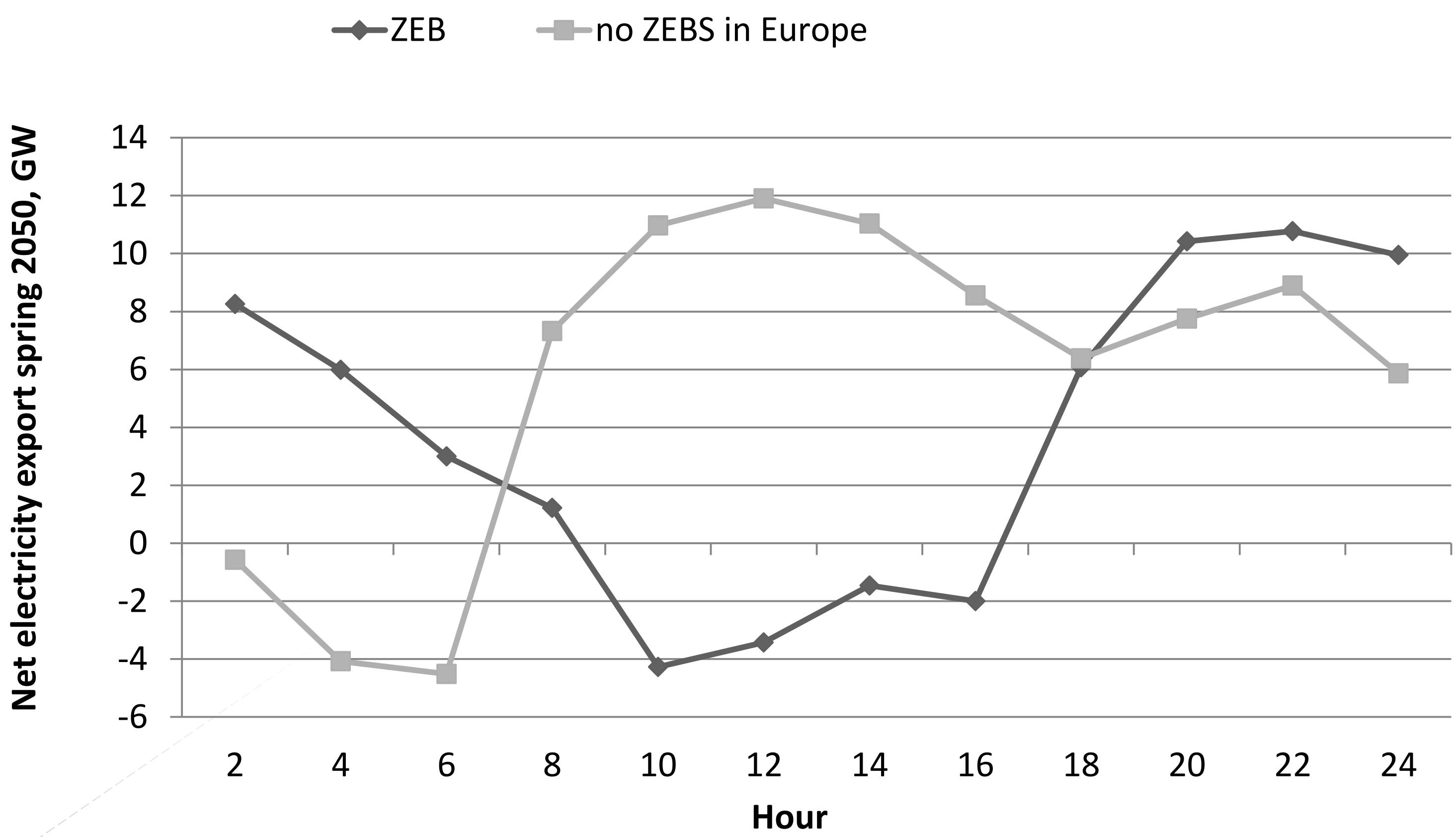
	2030 REF	2030 ZEB	2050 REF	2050 ZEB	
Total	192	174	190	155	
District heat	85	78	82	68	- 17 %
Gas	14	14	15	13	- 13 %
Heat Pump	36	27	38	27	- 29 %
Electricity	32	35	31	31	0 %
Biomass	24	20	24	17	- 29 %

System integration of PV

- With no storage in ZEBs & no new Scandinavian transmission
  - Expected loss of electricity in 2050 = 1.3 TWh/ 2.4% of PV production
- Example: Electricity balance in the Stockholm region



Net electricity export



Conclusions

- **Implementation of ZEBs with PV**
  - Influences cost-optimal investments and operation of the energy system
    - Lower heat demand & PV production
  - Reduces the competiveness of CHP, wind power and non-flexible hydropower
  - Increases the share of low-cost electricity heating
- **System integration of PV**
  - Scandinavian energy system is well suited to integrating a large amount of ZEBs with PV
  - 2 % of unutilized PV with no building storage in 2050
  - Scandinavian energy system does not require local energy storage in all ZEBs

Acknowledgements to:

NTNU

ZEB The Research Centre on Zero Emission Buildings

NVE

CenSES Centre for Sustainable Energy Studies

Forskningsrådet

Thank you for the attention

pernille.seljom@ife.no

For more details:

Seljom, P., Lindberg, K.B., Tomasgard, A., Doorman, G., Sartori, I., 2017. **The impact of Zero Energy Buildings on the Scandinavian energy system**. Energy 118, 284-296.