NTNU

Norwegian University of Science and Technology

Large scale integration of ZEBs reduces wind investments

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IFE Institutt for energiteknikk

NVE

CenSES Centre for Sustainable Energy Studies

ZEB

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Motivation

- EU's Energy Performance of Buildings Directive (EPBD)
- Recast of 2010

  → all new buildings shall be

  'nearly' zero energy buildings

  from 2018/2020

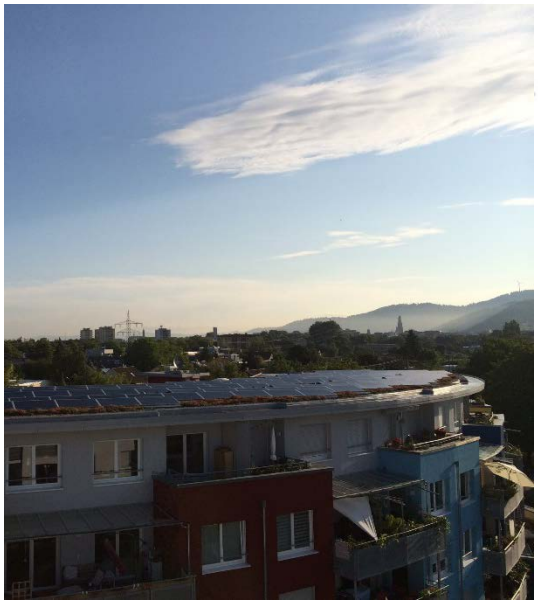


Photo: K.B.Lindberg

Zero Energy Buildings (ZEB)

Zero Emission Buildings (ZEB)

Zero Carbon Buildings (ZCB)

Scope

- Large scale introduction of ZEBs
  - What if all new and rehabilitated buildings towards 2050 become ZEBs with PV?
- How will this affect
  - electric production capacity
  - heating technologies in buildings
- Substantial PV production
  - possible to integrate in Scandinavia?

Foto: K.B.Lindberg

Foto: NVE

Outline

1. What is a ZEB?
2. Energy system analysis of Scandinavia
   with 50 % ZEB towards 2050
   - Model
   - Method
3. Results
4. Conclusions

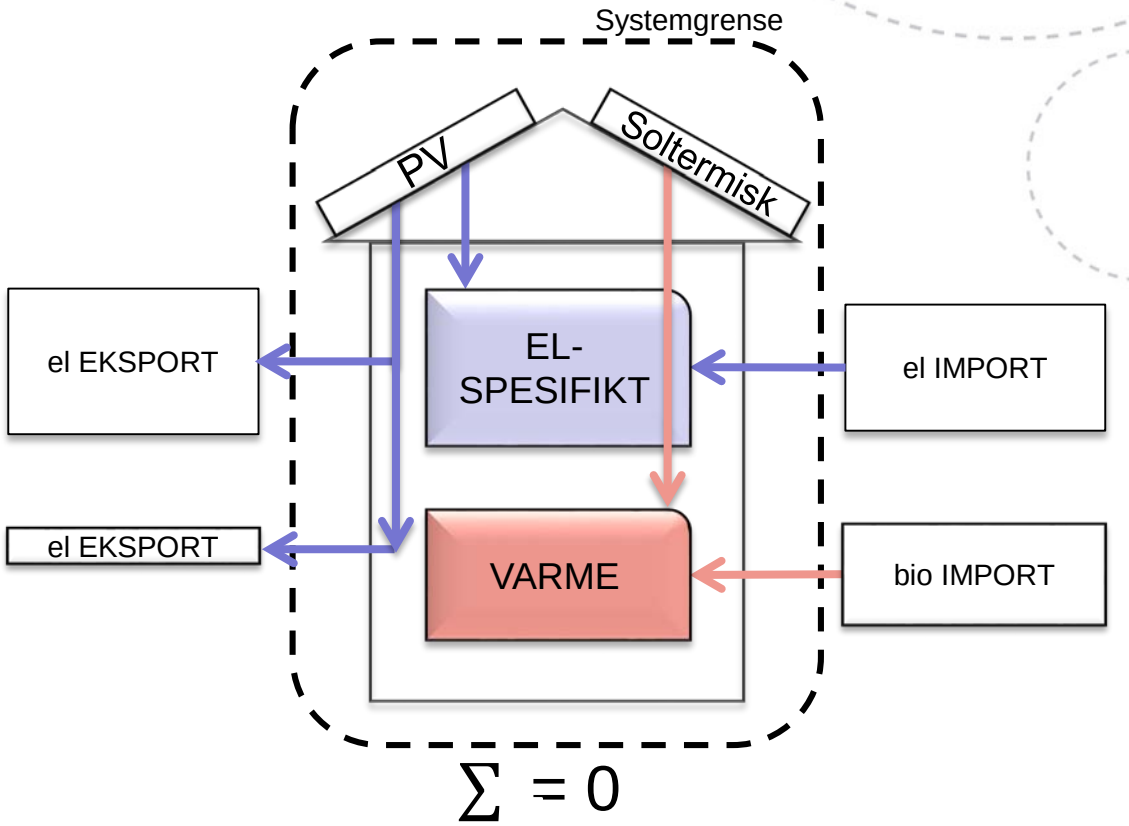
1. What is a ZEB?

Zero Energy Building

- ZEB definisjon
  - Netto null over året
  - Svært energieffektivt
  - Lokal produksjon → PV
- Vektingsfaktor for elektrisitet, f_{el}
  - Uvesentlig (les PhD-en!)
- Effektprofil
  - eksport fra bygget (sommer)
  - import til bygget (vinter)

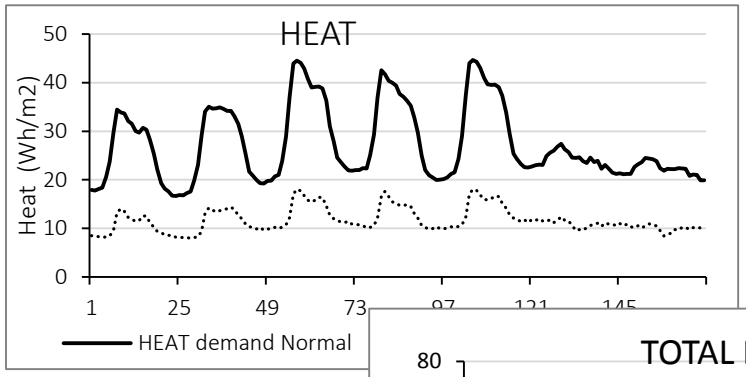
> 0 nær null
= 0 ZEB
< 0 pluss

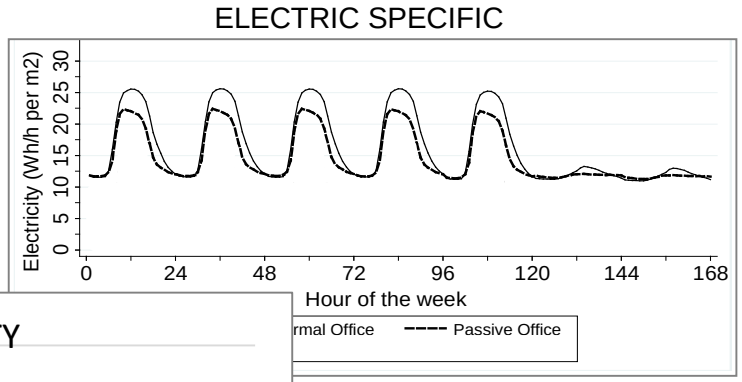
$$\sum_i \text{import}_i * f_i - \sum_i \text{eksport}_i * f_i = 0$$

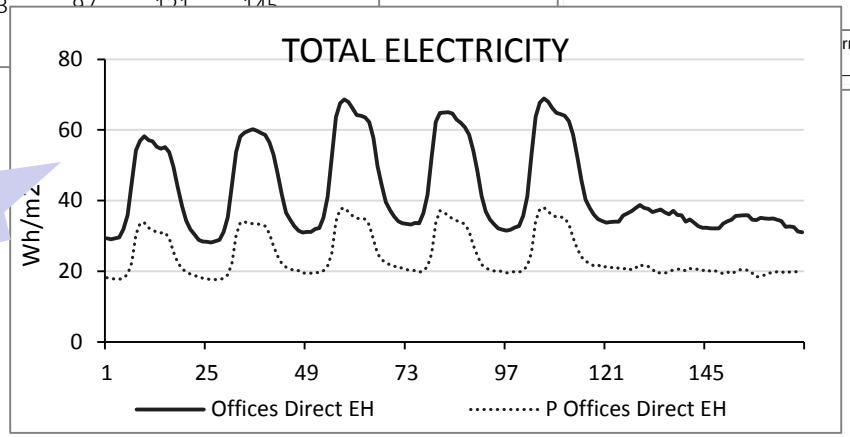


Effektprofil for ZEB

- Varmelast
  - romvarme & varmtvann
  - makslast (- 50 %) &
    årlig varmebehov (- 60 %)
- El-spesifikk last
  - apparater, lys, vifter og pumper
  - maks last liten endring
    (ca. - 10 % for Kontor)







NB! Hvis varmen dekkes av panelovn eller elkjel.

Peak power (- ca 40 %)

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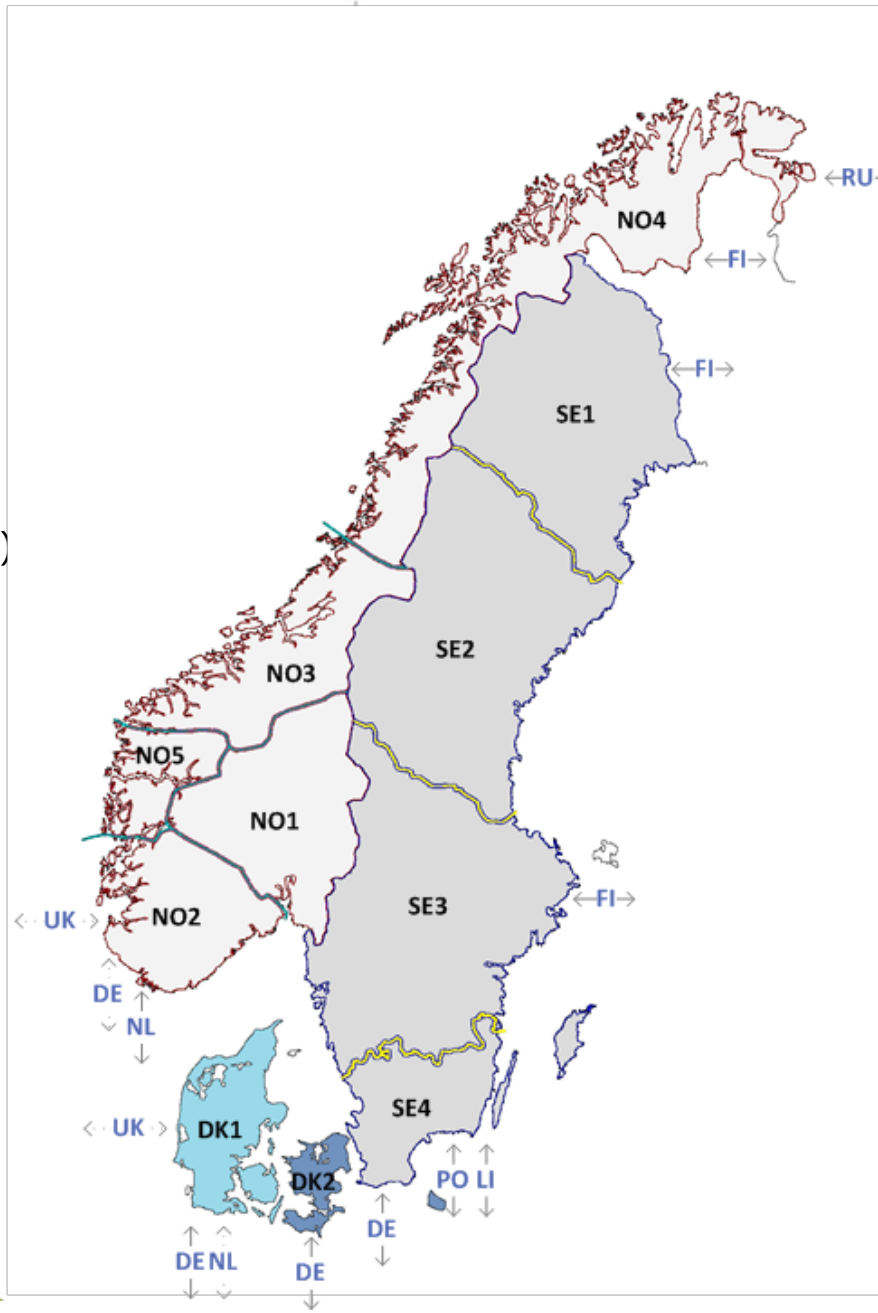
2. Energy system analysis

Model

- Assumptions on ZEBs
  - 50 % of building stock is ZEB in 2050
    - Reduced heat demand
    - Forced PV generation (53 TWh/a in 2050)
- TIMES model
  - Techno-economic bottom-up model
  - Minimises total system cost
  - Time horison: 40 years
    - 2hr time resolution (1 day per 4 seasons)
  - Investment decisions
  - Stochastic optimisation
  - 21 scenarios

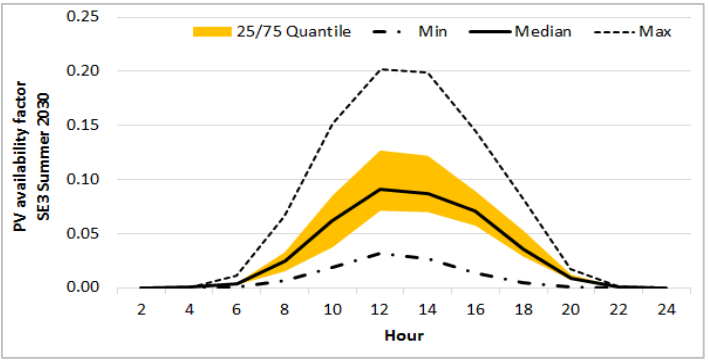


Stochastic optimisation

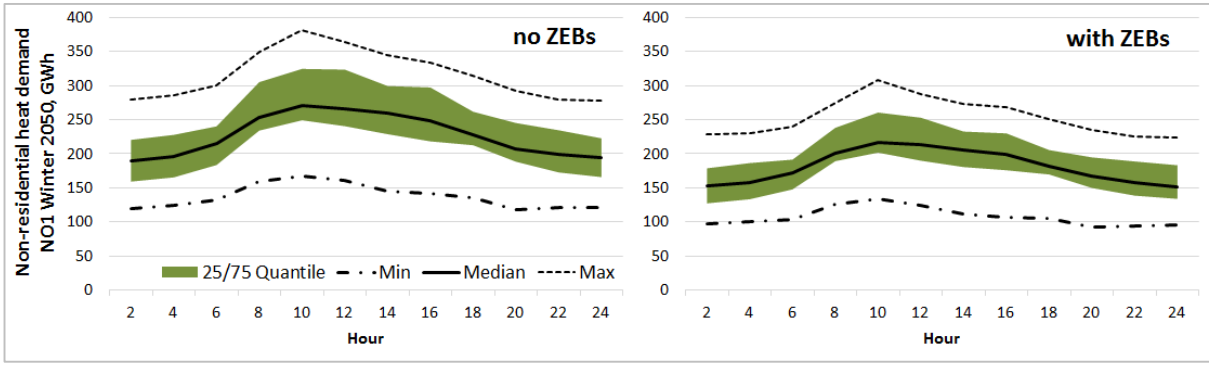
- Investment decisions are made with respect to uncertainty
  - PV
  - Wind
  - Hydropower
  - Heat demand in buildings
  - Electricity prices outside Scandinavia

21 stochastic scenarios

PV production

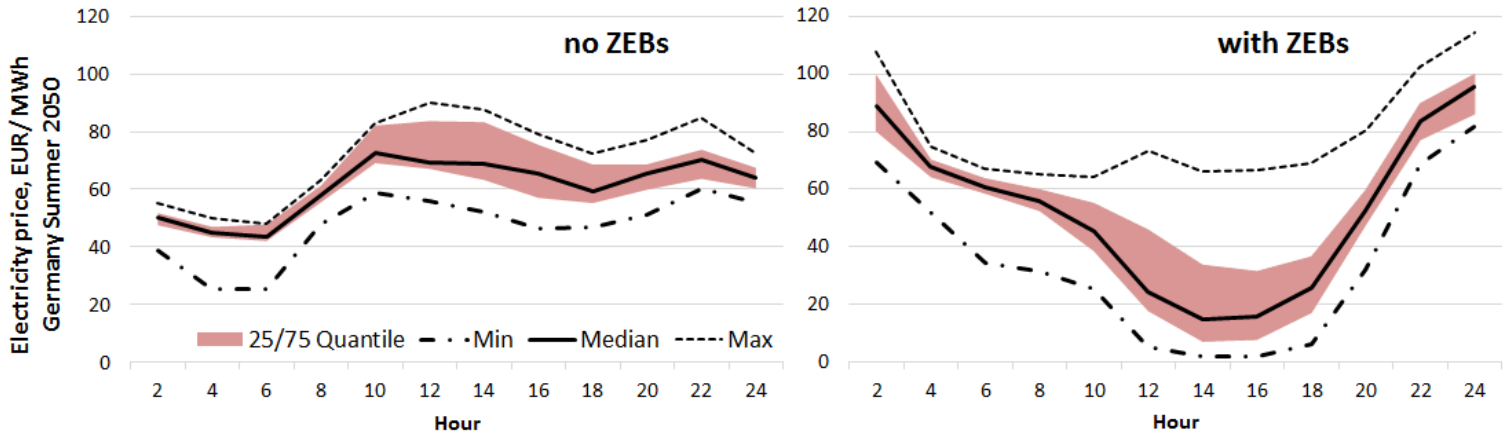


Heat demand, non-residential

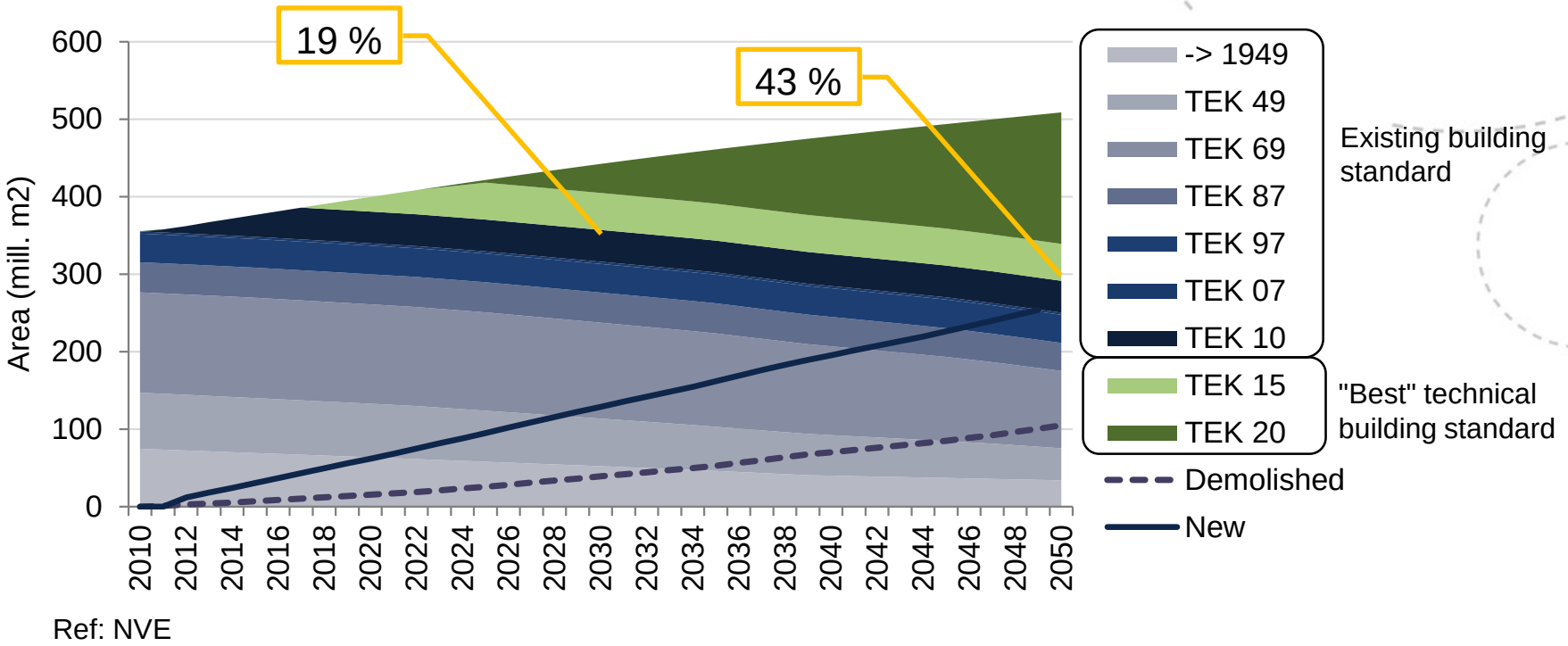


Randbetingelser

- Prisprofiler mot Tyskland



Future building stock



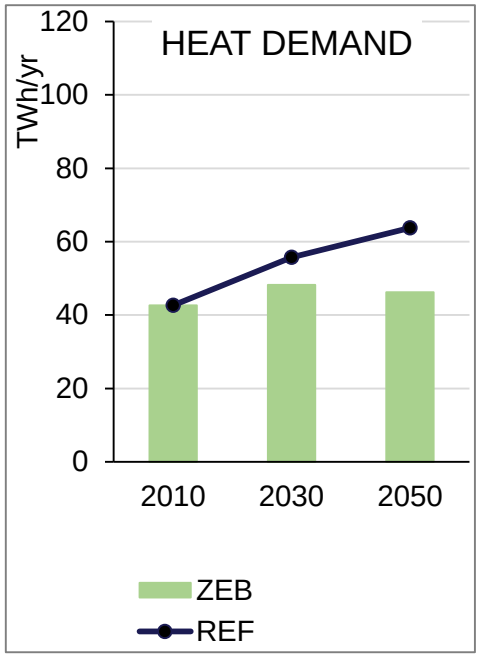
Ref: NVE

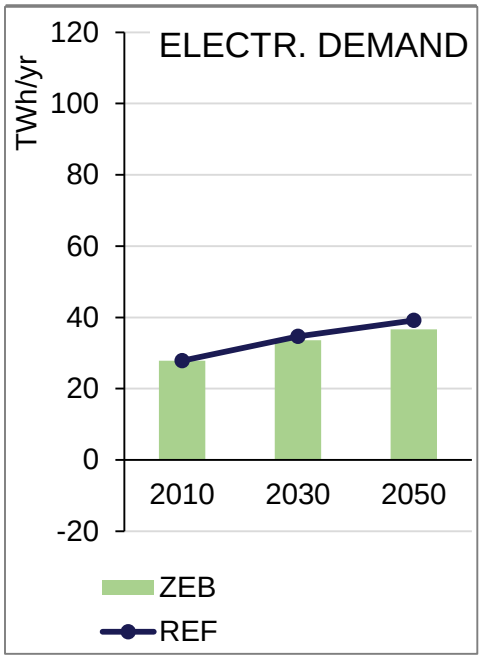
- Model case: 25 % ZEBs in 2030
  50 % ZEBs in 2050

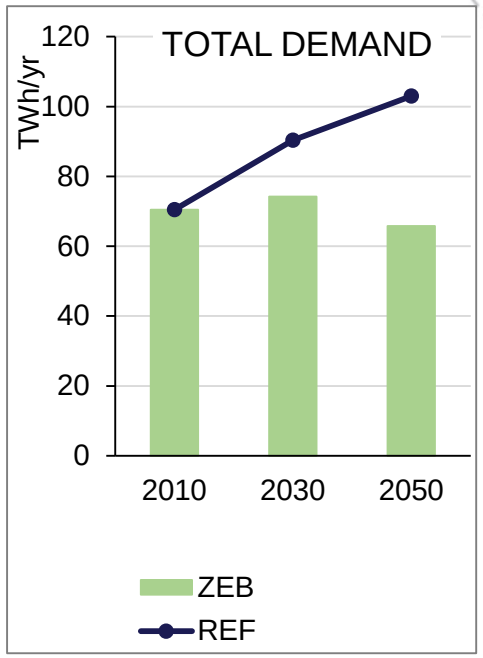
Model cases

Case	Passive building standard	On-site PV production
REF	No	No
ZEB	Yes	Yes

- REF: Business as usual
- ZEB: 50 % ZEB buildings towards 2050
  - Assuming: ZEBs PV production = ZEBs electric specific demand

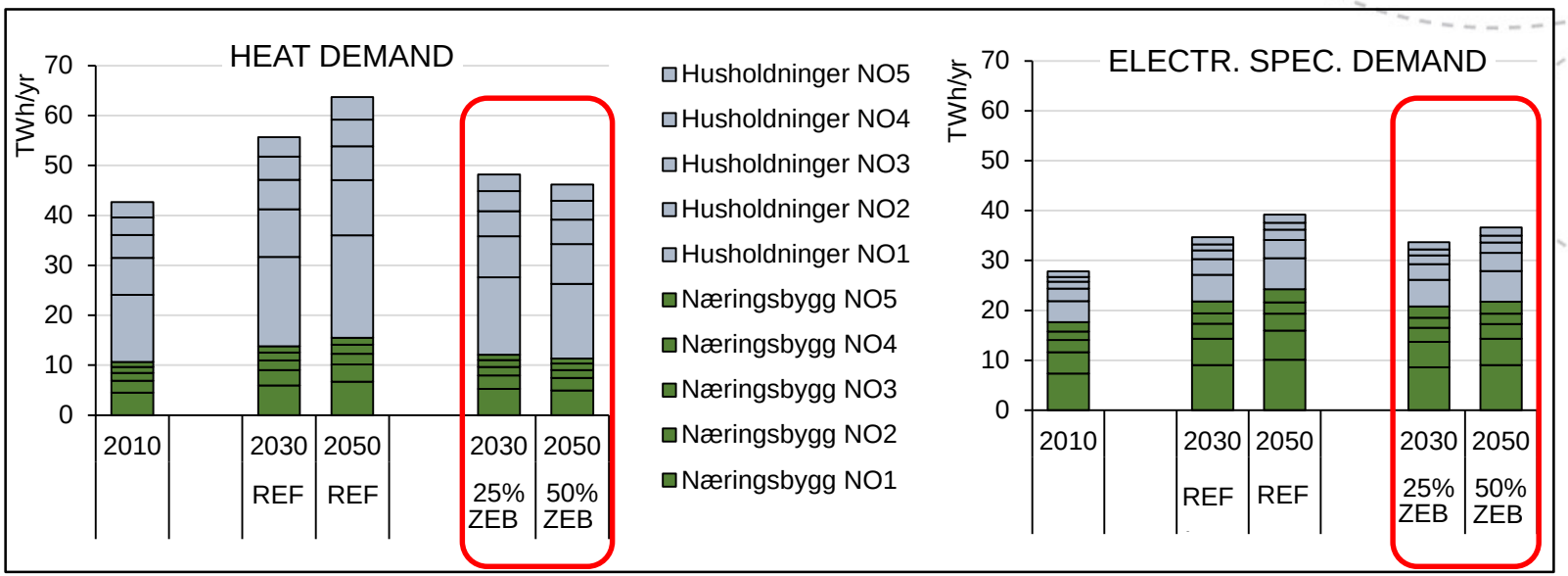






Future demand

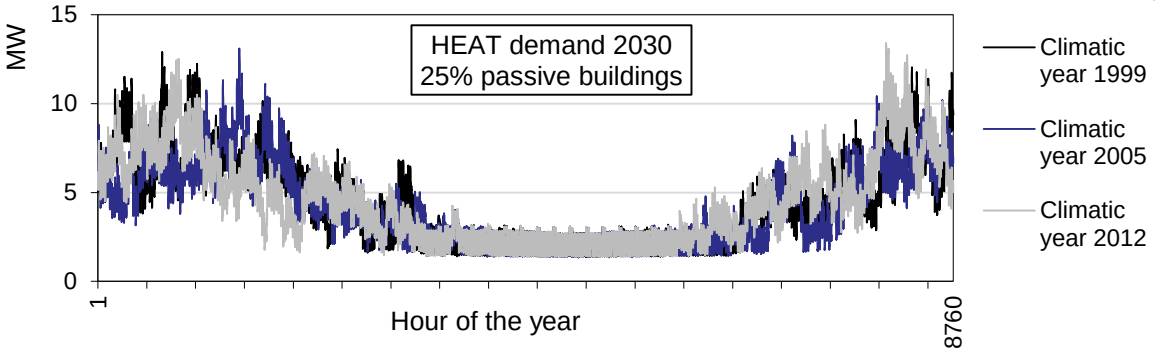
- Årlig energibehov (normalår)



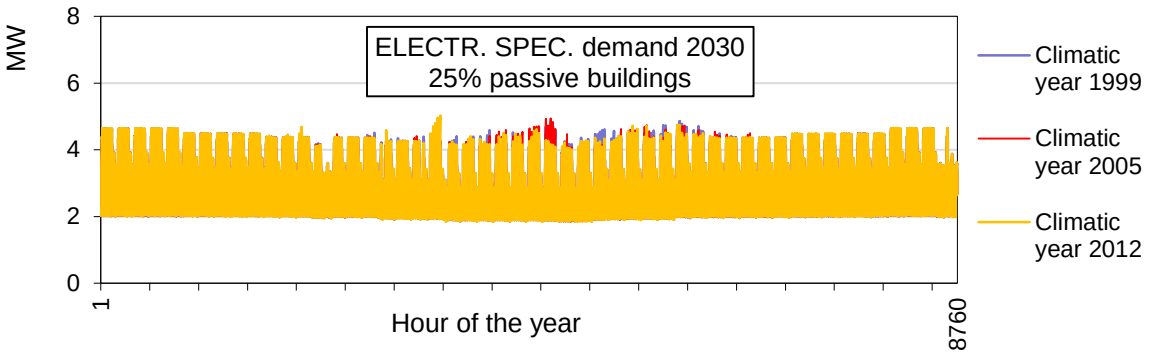
  - Varmebehov
    - dominert av husholdninger
    - TEK har stor innflytelse
  - El-spesifikt behov
    - dominert av næringsbygg
    - mindre påvirket av TEK

Hourly future demand

- 25 % passiv-bygg i 2030 (NO1)
  - Varmebehov



  - El-spesifikt

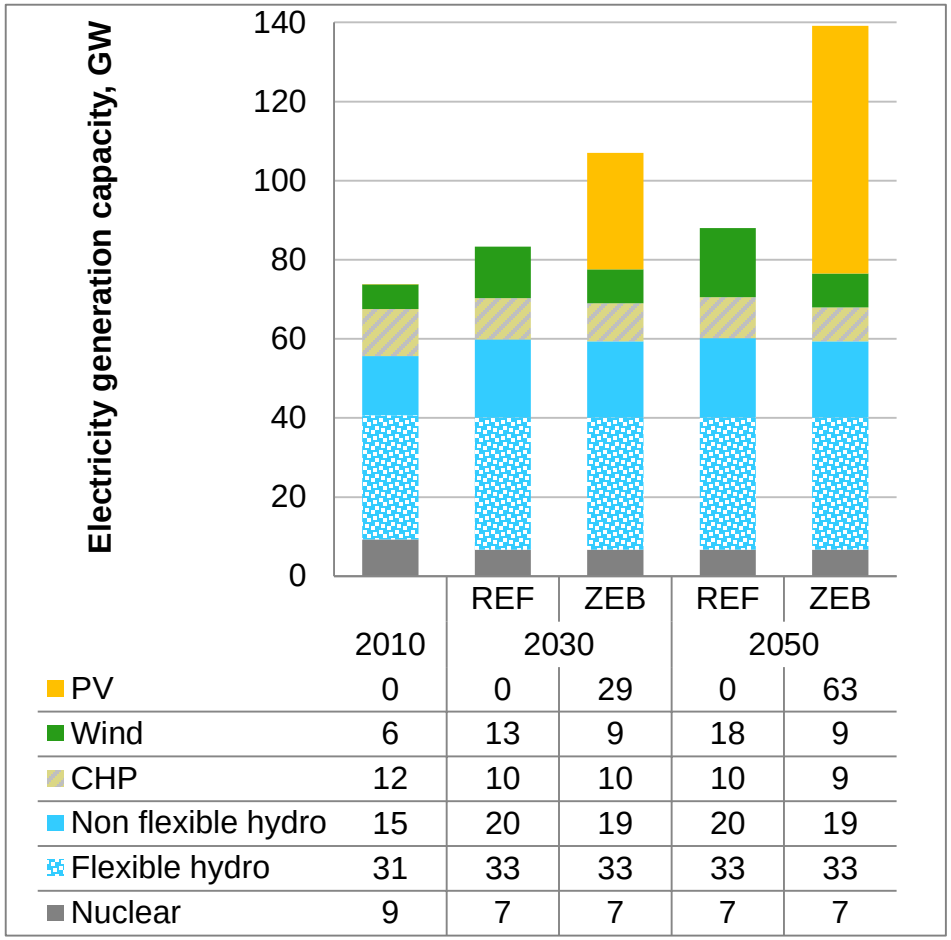


3. Results

«Large scale introduction of ZEBs in Scandinavia

→ Impact on the energy system towards 2050»

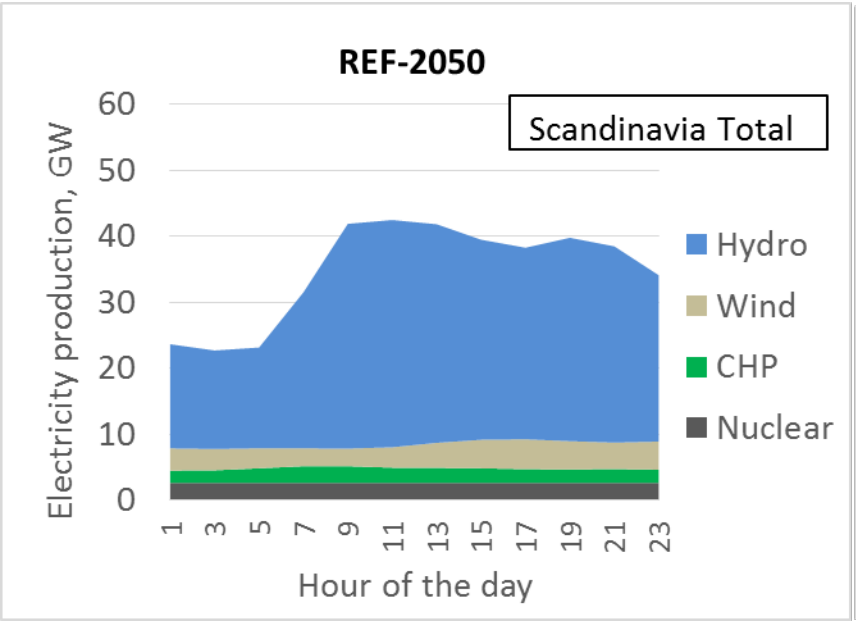
Installed capacity for electricity

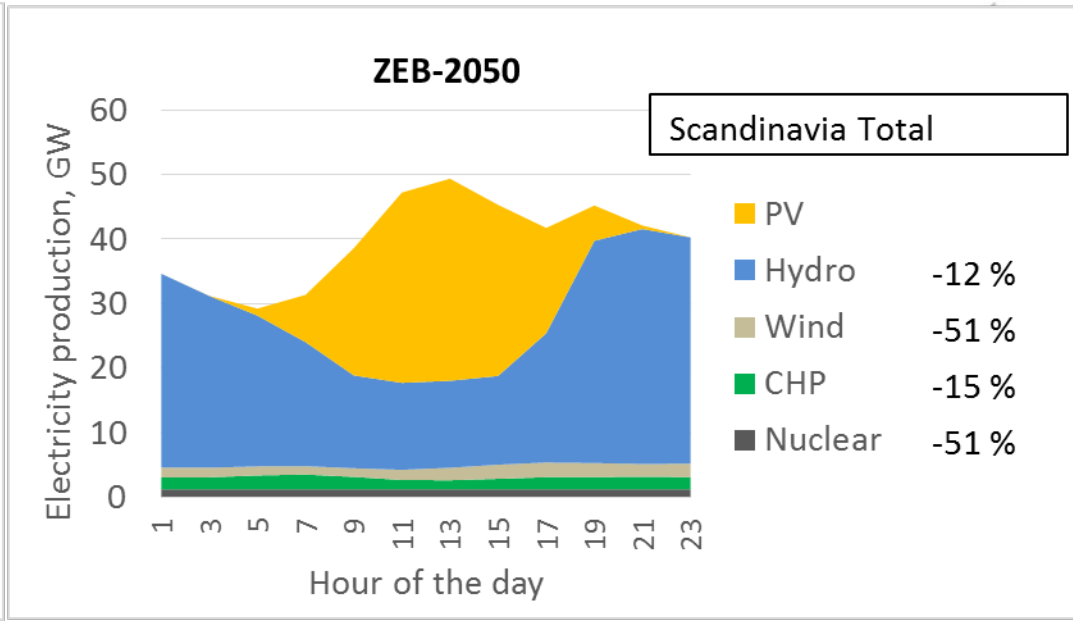


	2010	2030 REF	2030 ZEB	2050 REF	2050 ZEB	
PV	0	0	29	0	63	
Wind	6	13	9	18	9	-51%
CHP	12	10	10	10	9	-17%
Non flexible hydro	15	20	19	20	19	-4%
Flexible hydro	31	33	33	33	33	0%
Nuclear	9	7	7	7	7	0%

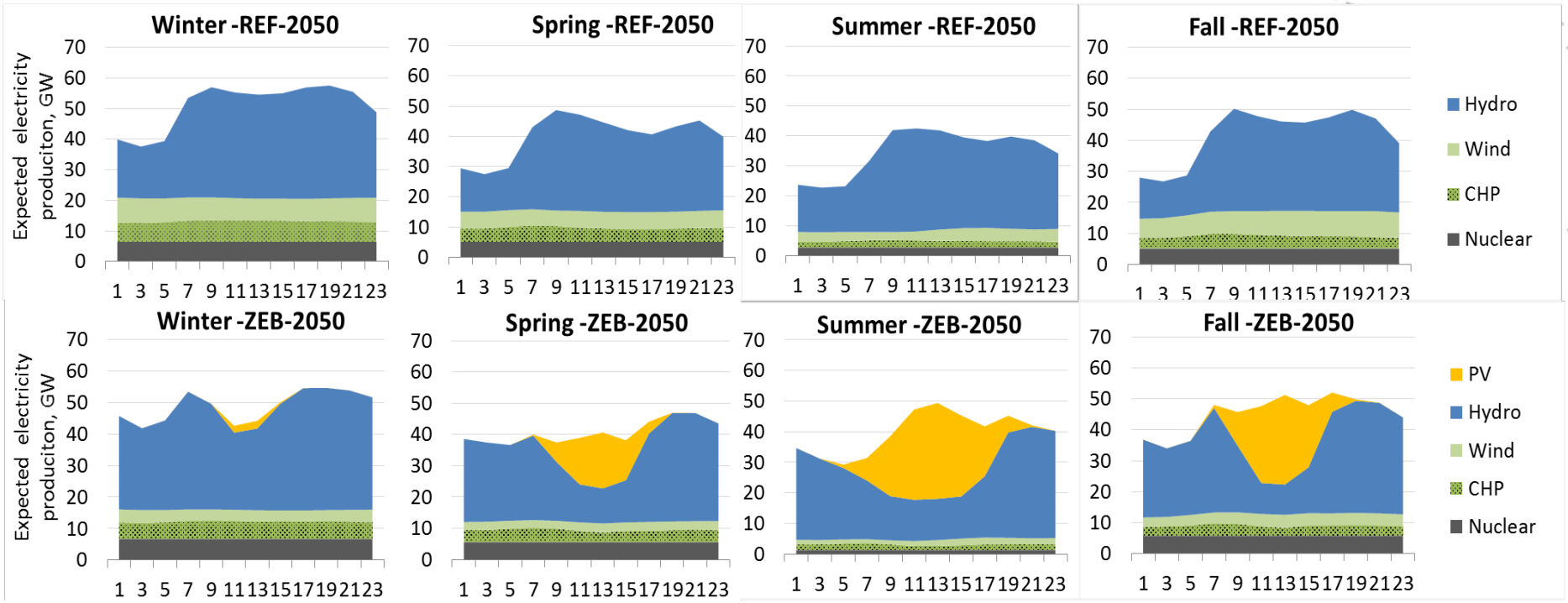
Daily electricity production

- Summer day (average)



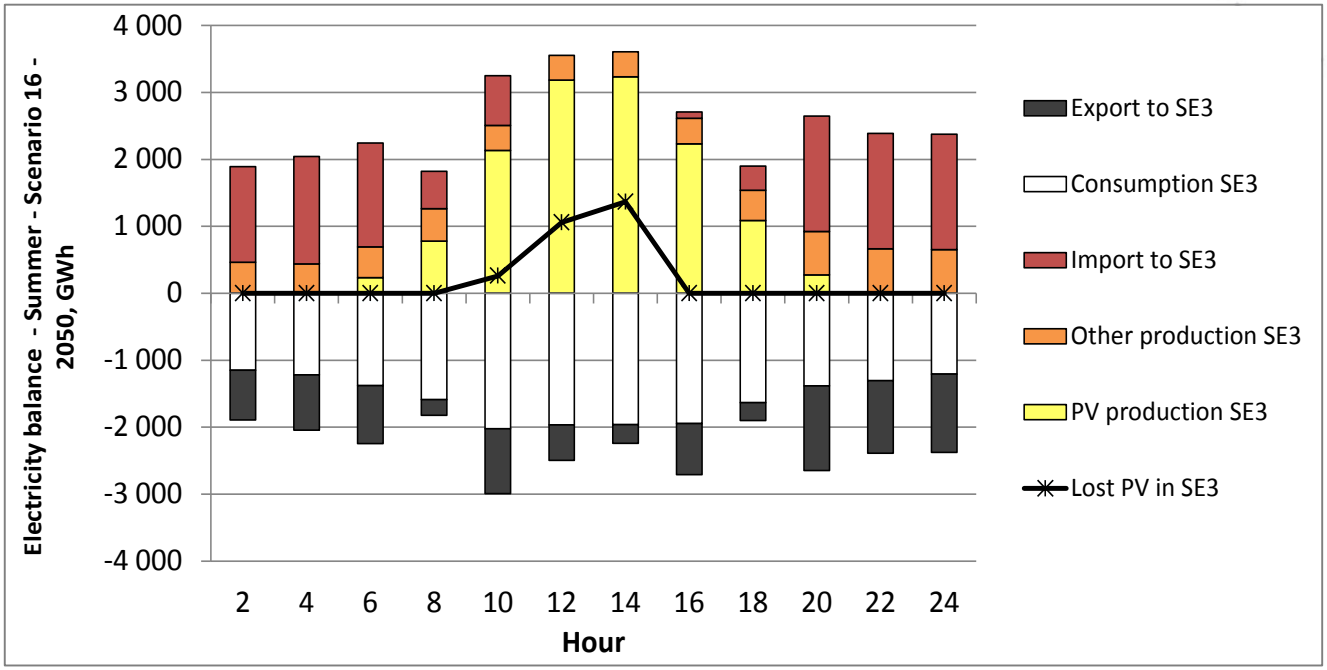


Electricity production



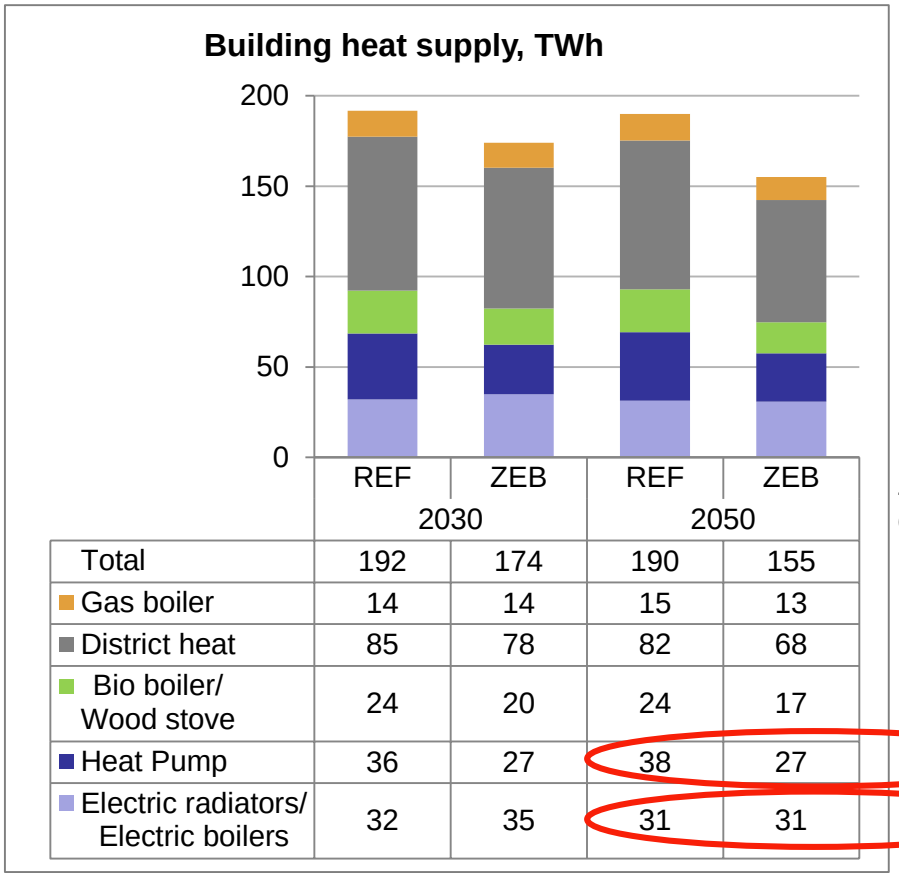
System integration of PV

- Electricity balance of SE3 a random day in summer:

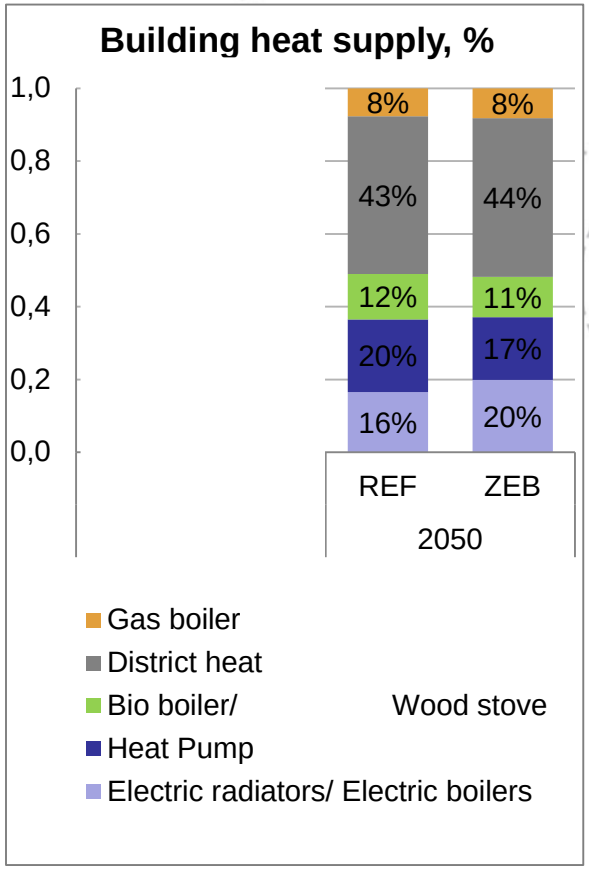


- Expected loss of PV production i 2050 in Scandinavia: 1,3 TWh
  - Without batteries or heat storage & no further grid capacity extentions
  - Equal to: 0,4 % of electricity consumpiton (2,4 % of PV-production)

Heat supply for buildings



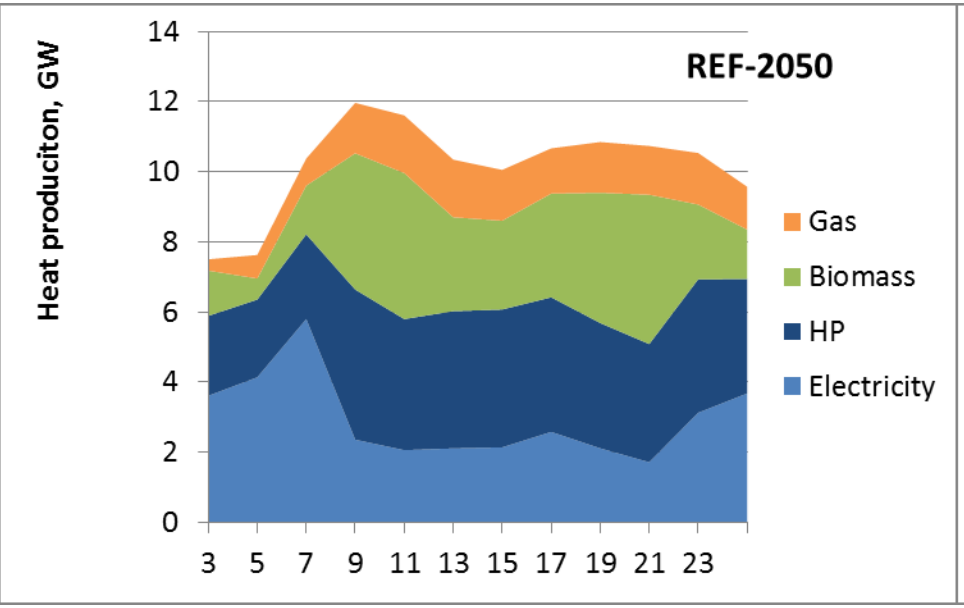
	2030 REF	2030 ZEB	2050 REF	2050 ZEB	REF and ZEB compared:
Total	192	174	190	155	-18 %
Gas boiler	14	14	15	13	-13 %
District heat	85	78	82	68	-18 %
Bio boiler/ Wood stove	24	20	24	17	-27 %
Heat Pump	36	27	38	27	-29 %
Electric radiators/ Electric boilers	32	35	31	31	-2 %

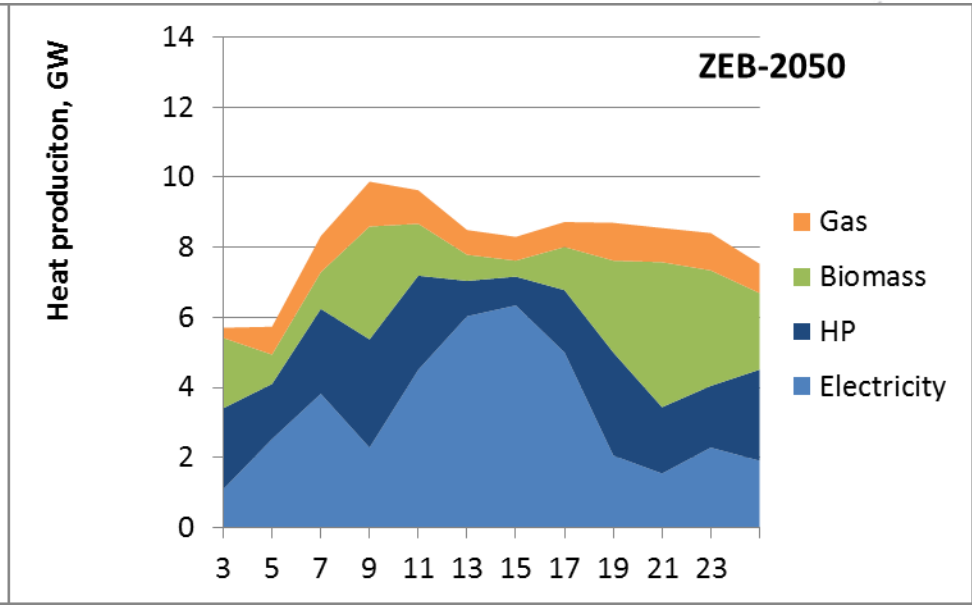


- All heat production is reduced
- Direct electric heating and HP changes its positions

Daily heat production

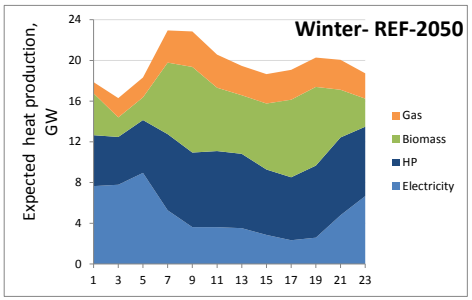
- Day in Autumn (average)

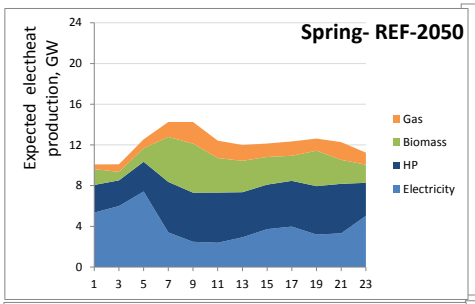


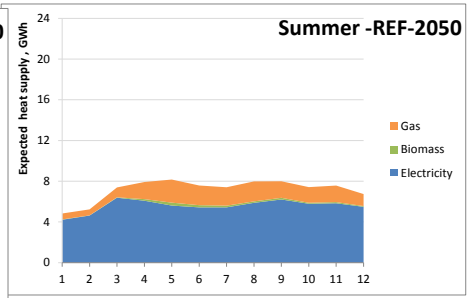


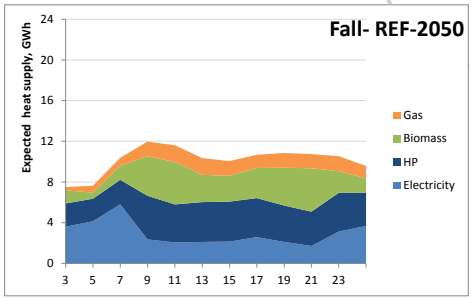
Seasonal heat production

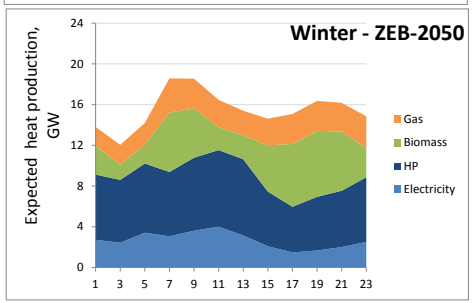
- Direct electric heating
  - Increased in spring and autumn (electricity is cheap)
  - Decreased in winter (heat demand is lower)

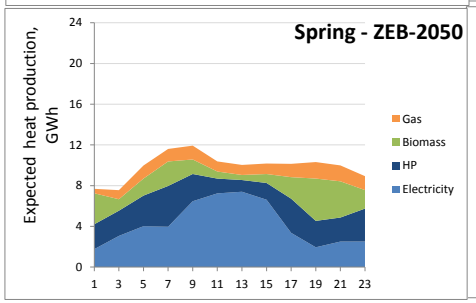


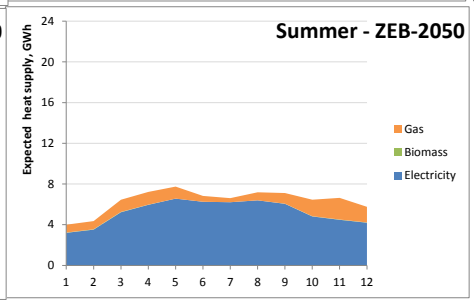


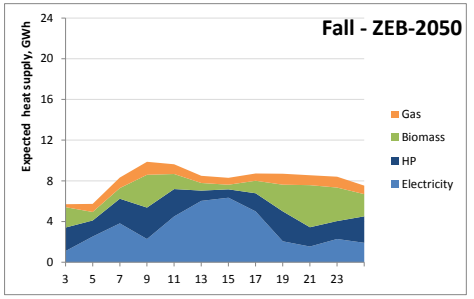












4. Conclusions

«Large scale introduction of ZEBs in Scandinavia

→ Impact on the energy system towards 2050»

Conclusions

- Energy demand
  - ÷ heat demand (winter)
  - + electricity from PV (summer)

  } Net energy demand **-36%** wrt REF

- PV production
  - Cost-optimal heat production technologies
    - Direct electric heating **more dominating**
  - Cost-optimal electricity capacity
    - Wind **-51%** and CHP **-17%** wrt REF
  - Electricity export out of Scandinavia in summer

Fordel å ha en stokastisk representasjon av usikre parametre.

- System integration
  - Scandinavia is able to handle a large introduction of PV
  - Only 2,5 % PV curtailment

Hovedpoeng

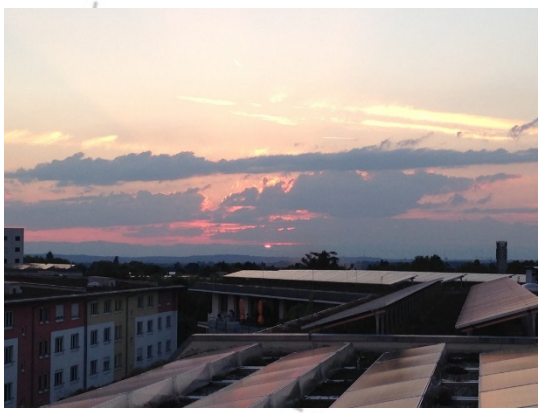


Foto: K.B. Lindberg

- ZEB
  - lavere effektbelastning enn eksisterende bygg
- ZEB i Norden er håndterbart på et overordnet energinivå
- Fleksibel vannkraft
  - Tilpasser seg til **daglige** variasjoner i PV produksjon → god match
  - MEN, **årlig** vannkraftproduksjon er uforandret → lavere kraftpriser
    - → mindre vindkraft
    - → høyere andel direkte el til oppvarming
- Nye forretningsmuligheter for Norge?
- Videre arbeid
  - Detaljerte nettsimuleringer på distribusjonsnivå og regional-nettnivå

Takk til

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Eller les artikkelen:

P. Seljom, K. B. Lindberg, A. Tomasgard, G. Doorman and I. Sartori, *"Impact of Zero Energy Buildings on the Scandinavian energy system"*, accepted in Energy 03.12.2016