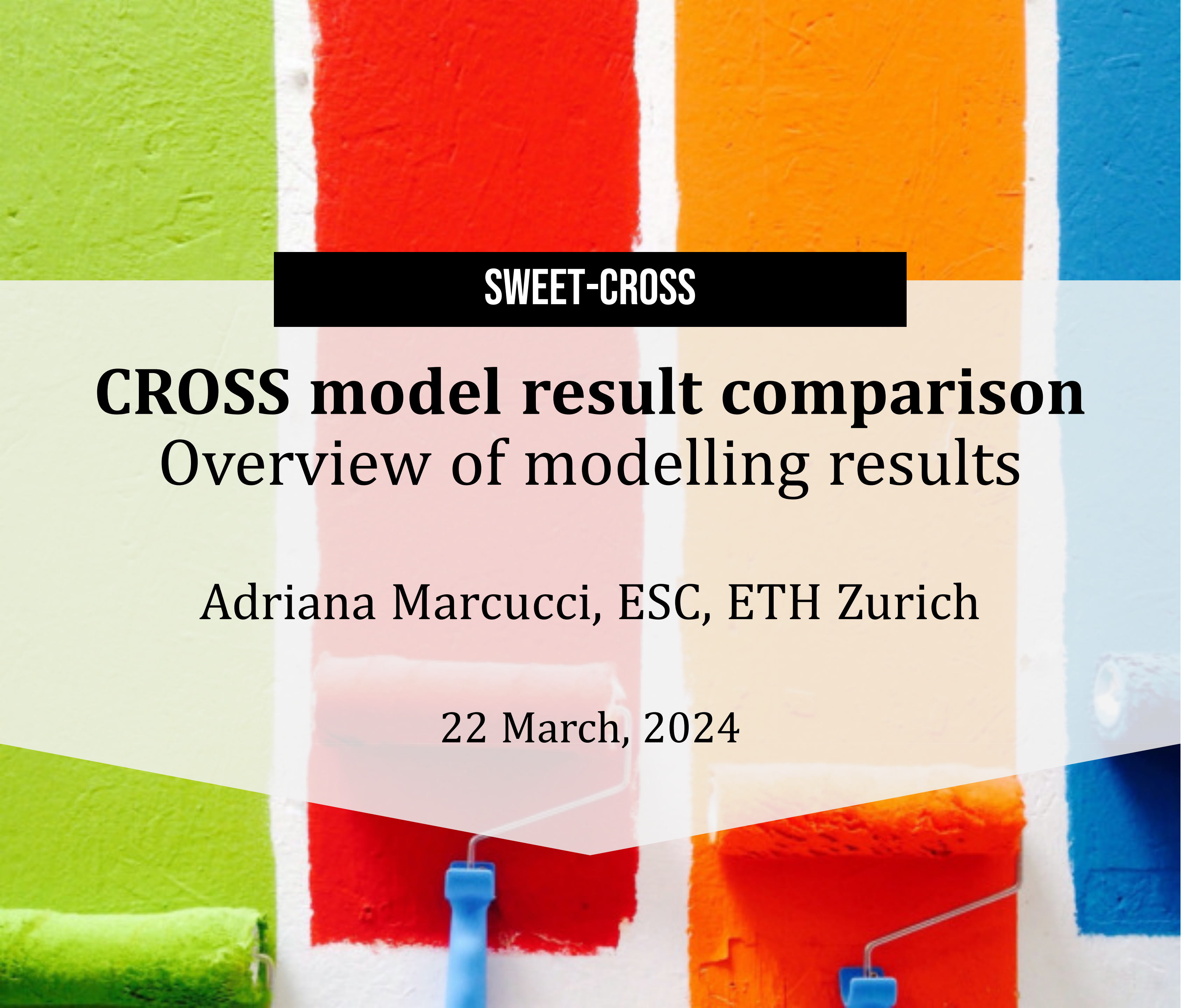

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CROSS

SWEET-CROSS

CROSS model result comparison
Overview of modelling results

Adriana Marcucci, ESC, ETH Zurich

22 March, 2024

Agenda

1. Energy scenarios in Switzerland
2. CROSS scenarios
3. Models
4. Electricity, annual
5. Electricity, hourly
6. Hydrogen
7. Heat
8. Transport
9. What next?

1. Energy scenarios in Switzerland
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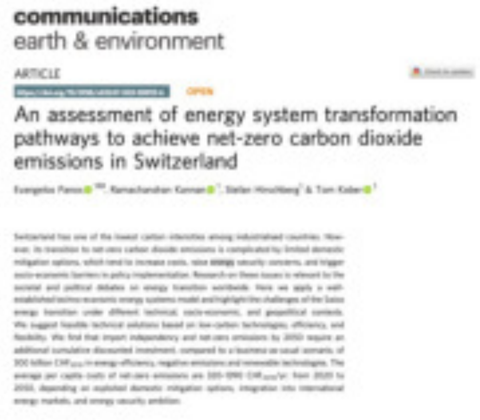
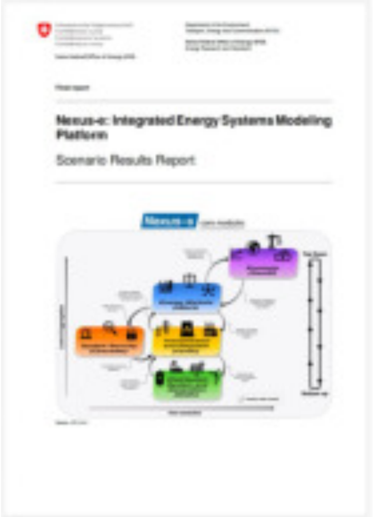
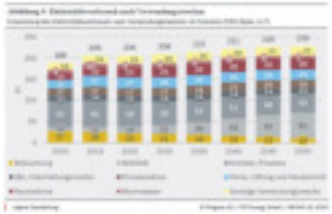
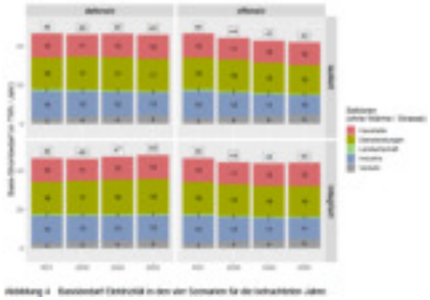
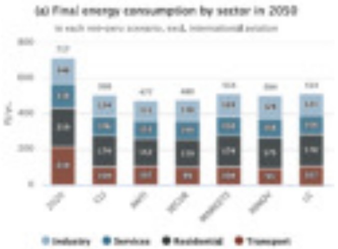
Energy scenarios in Switzerland

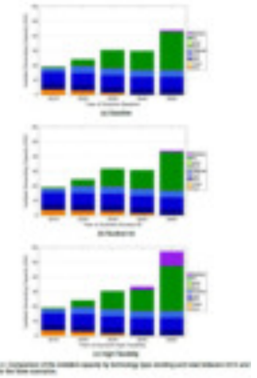












About energy scenarios

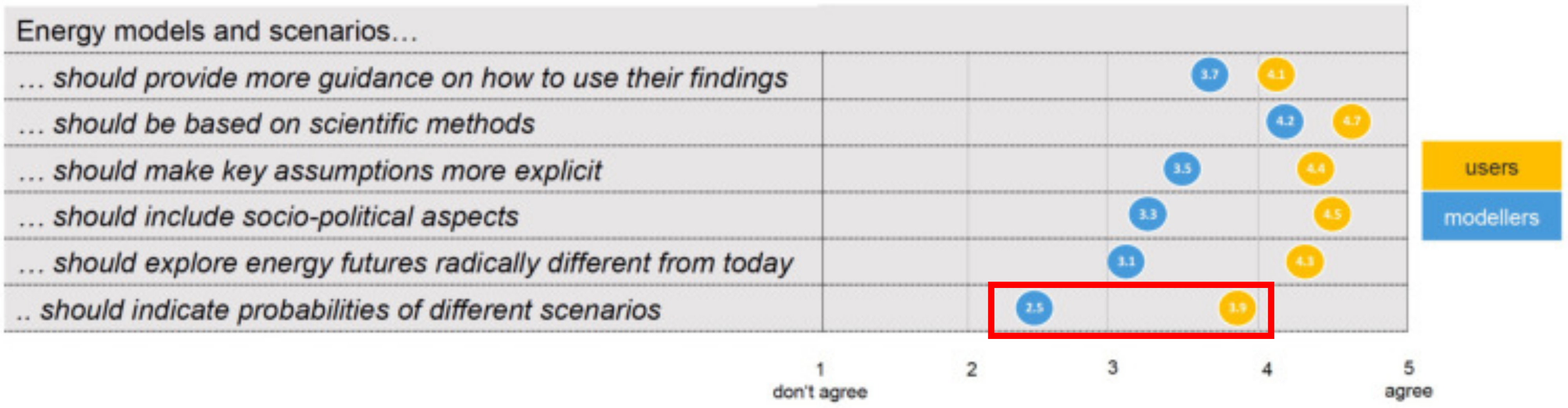


figure 2: Assessments of users (n=246) and modellers (n=105) concerning a set of beliefs ("*Do you agree with the following statements about energy models and scenarios?* ", *5-point scale*) related to energy models and scenarios.

Braunreiter, L and Blumer, Y (2023). ProdUse: Closing the gap between model-based energy scenarios and its potential users to support evidence-based decision-making for the transformation of the Swiss energy system. SOUR project.

About preferred formats of communication

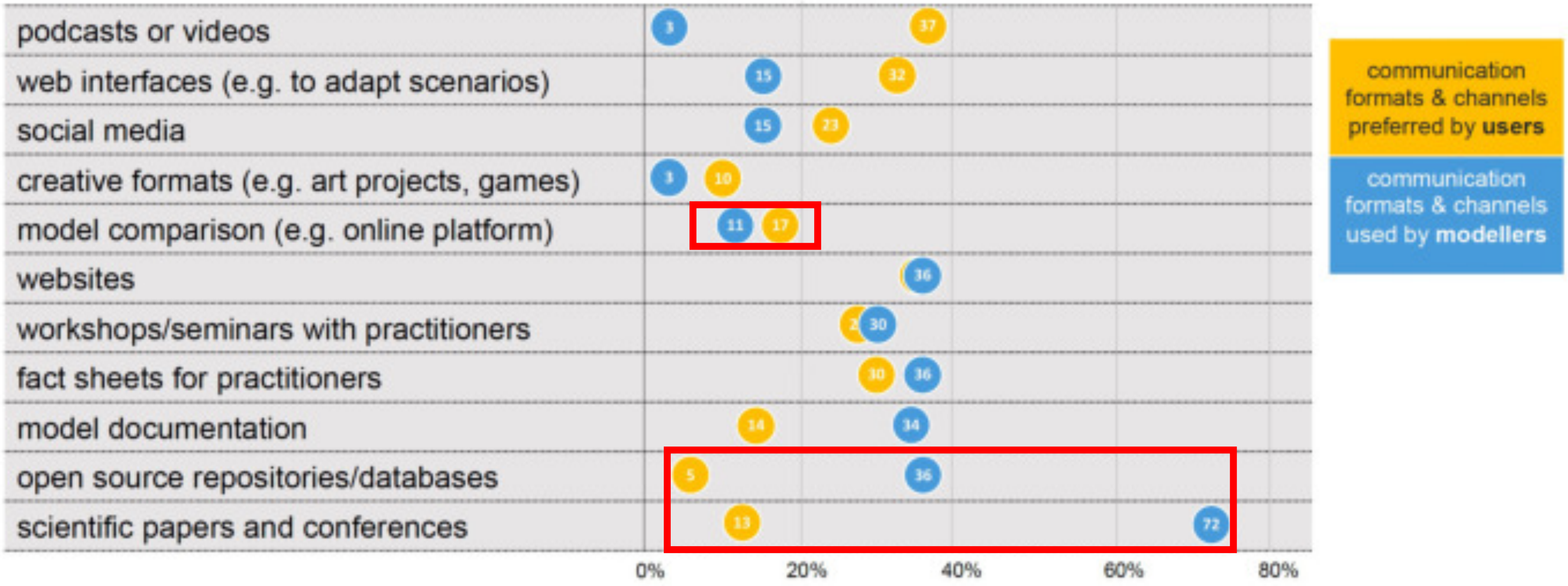


figure 5: Comparison of formats and channels for communicating scenario insights preferred by (i) users ("*What formats and communication channels would you like to have as an option to interact with energy models and scenarios?*", n= 246) and (ii) provided by modellers ("*What formats and communication channels do you use to communicate your findings?*", n=105).

Goal

- Run the same scenarios with similar models
  - Different realizations: uncertainty (only model uncertainty)
  - Common and uncommon
  - Reasons for them

- Ongoing process
  - Today: status, workshop
  - New questions
  - New scenarios

1. Energy scenarios in Switzerland
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CROSS scenarios v2022-09

Climate policy	Energy market integration	
Net-zero without compensation abroad	High integration	**domestic-together**
	Low integration	**domestic-alone**
Net-zero with compensation abroad	High integration	**abroad-together**
	Low integration	**abroad-alone**

Complete documentation and data: https://sweet-cross.ch/scenarios/

Climate policy dimension

Climate policy

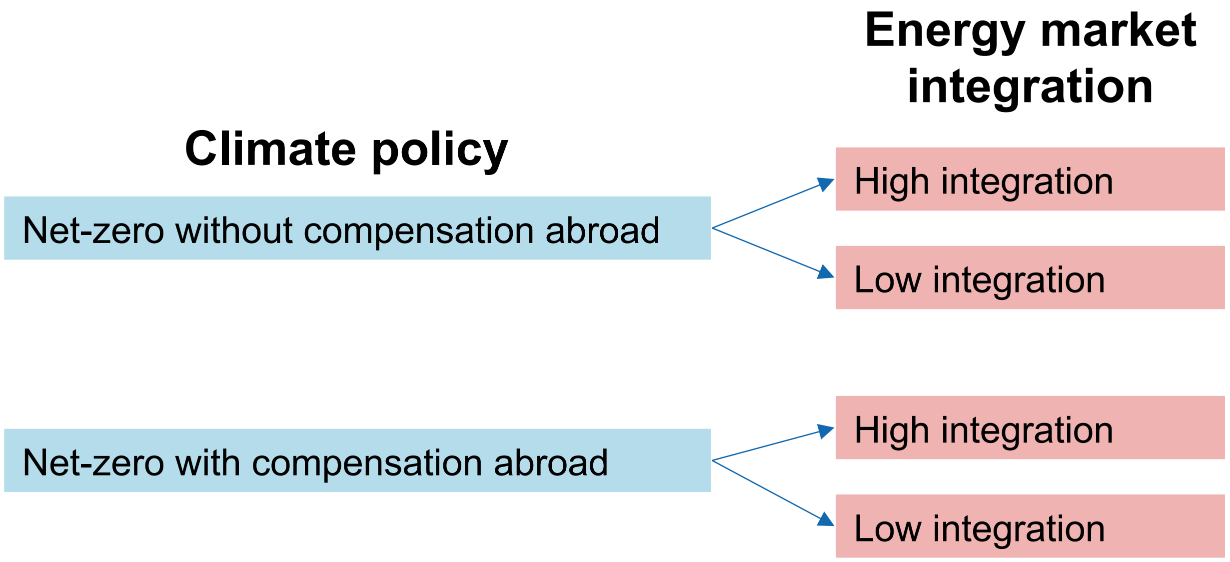
Net-zero without compensation abroad

Net-zero with compensation abroad

- Goal of the Swiss Federal Council to reduce the GHG emissions to **net-zero by 2050**.
  - Covering emissions in **all sectors** and all GHG's
- **Energy sector compensates** for emissions difficult to avoid **outside** the energy sector (**5.7 $MtCO_2$**)
  - Industry: Cement and chemicals: 3.6 $MtCO_2e$ - 3 $MtCO_2e$ (CCS) = 0.6 $MtCO_2e$
  - Agriculture: 4.6 $MtCO_2e$
  - Waste disposal and waste: 0.5 $MtCO_2e$
- Domestically or abroad:

Variant	Domestic	Abroad	Total
Domestic	-5.7 $MtCO_2$	0 Mt CO_2	-5.7 $MtCO_2$
Abroad	0 $MtCO_2$ to -5.7 $MtCO_2$	Up to -5.7 $MtCO_2$	-5.7 $MtCO_2$

Energy market integration dimension



Commodity	Low	High
Electricity	30% NTC	100% NTC
Biofuels and biomass	No imports	56 PJ in 2050
Synthetic e-fuels	No imports	64 PJ in 2050
Hydrogen	No imports	40 PJ in 2050

CROSS scenarios result comparison

CROSS scenarios v2022-09

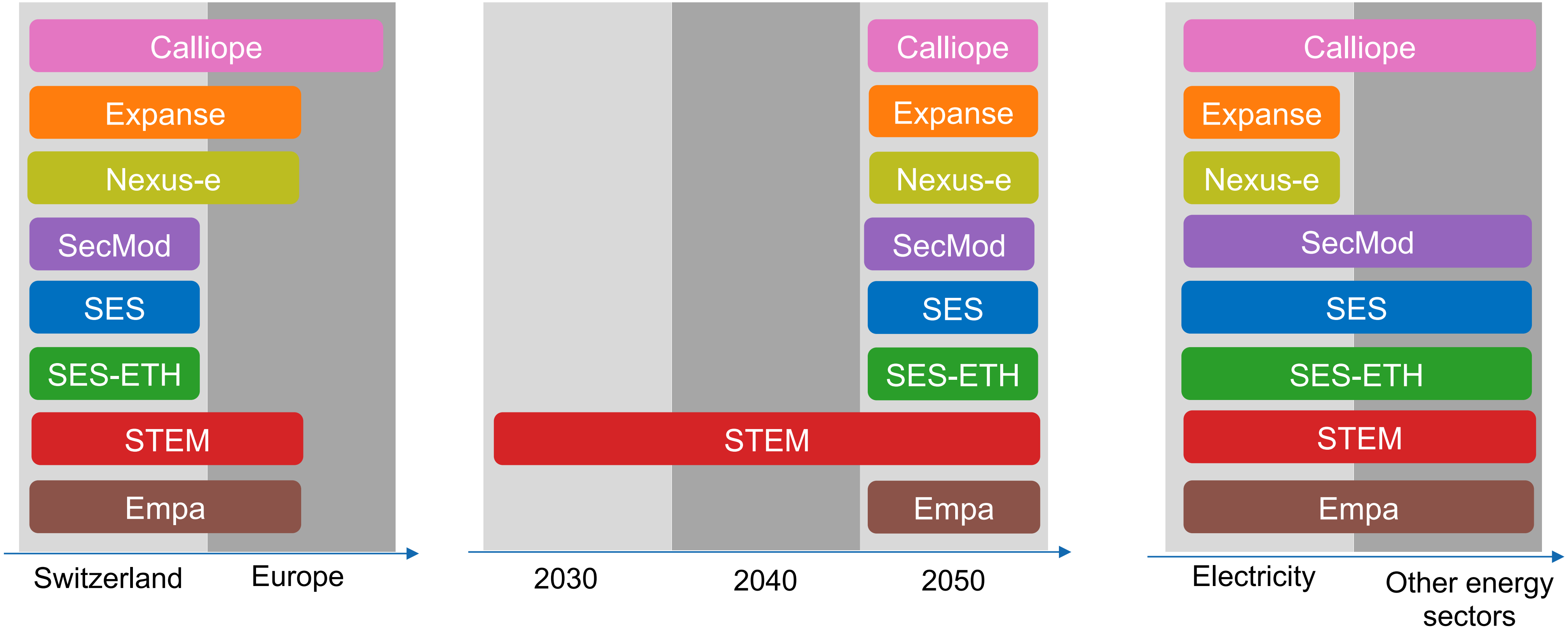
Climate policy	Energy market integration	
Net-zero without compensation abroad	High integration	**domestic-together**
	Low integration	**domestic-alone**
Net-zero with compensation abroad	High integration	**abroad-together**
	Low integration	**abroad-alone**

Other scenario parameters:
- Harmonized in CROSS: Demands, biomass potentials
- Rest: Model choice (technology costs, renewable potentials)

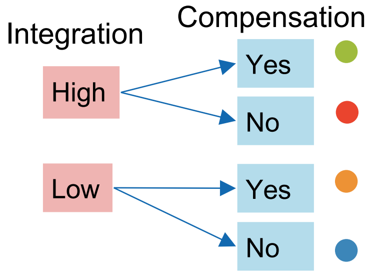
Models and studies in CROSS model results comparison

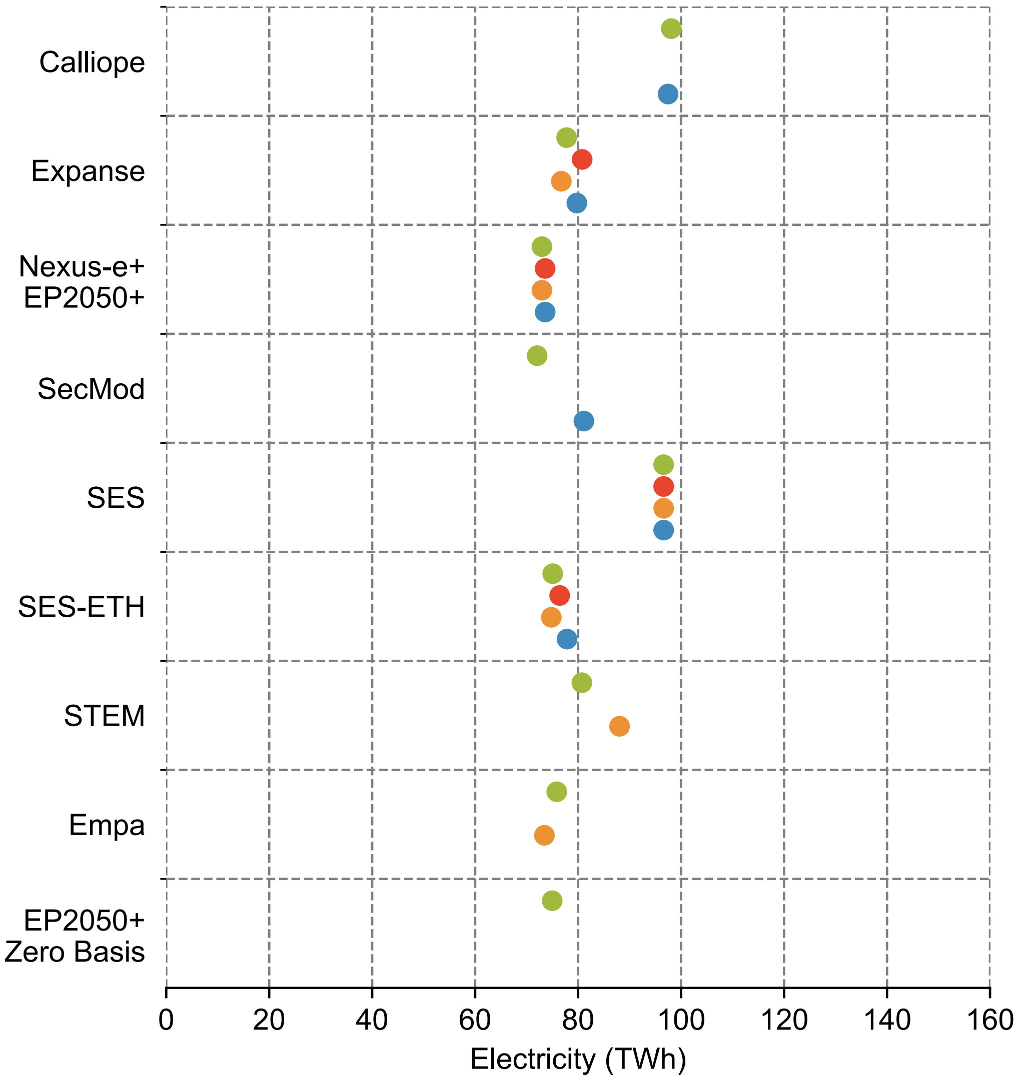
	Model / study name	Documentation	Model page
Calliope	Calliope, TU Delft	Link	Link
Expanse	Expanse, UNIGE	Link	
Nexus-e	Nexus-e, ETH Zurich	Link	Link
SecMod	SecMod, ETH Zurich	Link	
SES	Swiss Energy Scope, EPFL		Link
SES-ETH	Swiss Energy Scope, ETH Zurich	Link	
STEM	Swiss TIMES Energy Systems Model (STEM), PSI	Link	Link
Empa- VSE	Energiezukunft 2050, EMPA and VSE	Link	
BFE – EP2050+	Energy Perspectives 2050+ (EP 2050+), Zero Basis scenario, Swiss Federal Office of Energy	Link	

Models and studies in CROSS model results comparison



Electricity demand (2050)





- 2 groups of results:
  - 80 TWh (only 20 TWh more than today)
  - 100 TWh:
    - Calliope: 13 TWh more for Base
    - SES

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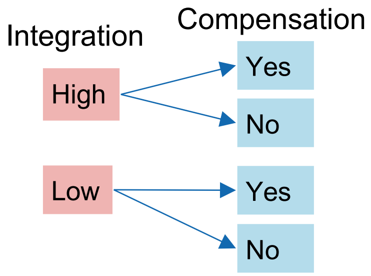
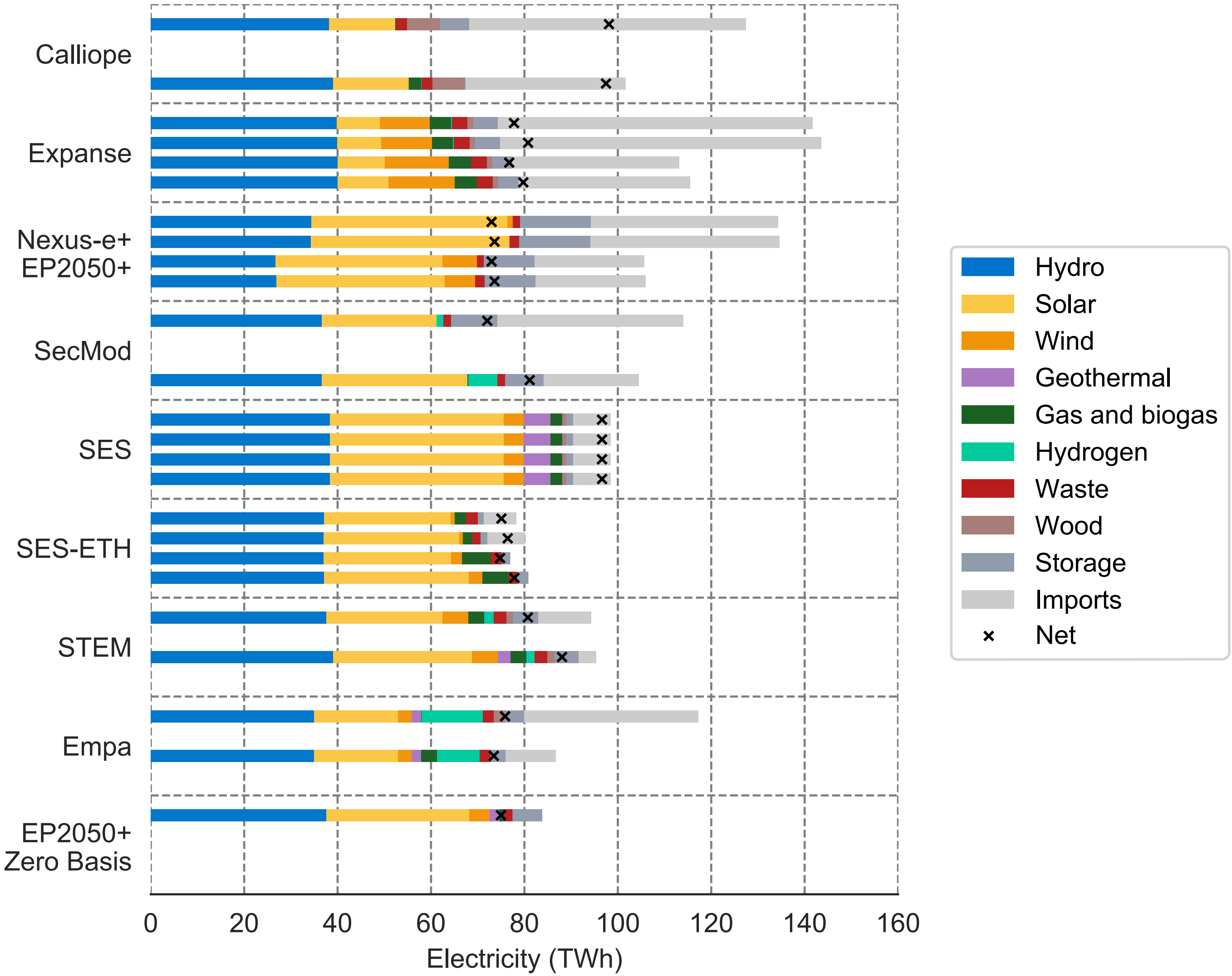
Disclaimer: Preliminary results

Electricity supply (2050)





Trade

- Differences in the modelling
- Models with representation of neighboring countries: Transit flows

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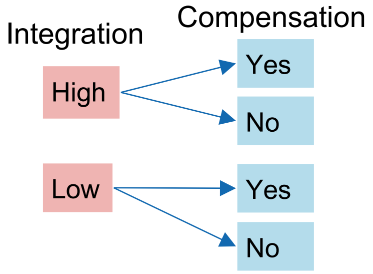
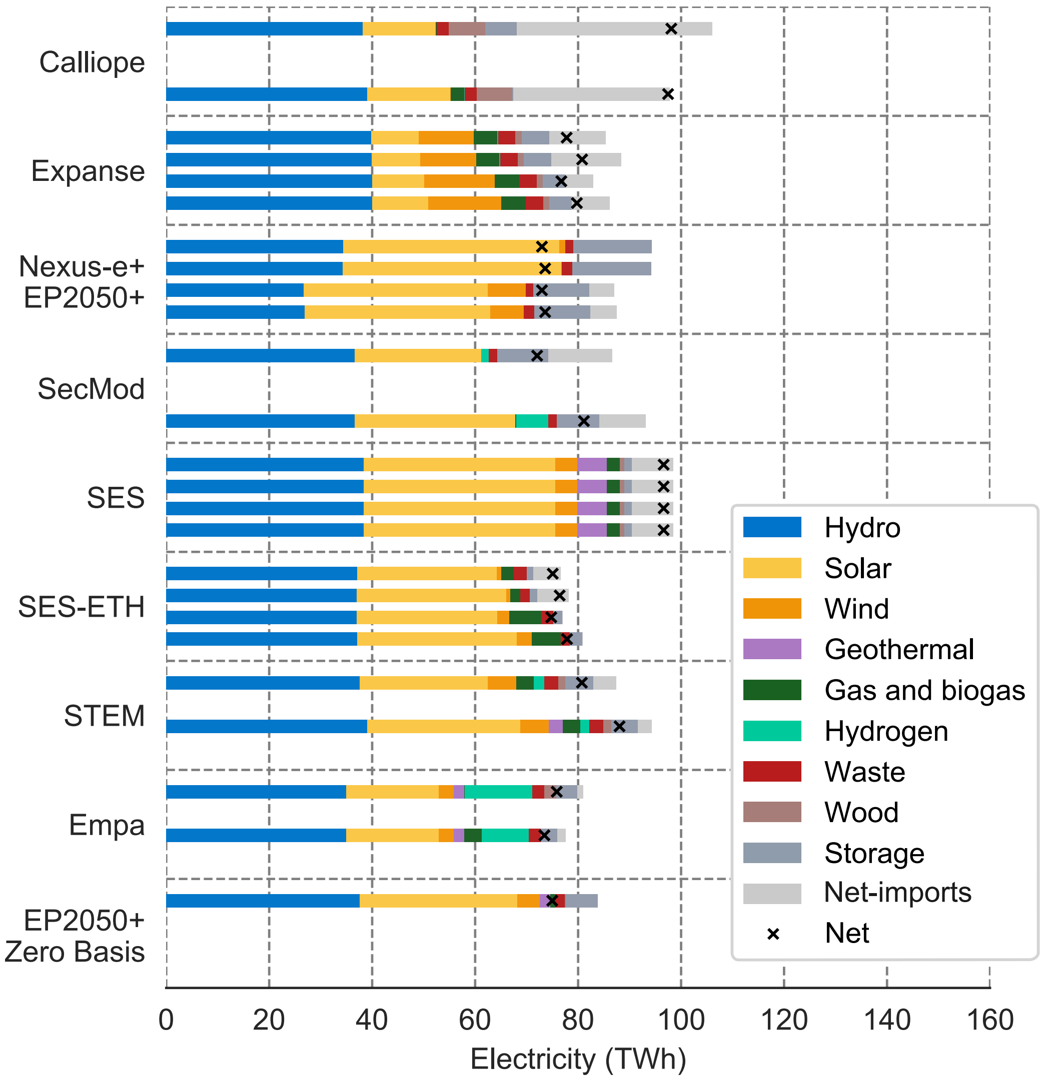


Electricity supply (2050): Net imports



Different between models >>> different between scenarios

Hydro

- Around 38 TWh
  - Nexus-e: Mapping to dams or pumped, curtailment (model of neighboring countries)

Wind

- Expanse: Larger wind (local vs. system perspective)

Solar

- Nexus-e: Mainly rooftop (around 2 TWh alpine)
- SES: rooftop

Hydrogen

- Empa: +++ low H2 import price (75 vs. 160 CHF/MWh = 2.5 vs. 5.3 CHF/kg H2) ⟶ High electricity production from H2

Low integration

- Expanse: Wind replaces imports
- Nexus-e:
  - Winter higher wind ➔ Lower solar
  - Lower hydro ➔ curtailment
- SES-ETH: Biogas replaces imports
- STEM: Solar replaces imports

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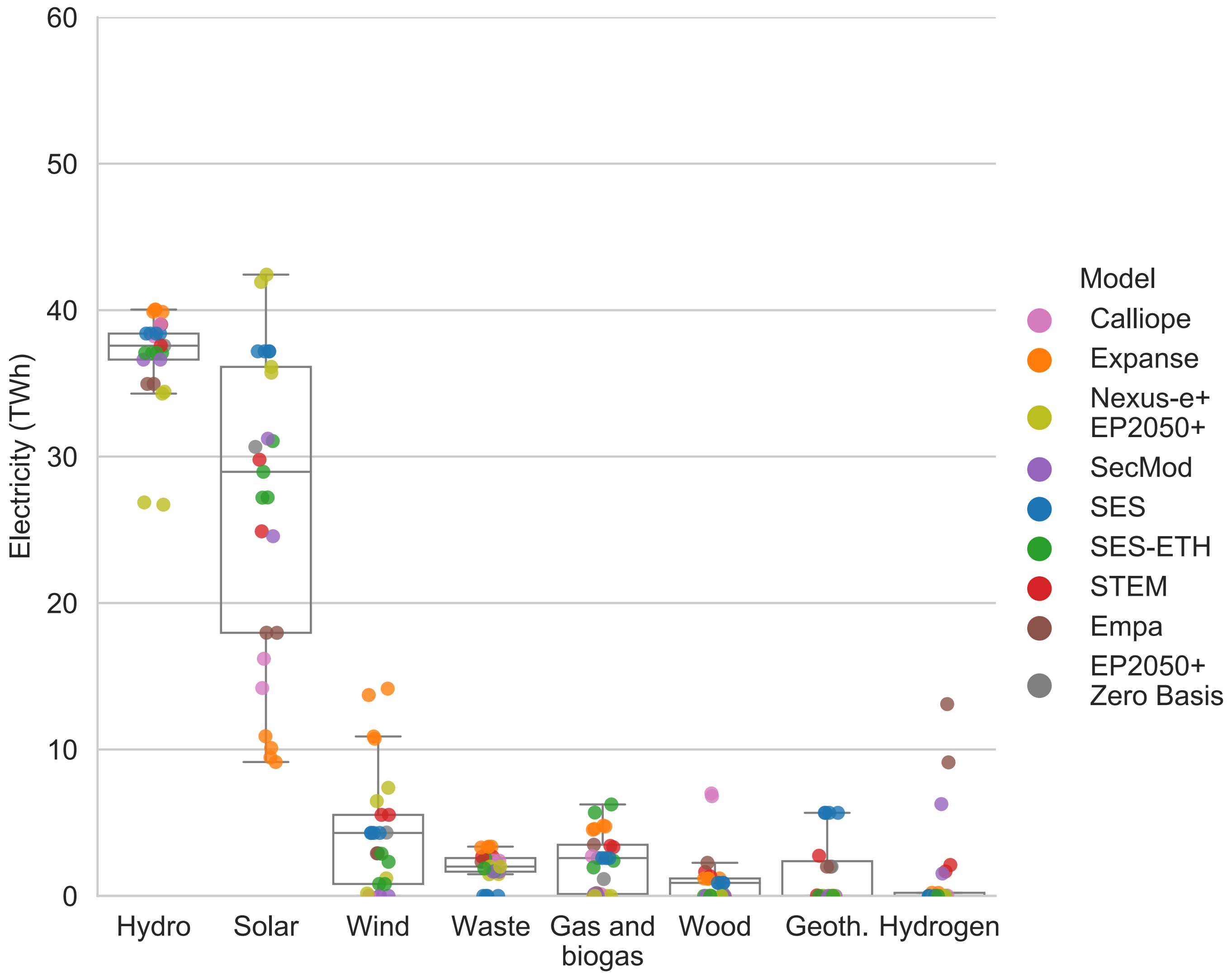
Electricity supply (2050)



Commons:

- Hydro (Dams and RoR)
- Complementarity of solar and wind
- Minor contribution of waste and wood

Less-agreement:

- Solar: we need it, how much?
- Wind
- Gas and biogas
- Geothermal
- Hydrogen

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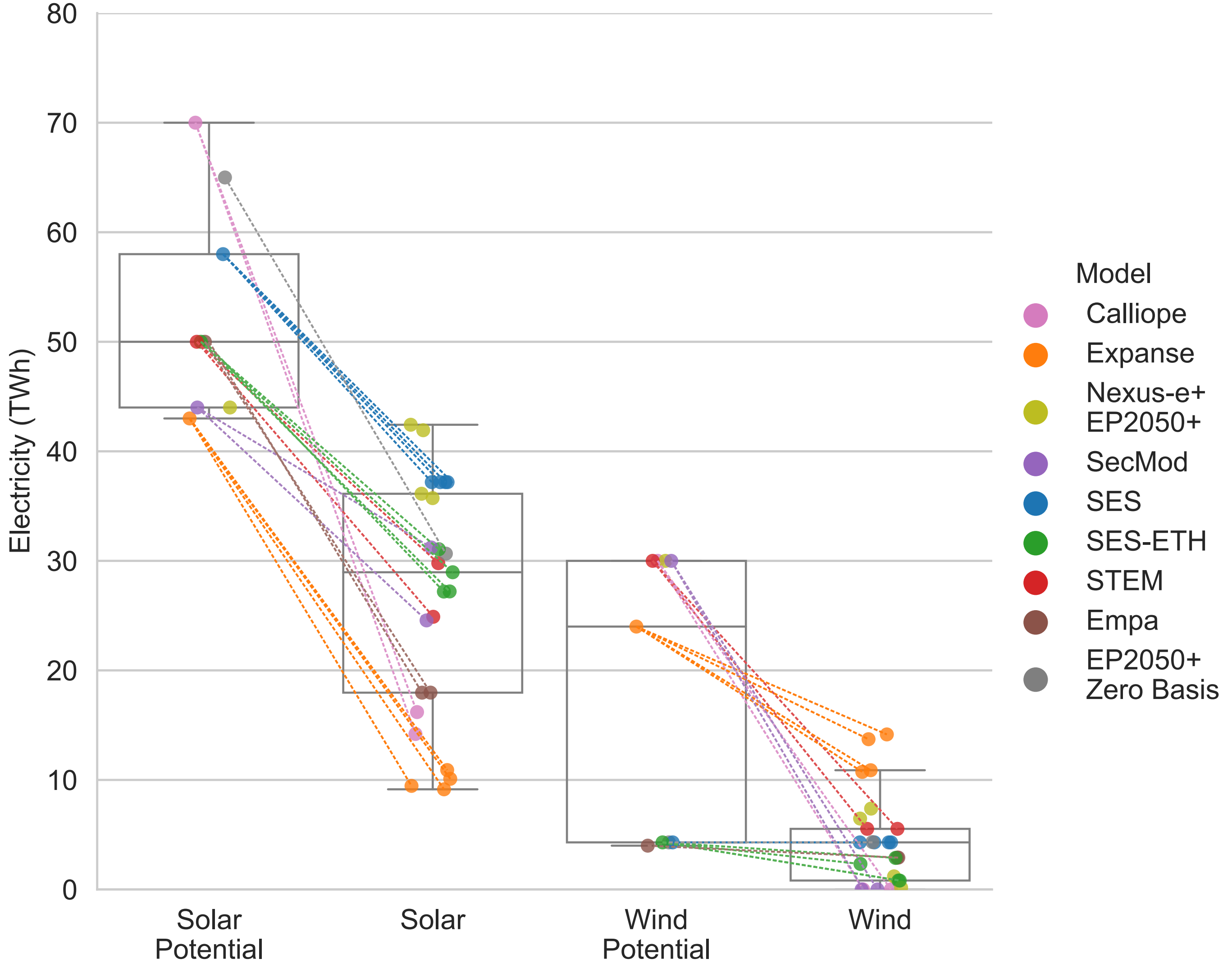
Wind and solar: Potential vs. production



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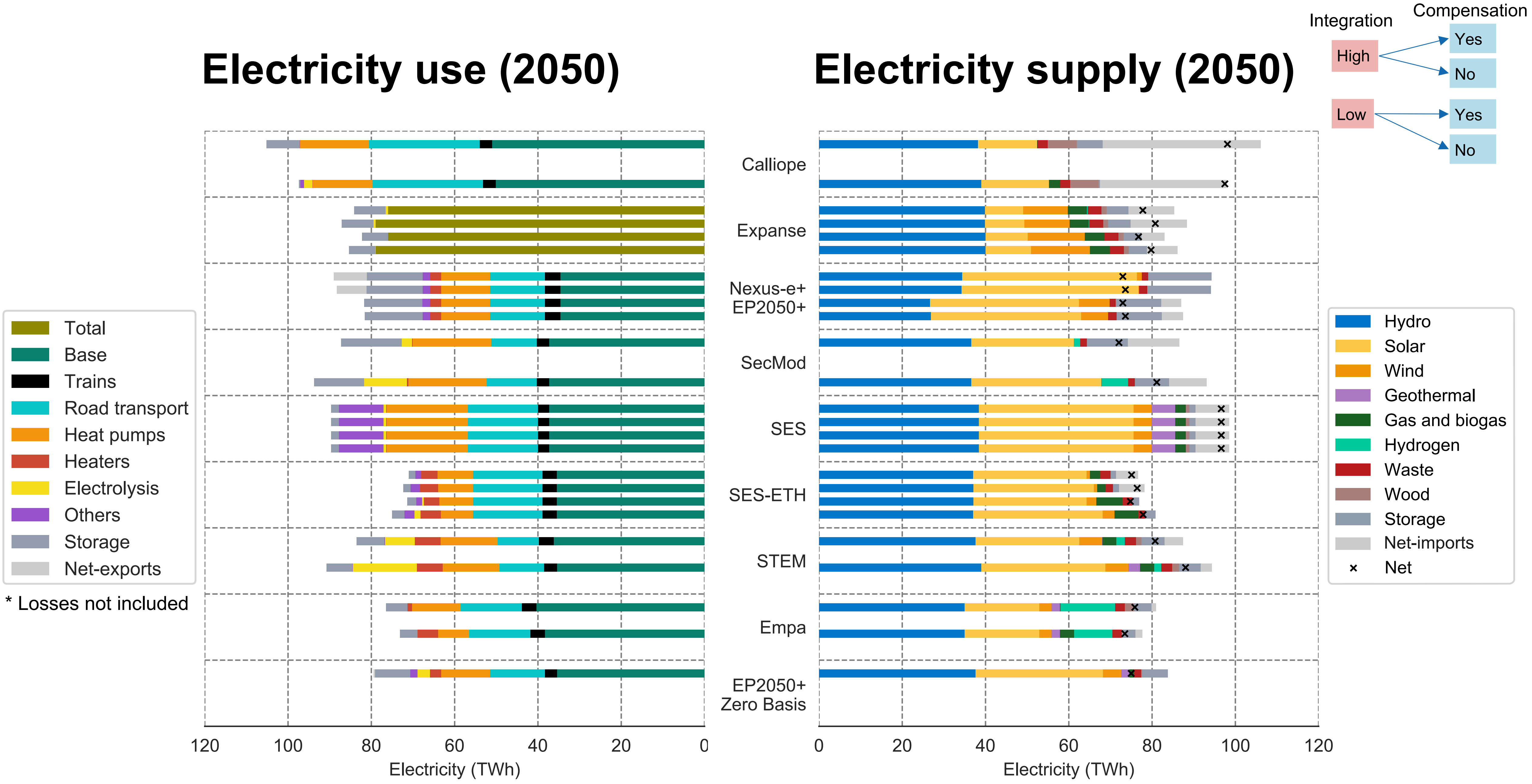
Electricity use (2050)

Electricity supply (2050)



* Losses not included

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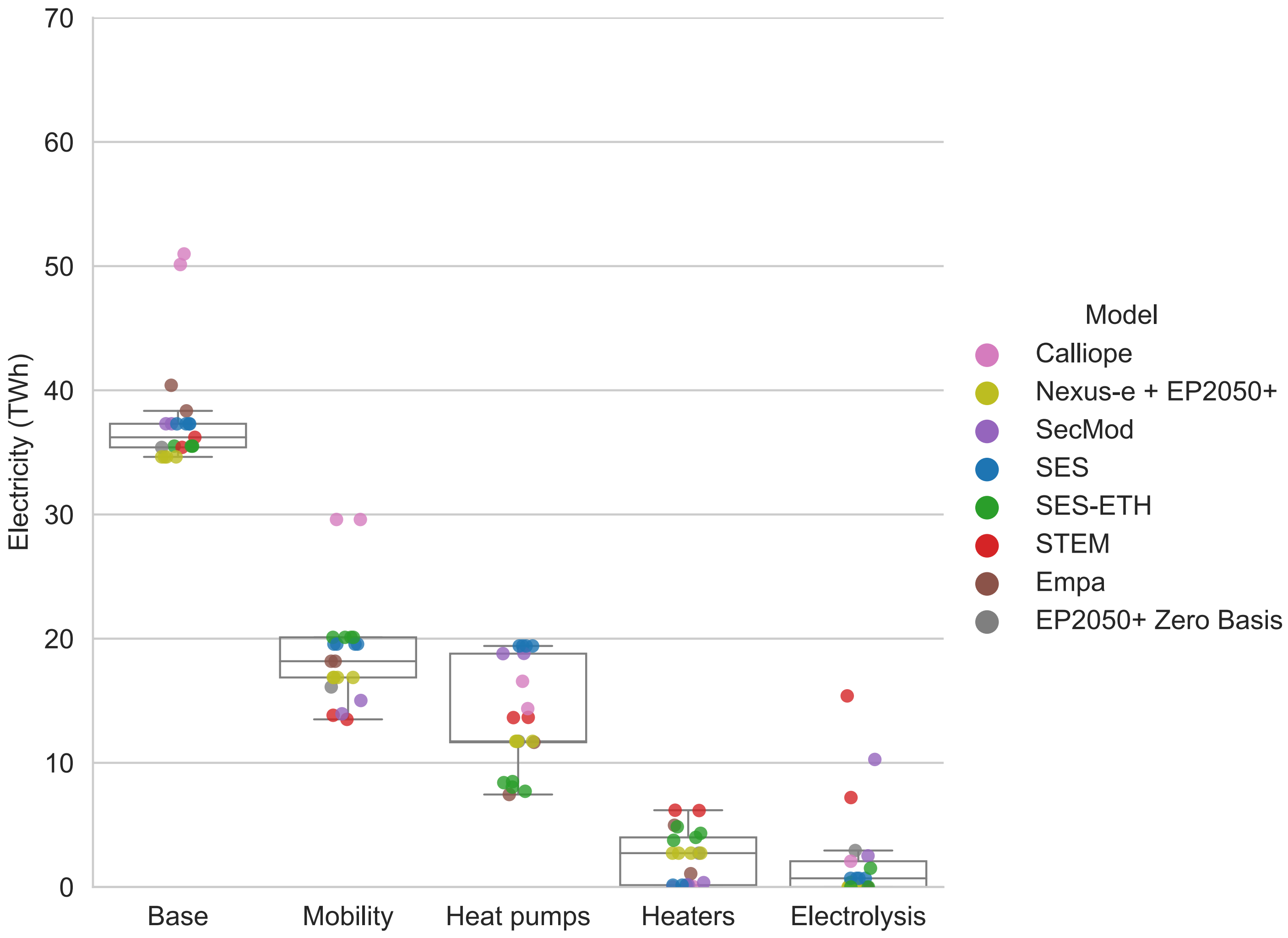
Electricity use (2050)



Base

Mobility

- Different assumption maximum share of electrification
- Efficiency assumptions:
  - Calliope: 32 KWh/100km
  - SES-ETH: 20 kWh/100km
  - SecMod: 14 kWh/100km

Heat pumps:

- Different assumption of max. share of electrification
- Some models don't include renovation
- COP:
  - STEM: 2.2
  - Calliope: 2.5
  - SecMod: 2.9
  - SES, SES-ETH, EP2050+: 3.2-3.3
  - Empa: 3.6

Electrolysis and heaters: less used

- SES-ETH and STEM: Industrial heat

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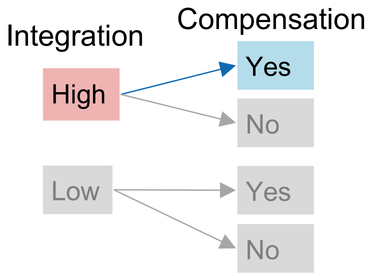
Hourly profiles: Summer, abroad-together



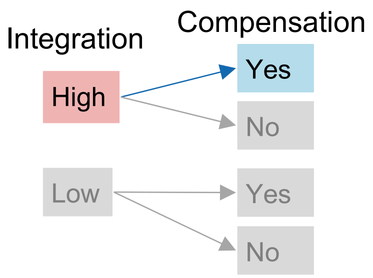
Calliope Jul 20 | Expanse Jul 02 | Nexus-e+ EP2050+ Jul 02 | SecMod Typical day | SES Typical day | SES-ETH Typical day | STEM Week day | Empa Jul 11 | EP2050+ Zero Basis avg. Aug. 13-19

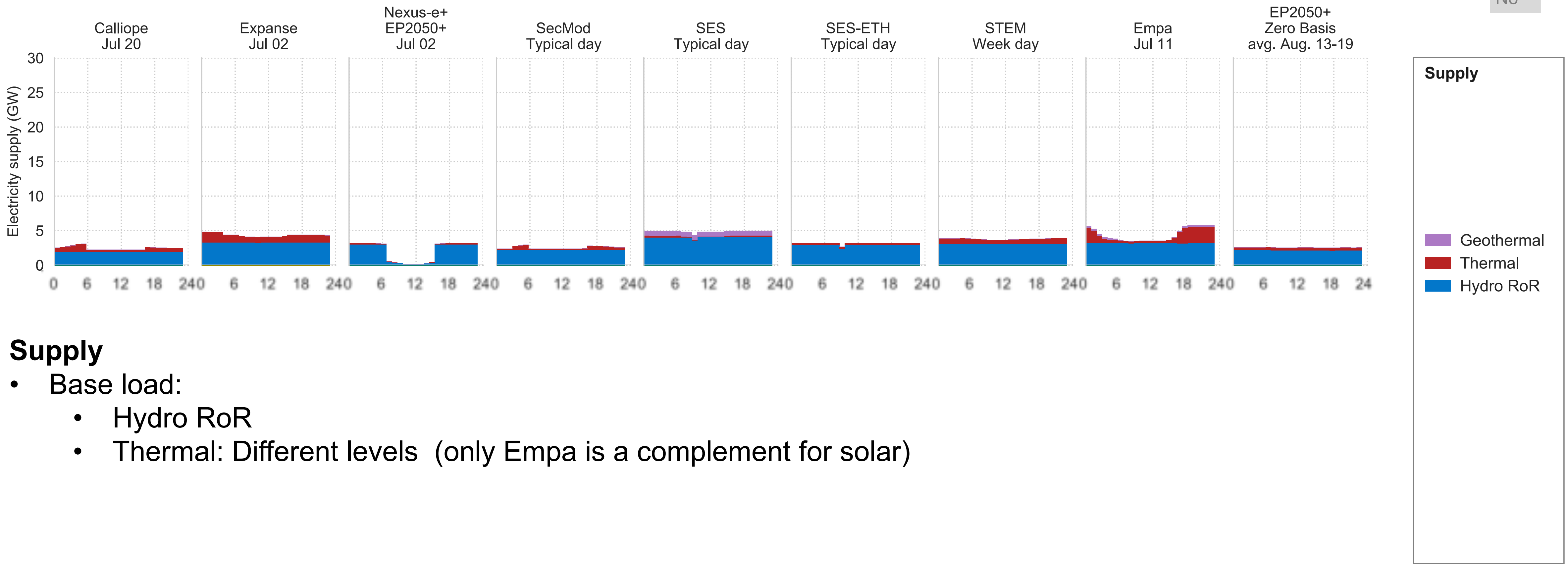
Differences in the hourly profiles

- Models with 365-day resolution:
  - ➔ One single day: Calliope, Expanse, Nexus-e, Empa
  - ➔ Average one week: EP2050+

- Typical days ➔ One typical day: SecMod, SES, SES-ETH, STEM

Hourly profiles: Summer, abroad-together



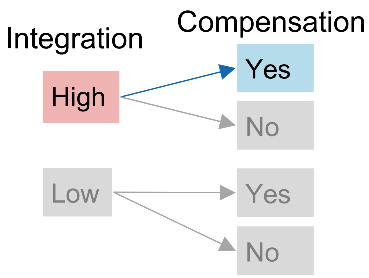


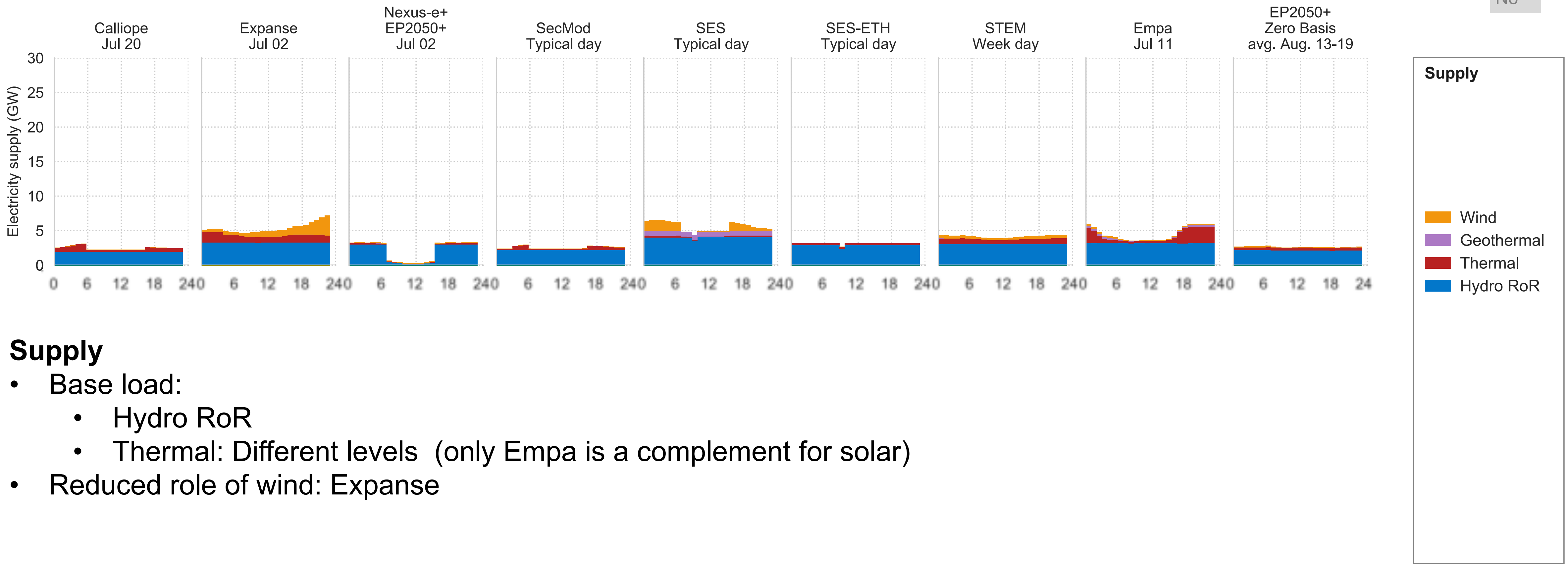
Supply

- Base load:
  - Hydro RoR
  - Thermal: Different levels (only Empa is a complement for solar)

Disclaimer: Preliminary results

Hourly profiles: Summer, abroad-together

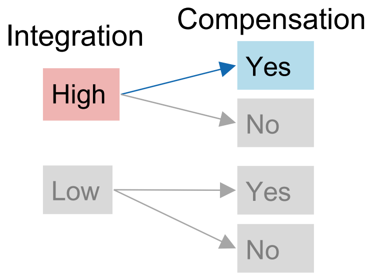


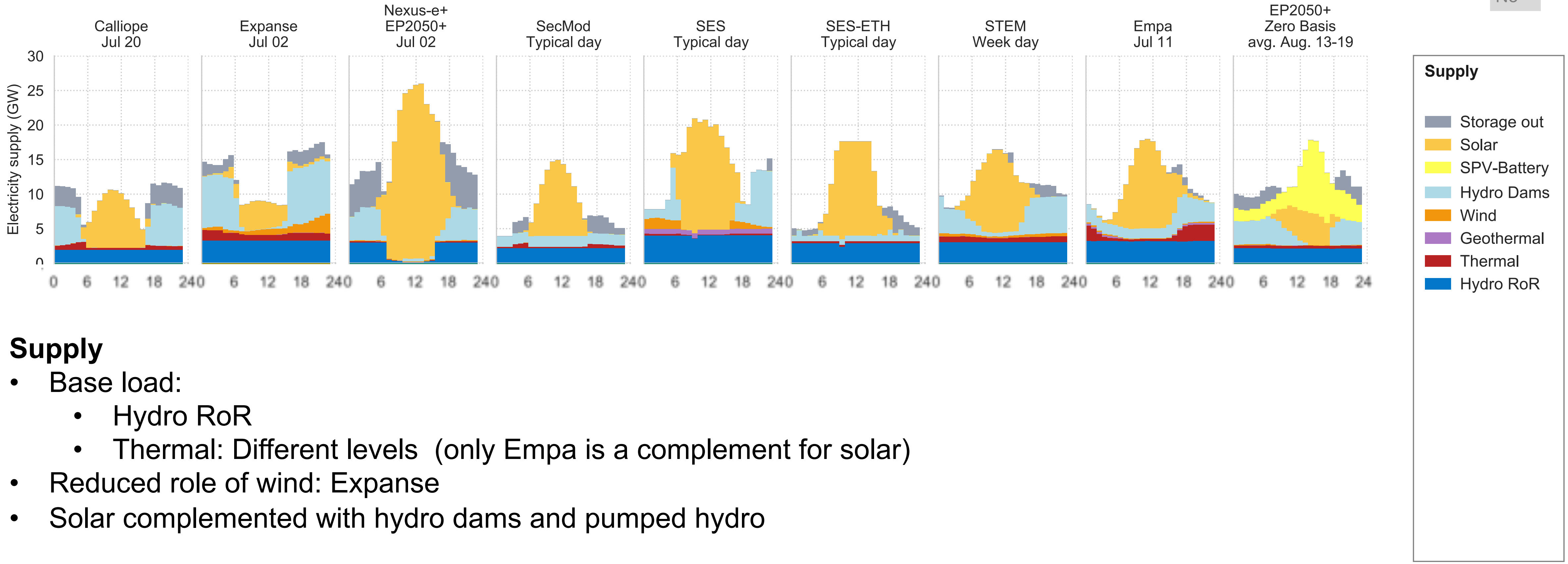


Supply

- Base load:
  - Hydro RoR
  - Thermal: Different levels (only Empa is a complement for solar)
- Reduced role of wind: Expanse

Hourly profiles: Summer, abroad-together

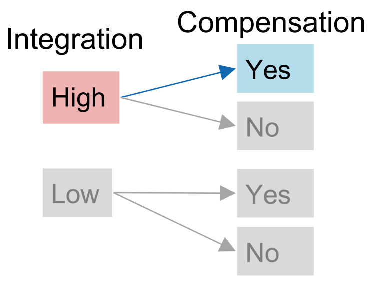


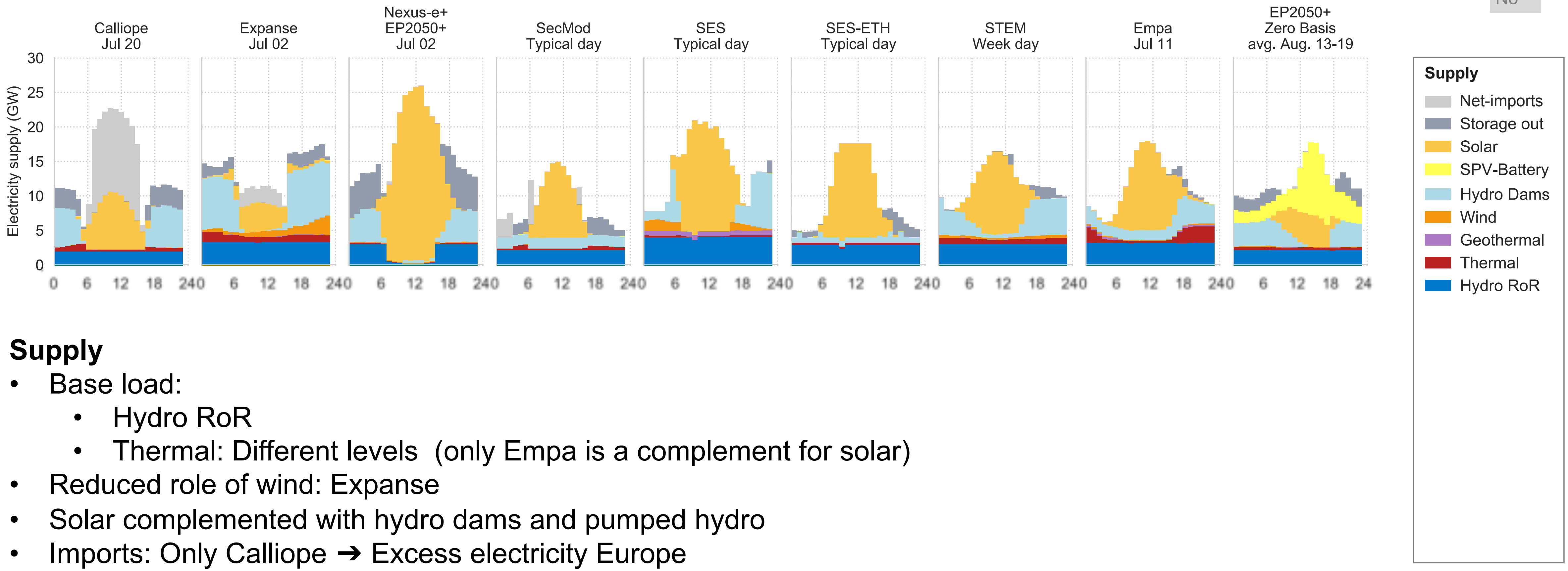


Supply

- Base load:
  - Hydro RoR
  - Thermal: Different levels (only Empa is a complement for solar)
- Reduced role of wind: Expanse
- Solar complemented with hydro dams and pumped hydro

Hourly profiles: Summer, abroad-together





Supply

- Base load:
    - Hydro RoR
    - Thermal: Different levels (only Empa is a complement for solar)
- Reduced role of wind: Expanse
- Solar complemented with hydro dams and pumped hydro
- Imports: Only Calliope ➔ Excess electricity Europe

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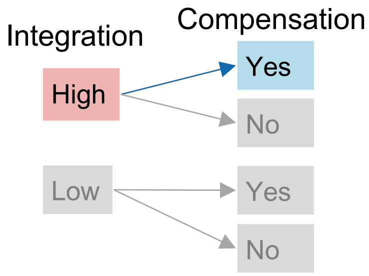
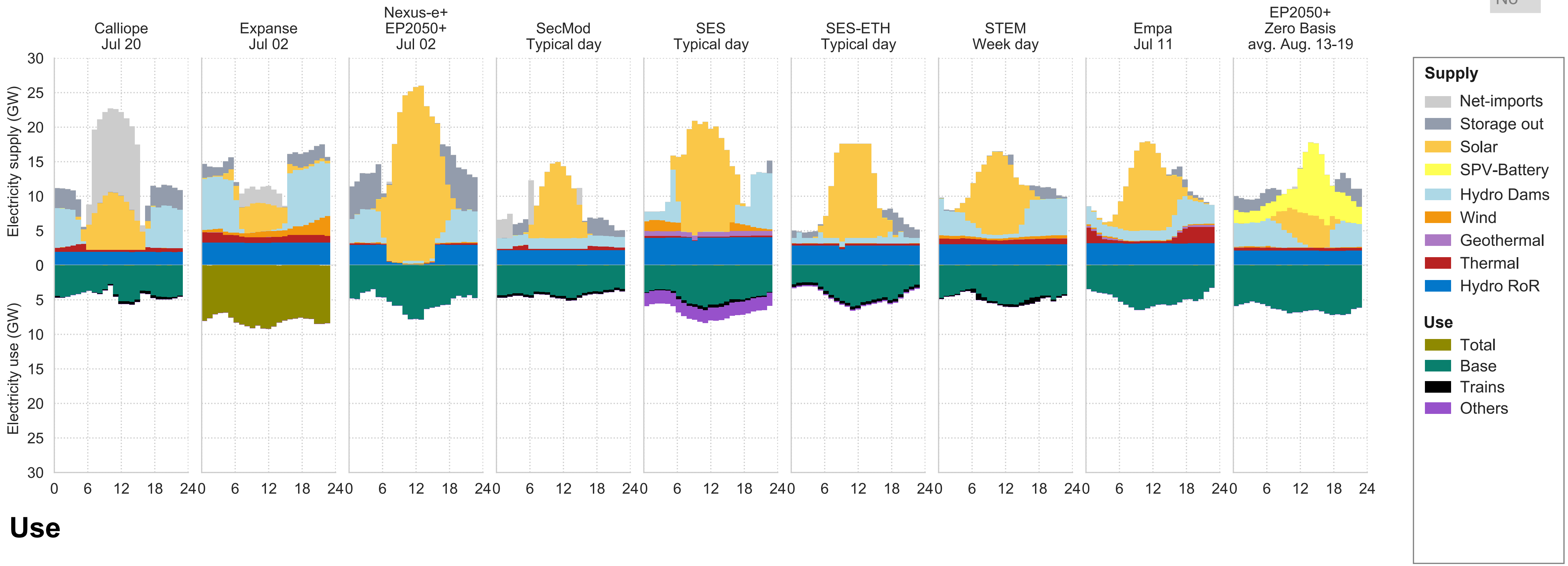
Hourly profiles: Summer, abroad-together





Use

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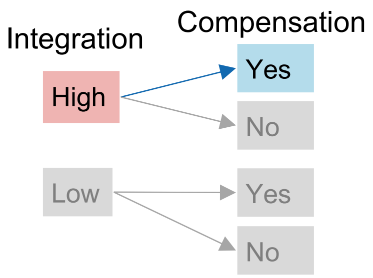
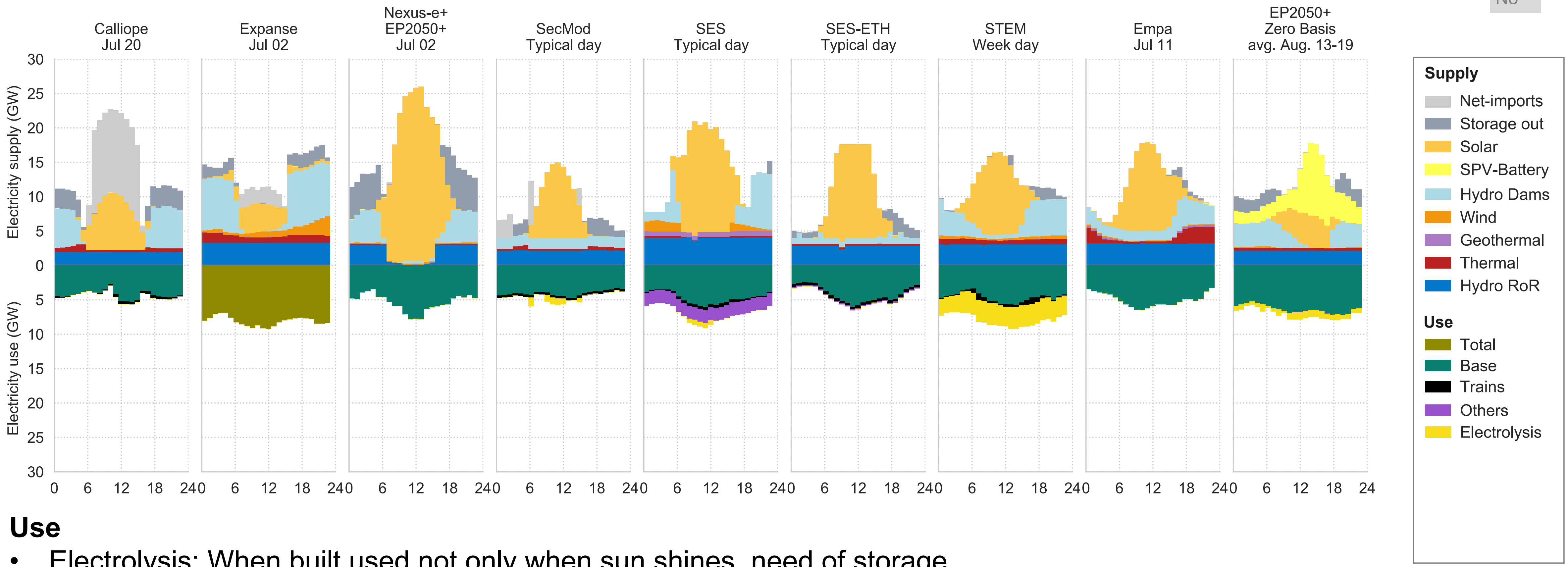
Hourly profiles: Summer, abroad-together

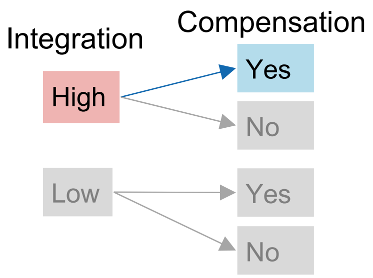


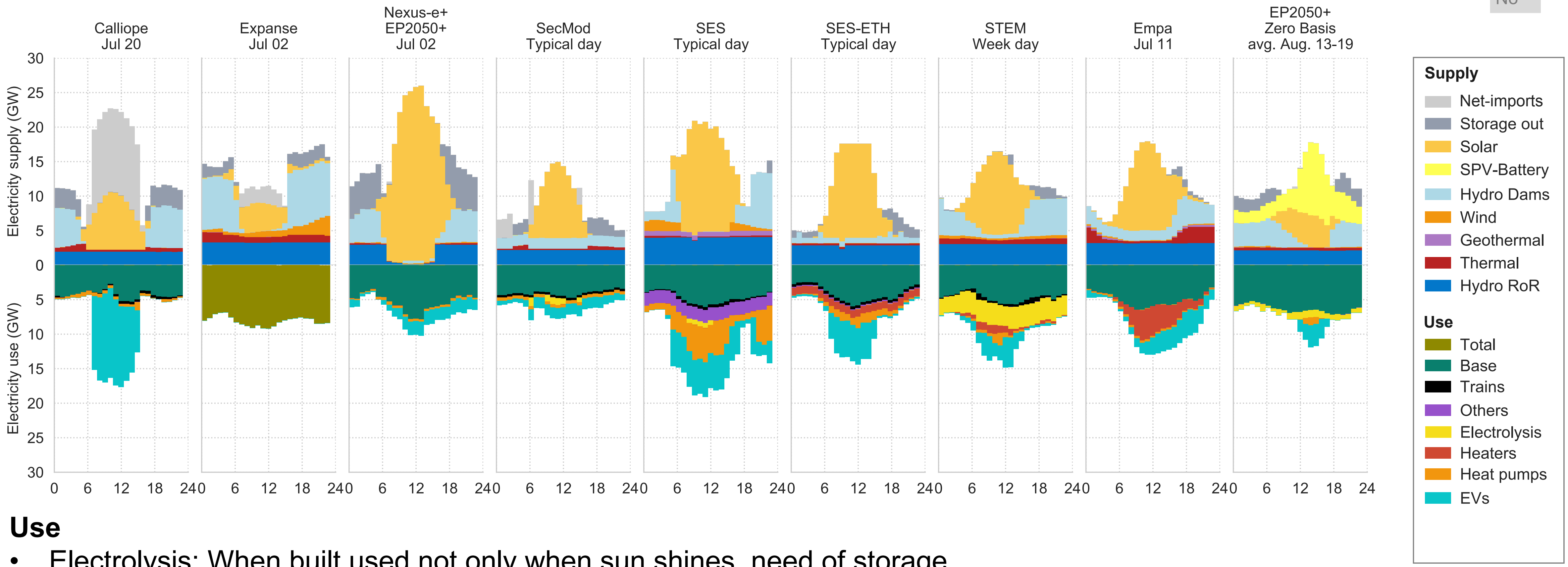


Use

- Electrolysis: When built used not only when sun shines, need of storage

Hourly profiles: Summer, abroad-together



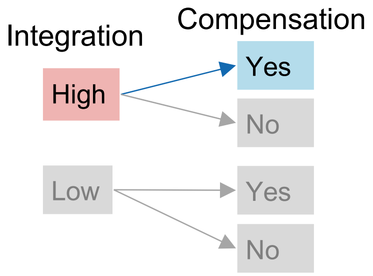


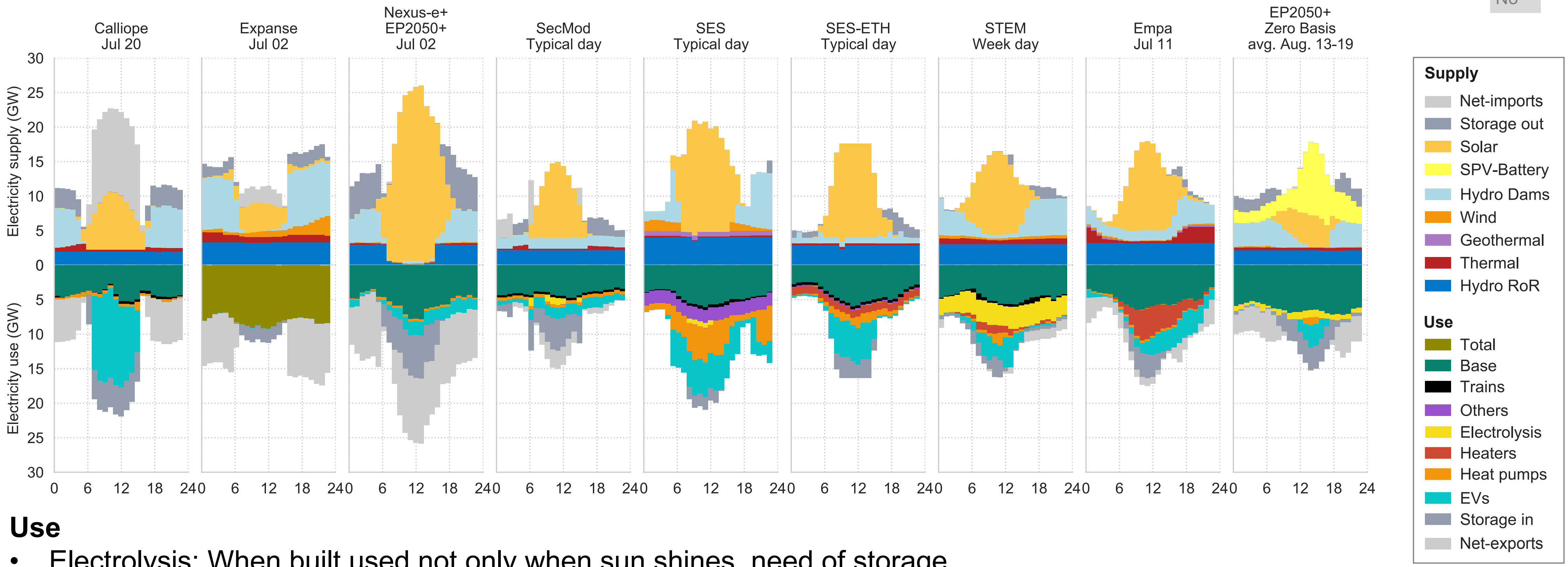
Use

- Electrolysis: When built used not only when sun shines, need of storage
- Electricity uses for excess solar: EVs, Heat pumps, Heaters, Trade

Disclaimer: Preliminary results

Hourly profiles: Summer, abroad-together





Use

- Electrolysis: When built used not only when sun shines, need of storage
- Electricity uses for excess solar: EVs, Heat pumps, Heaters, Trade
- Pumped hydro and imports:
    - Detailed representation of Europe: Pumped hydro: Switzerland ≈ Battery for Europe
    - No detailed representation of Europe: Flexibility provider

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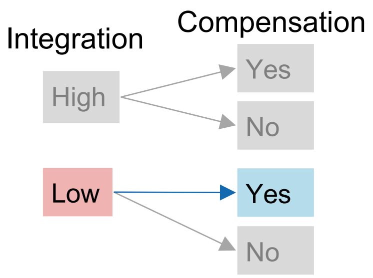
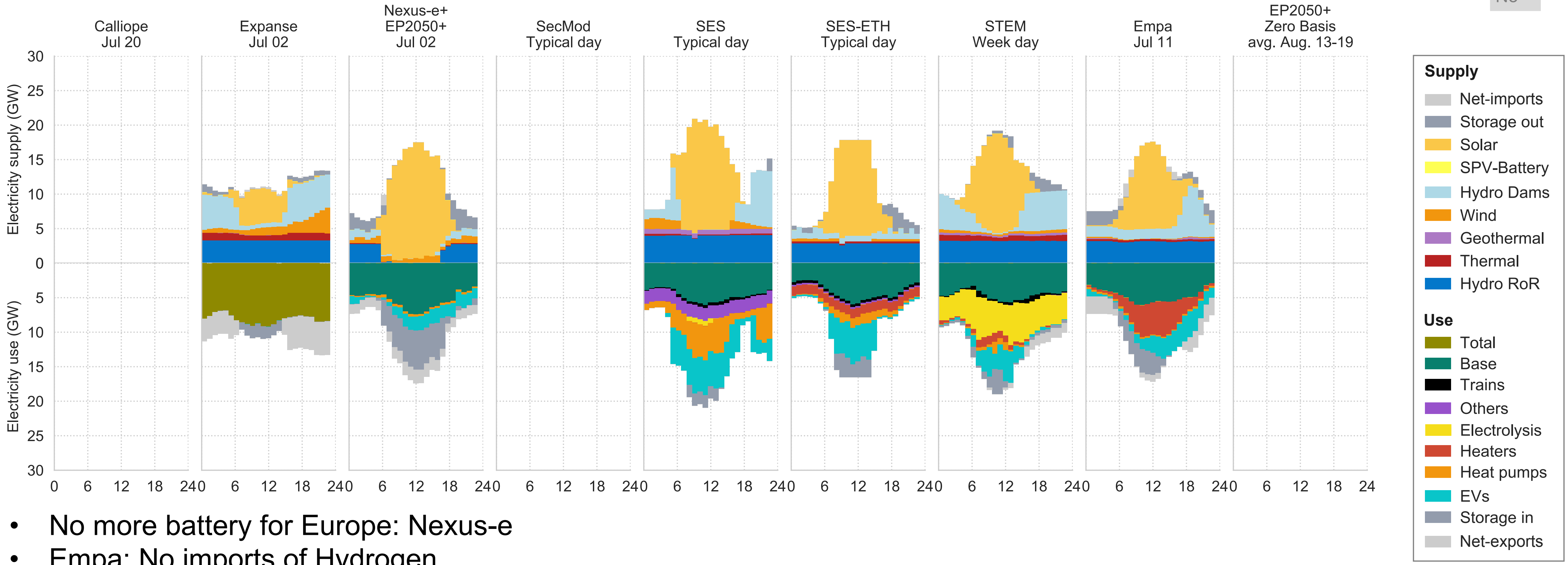
Hourly profiles: Summer, abroad-alone





- No more battery for Europe: Nexus-e
- Empa: No imports of Hydrogen
- STEM: Additional electrolysis

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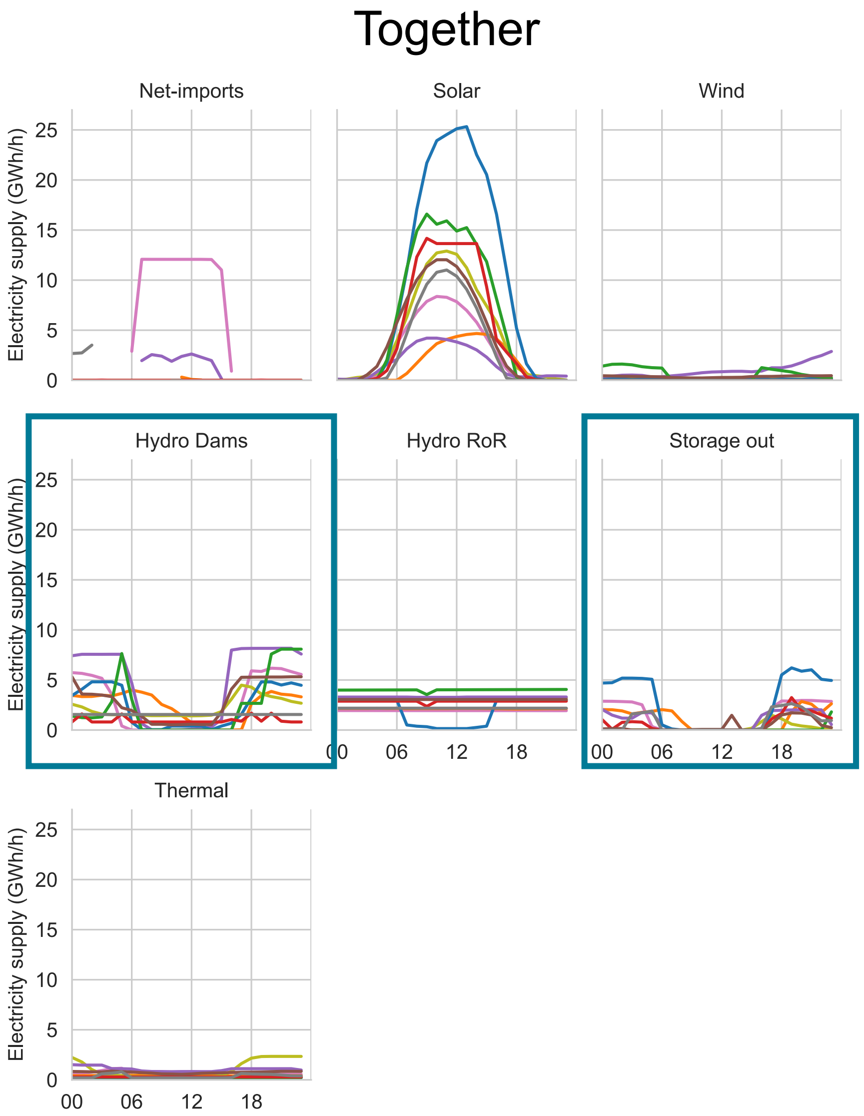
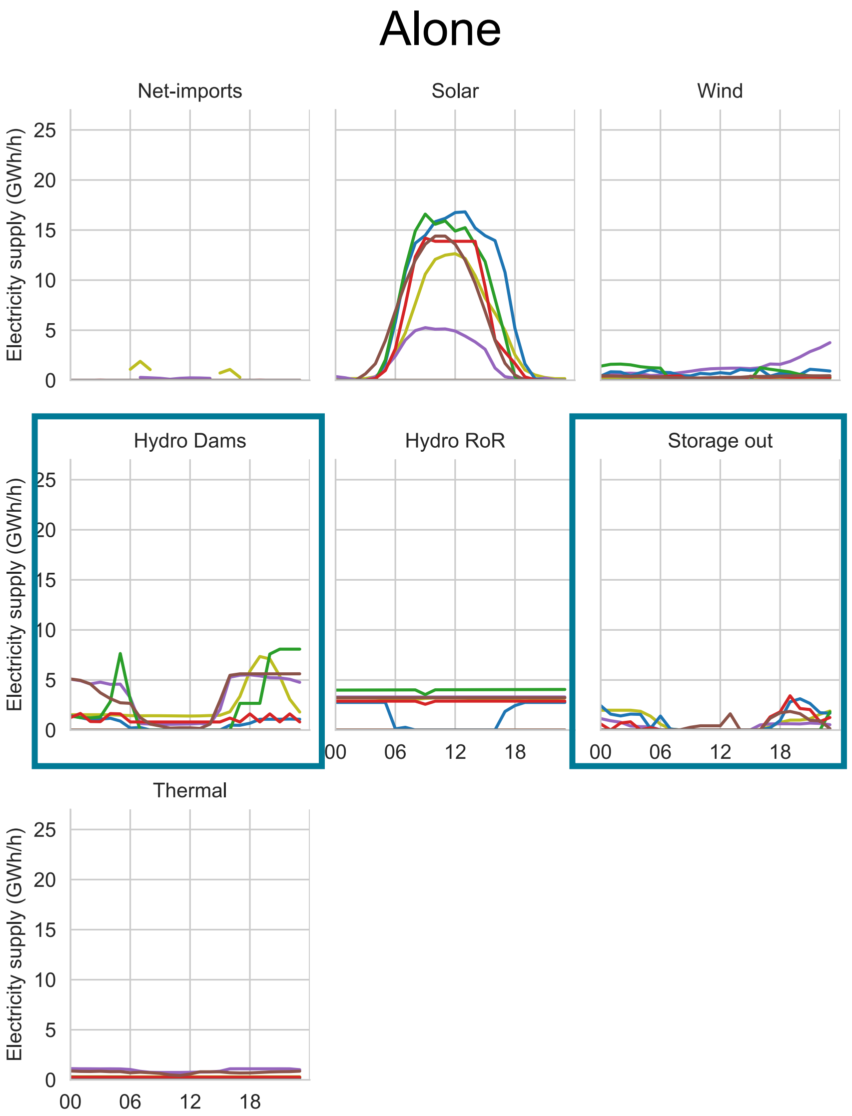
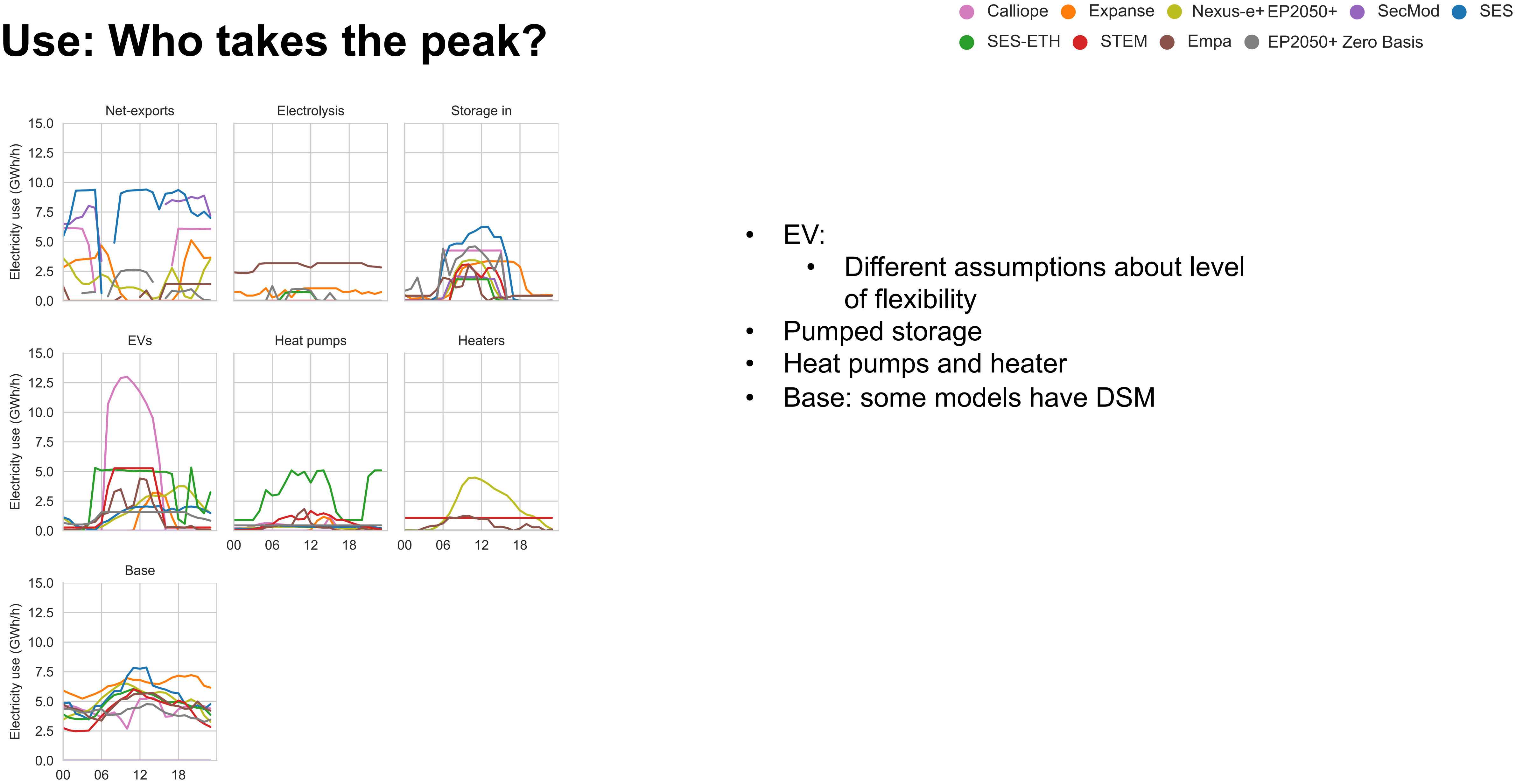
Supply: Who replaces solar in the evening?

Calliope · Expanse · Nexus-e+ EP2050+ · SecMod · SES · SES-ETH · STEM · Empa · EP2050+ Zero Basis



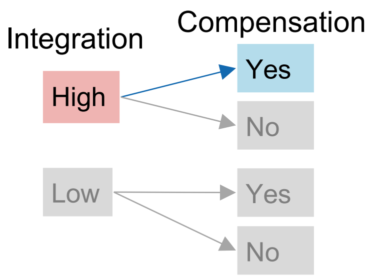


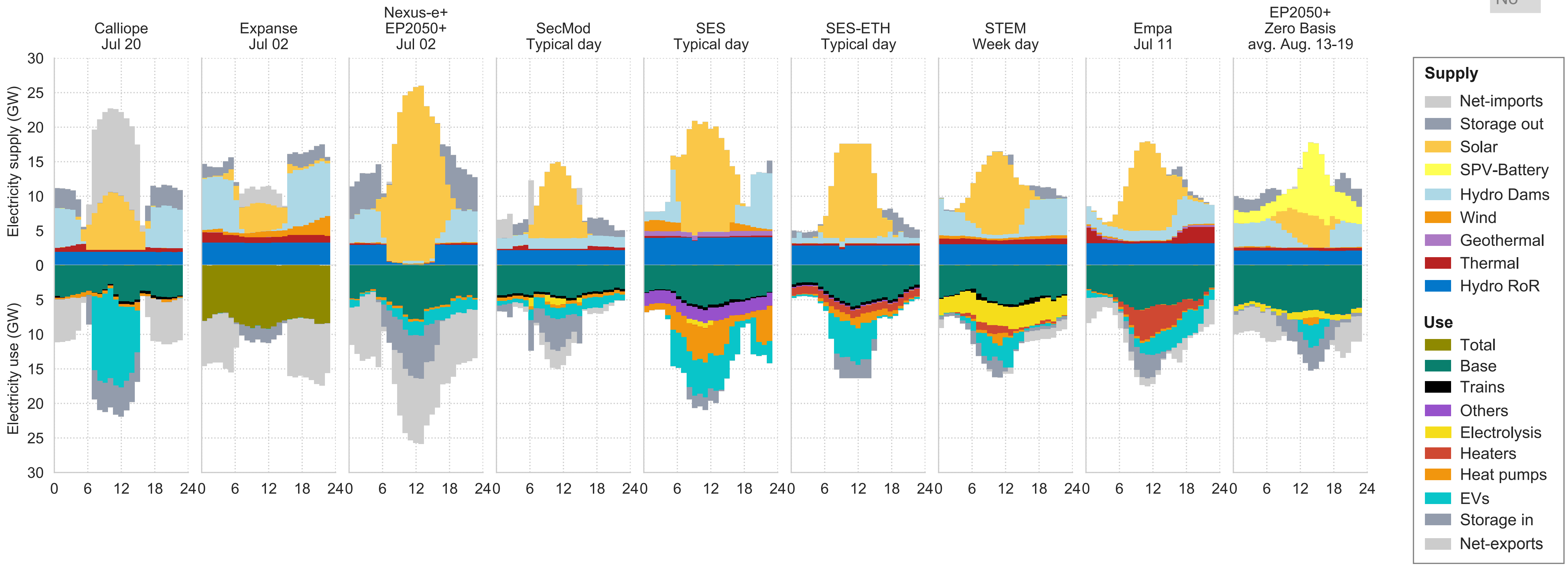
Use: Who takes the peak?



- EV:
  - Different assumptions about level of flexibility
- Pumped storage
- Heat pumps and heater
- Base: some models have DSM

Hourly profiles: Summer, abroad-together





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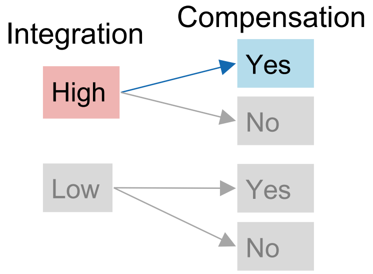
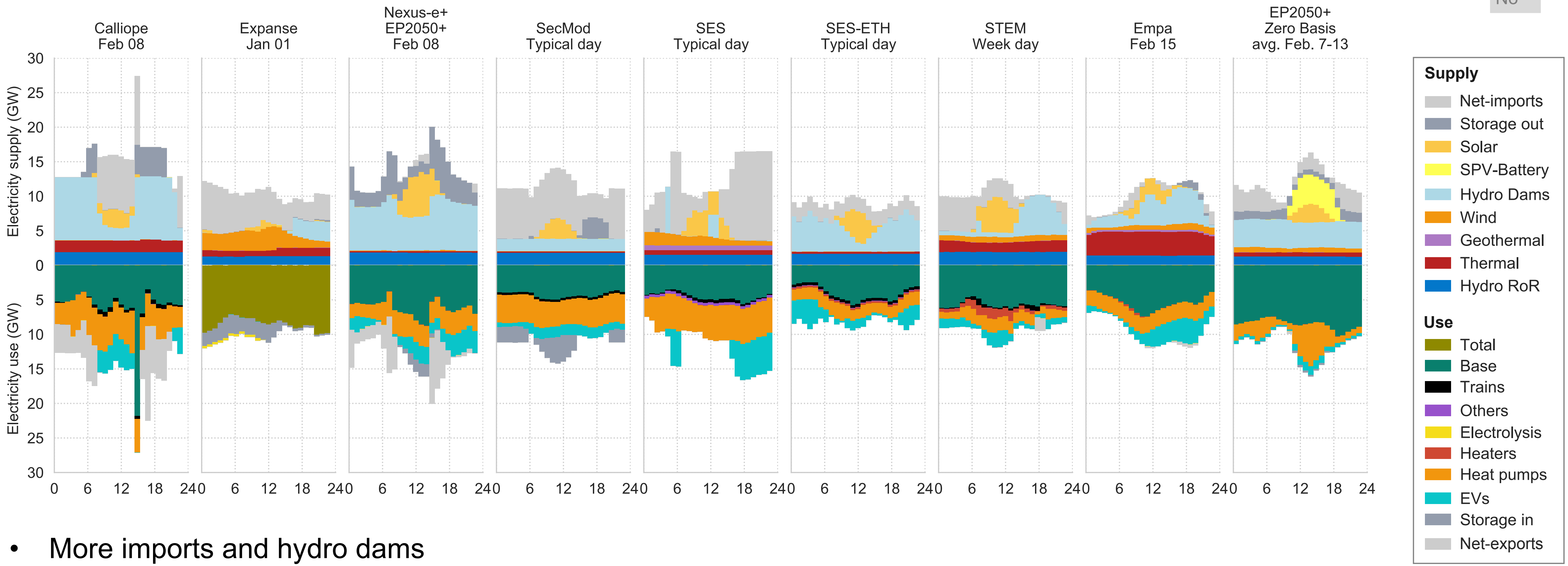
Hourly profiles: Winter, abroad-together





- More imports and hydro dams
- A lot less flexibility needs

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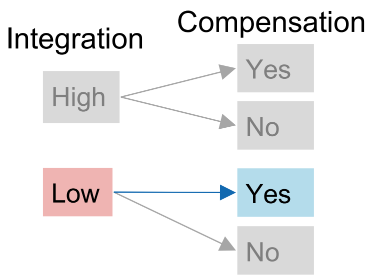
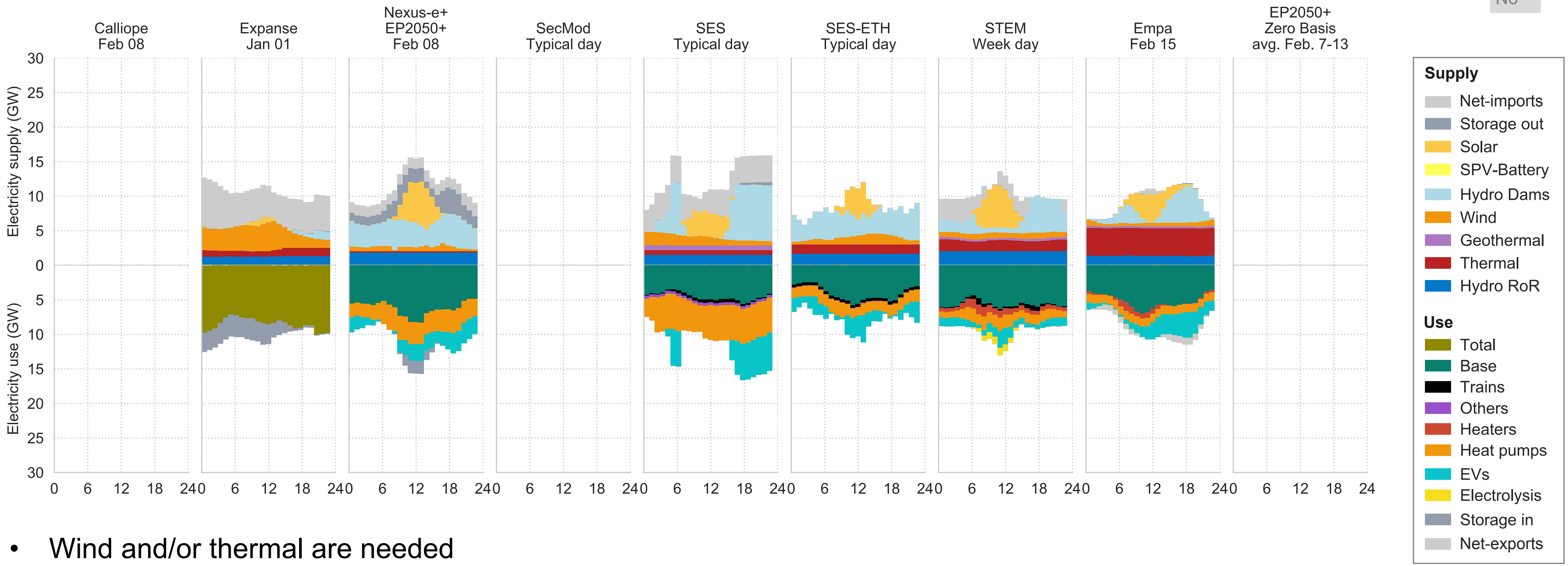
Hourly profiles: Winter, abroad-alone



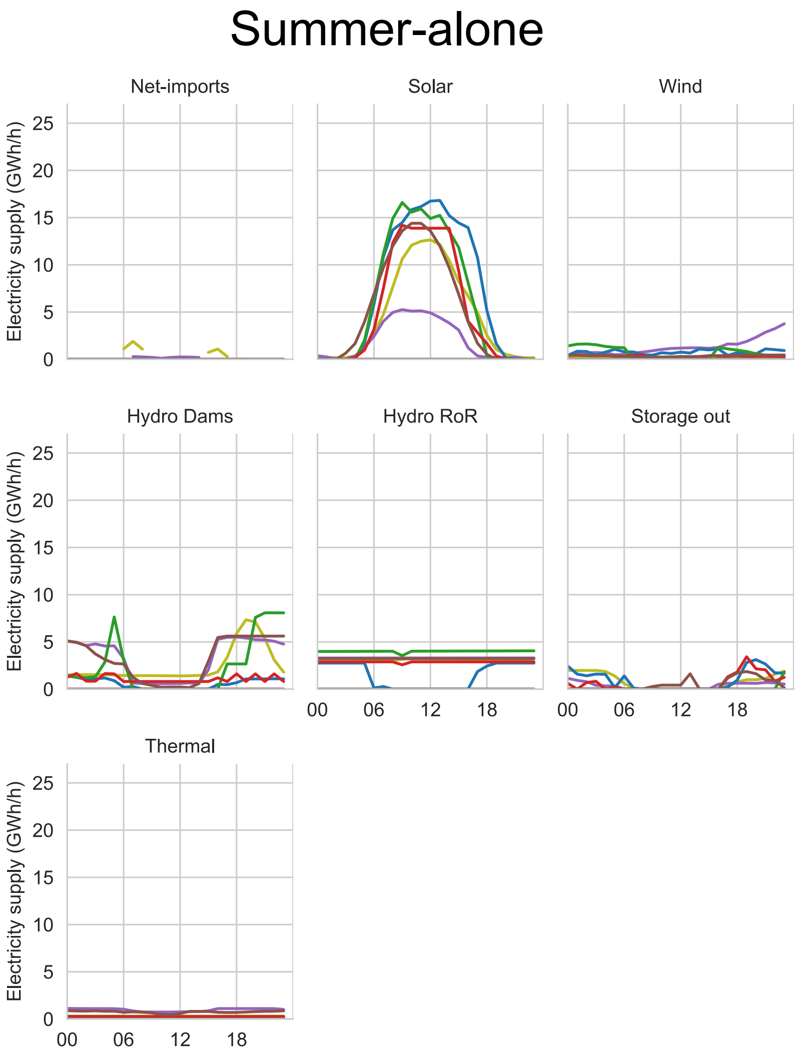


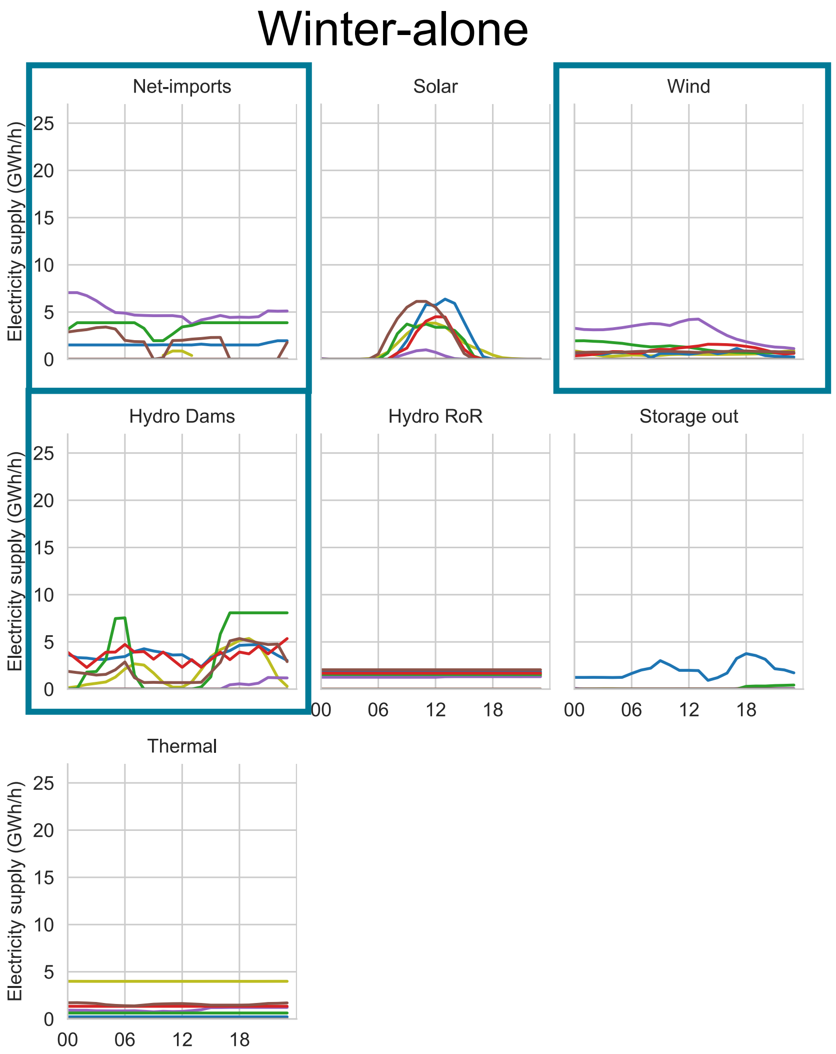
- Wind and/or thermal are needed

Disclaimer: Preliminary results

Supply: Who replaces solar in the winter?

Calliope · Expanse · Nexus-e+ EP2050+ · SecMod · SES · SES-ETH · STEM · Empa · EP2050+ Zero Basis





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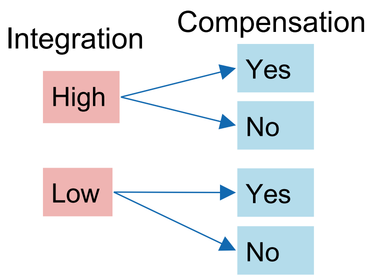
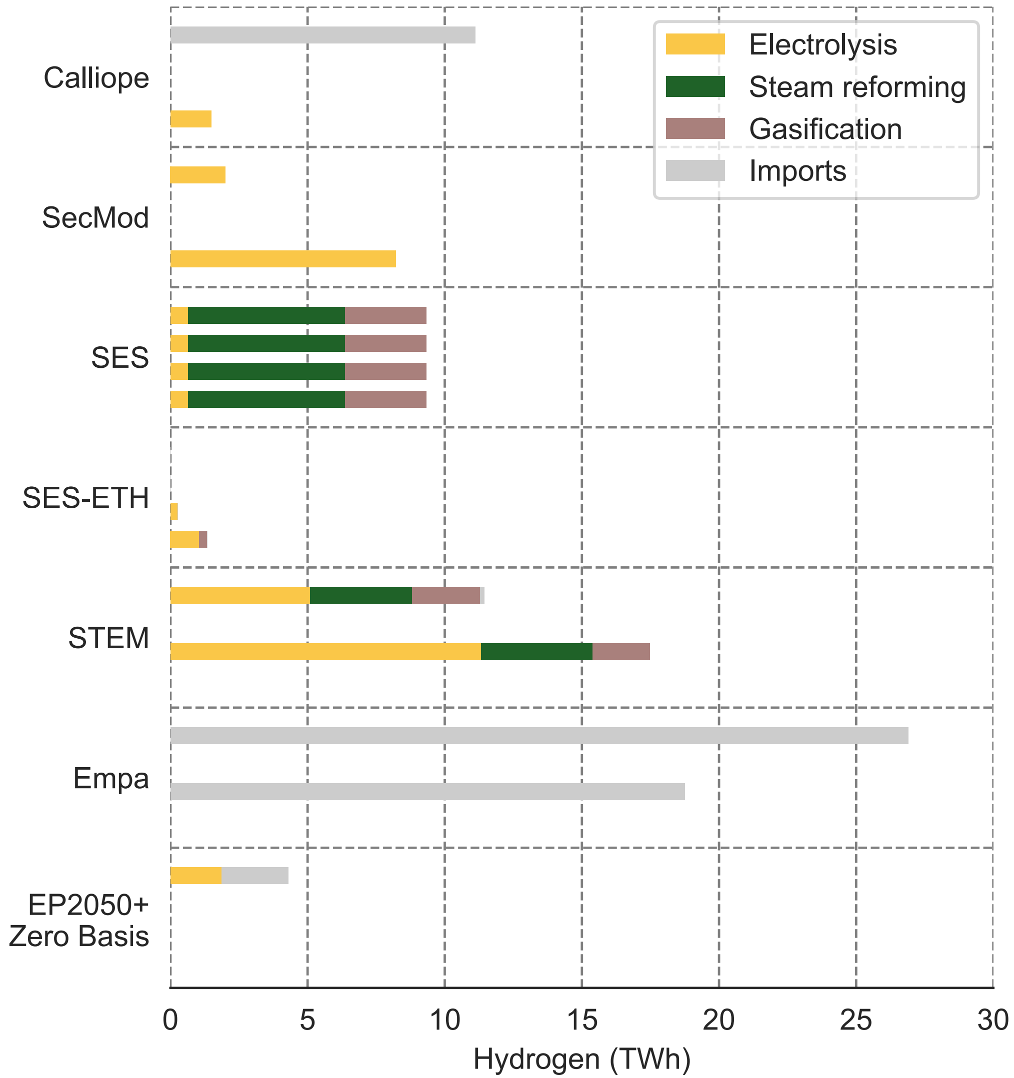
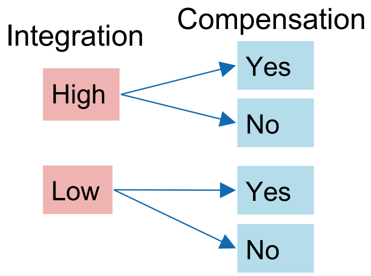
Hydrogen supply (2050)

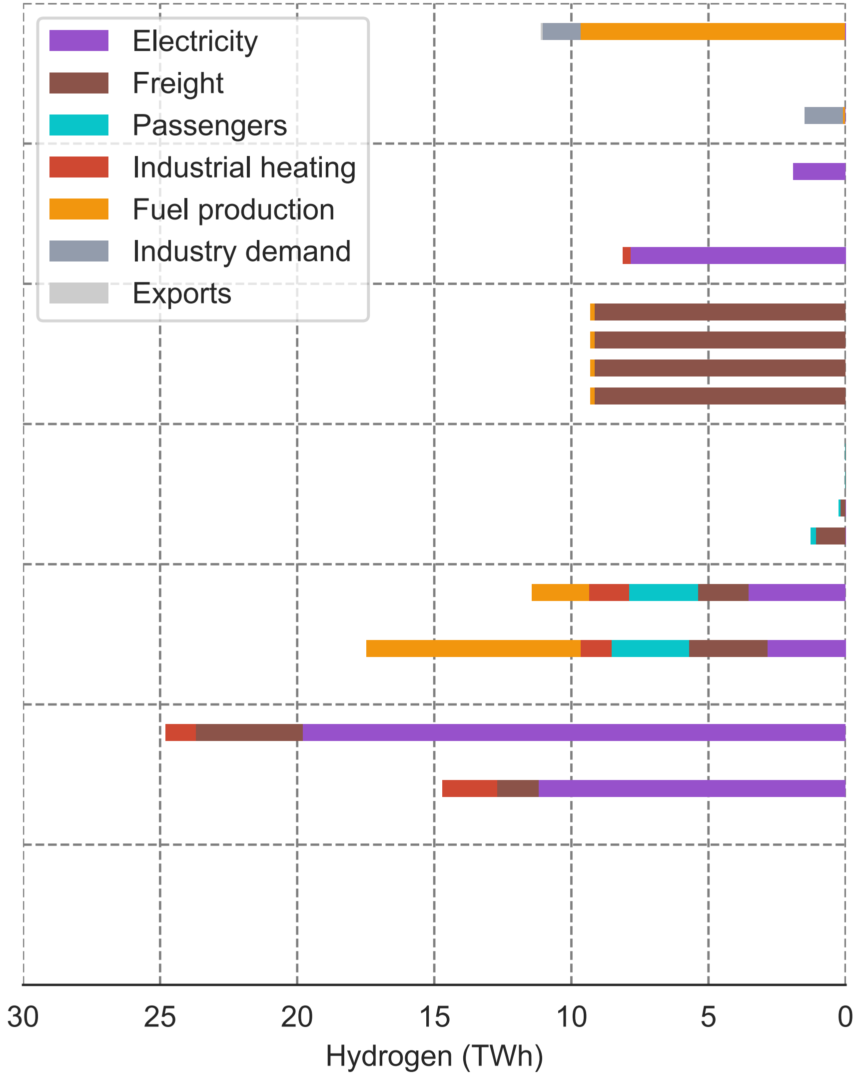


Larger disagreement:
- Wood gasification
- Imports
- Electrolysis
- Methane reforming

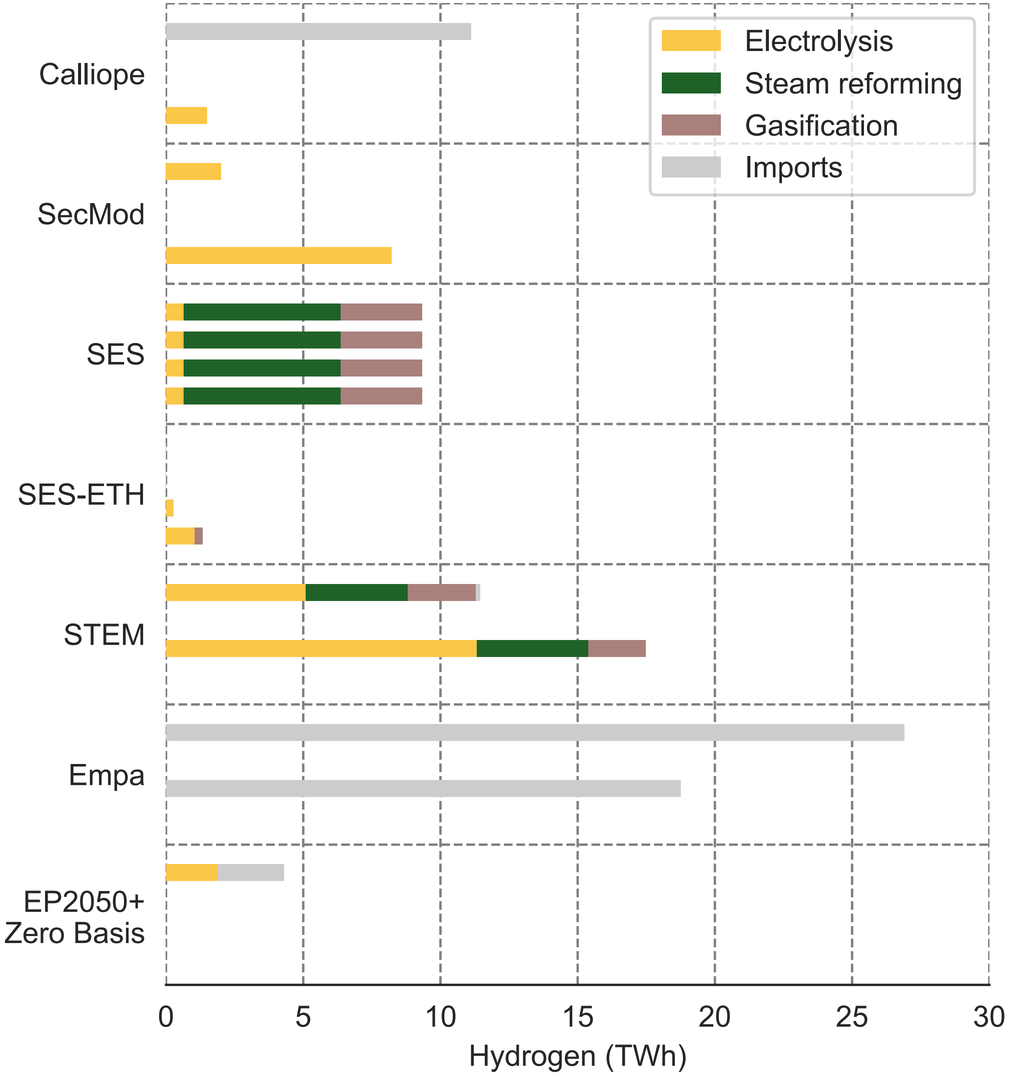




Hydrogen use (2050)



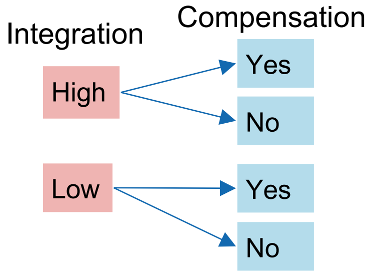
Hydrogen supply (2050)

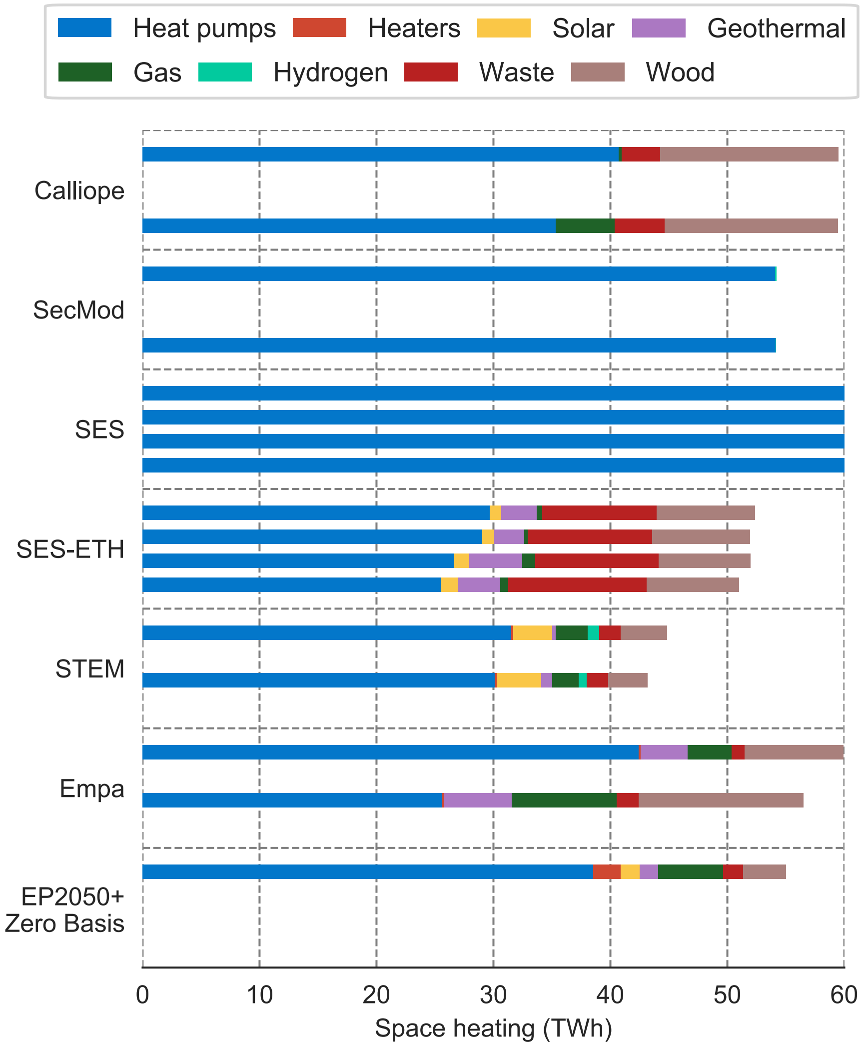


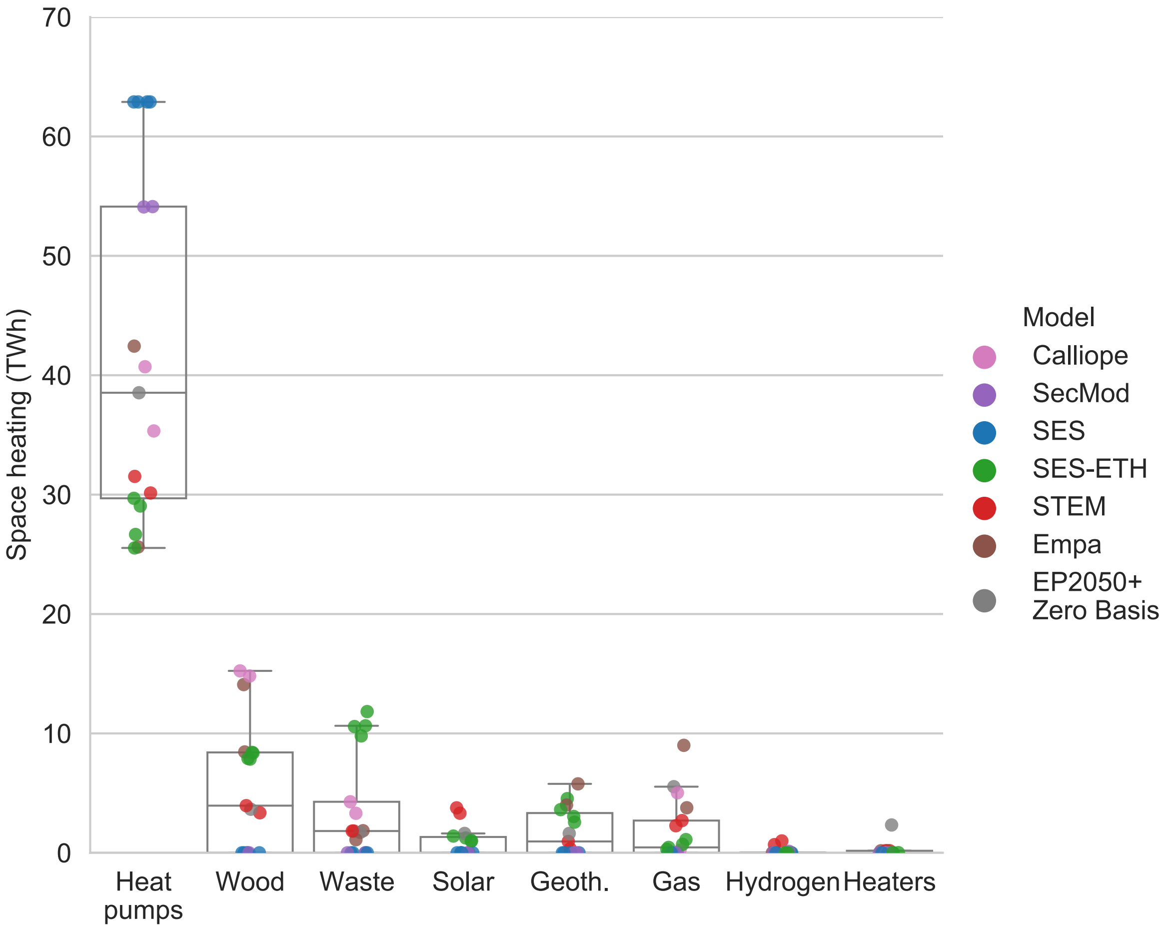
Disclaimer: Preliminary results

1. Energy scenarios in Switzerland
2. CROSS scenarios
3. Models
4. Electricity, annual
5. Electricity, hourly
6. Hydrogen
7. **Heat**
8. Transport
9. What next?

Space heating and hot water (2050)







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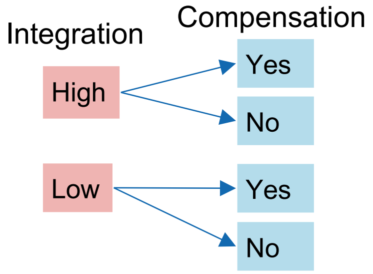
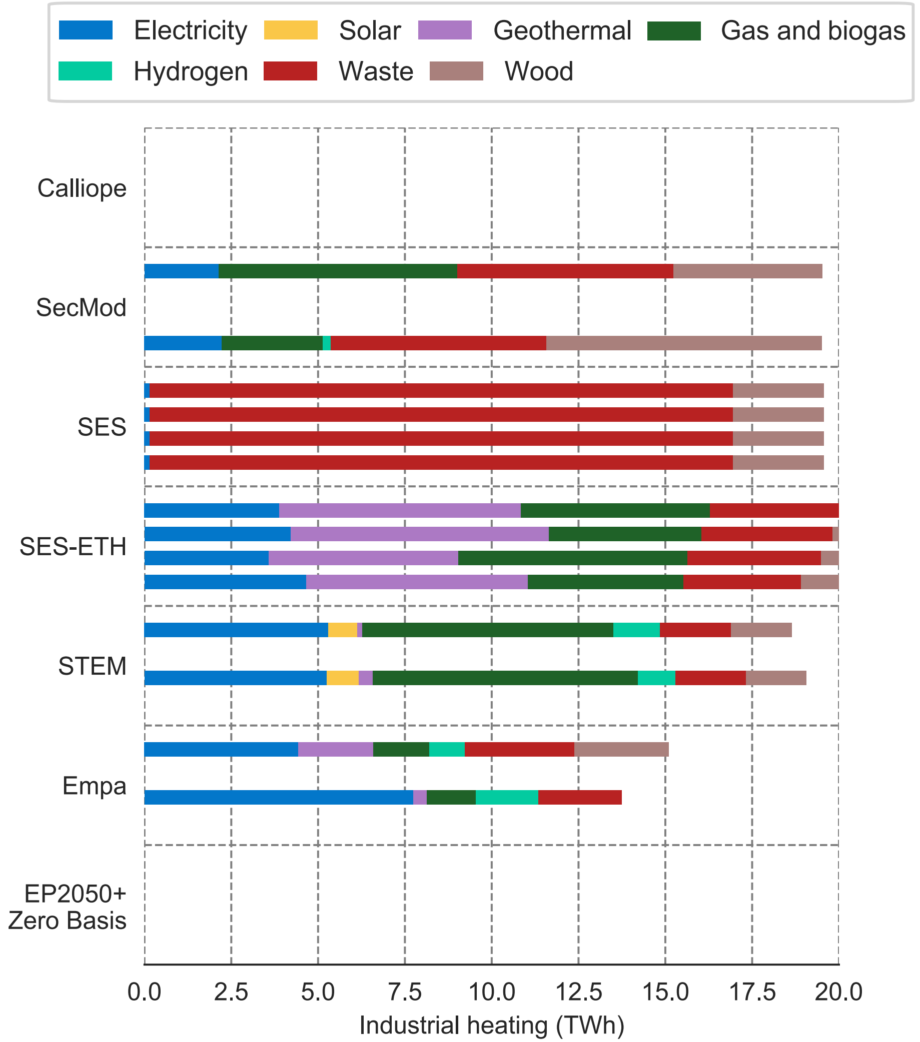
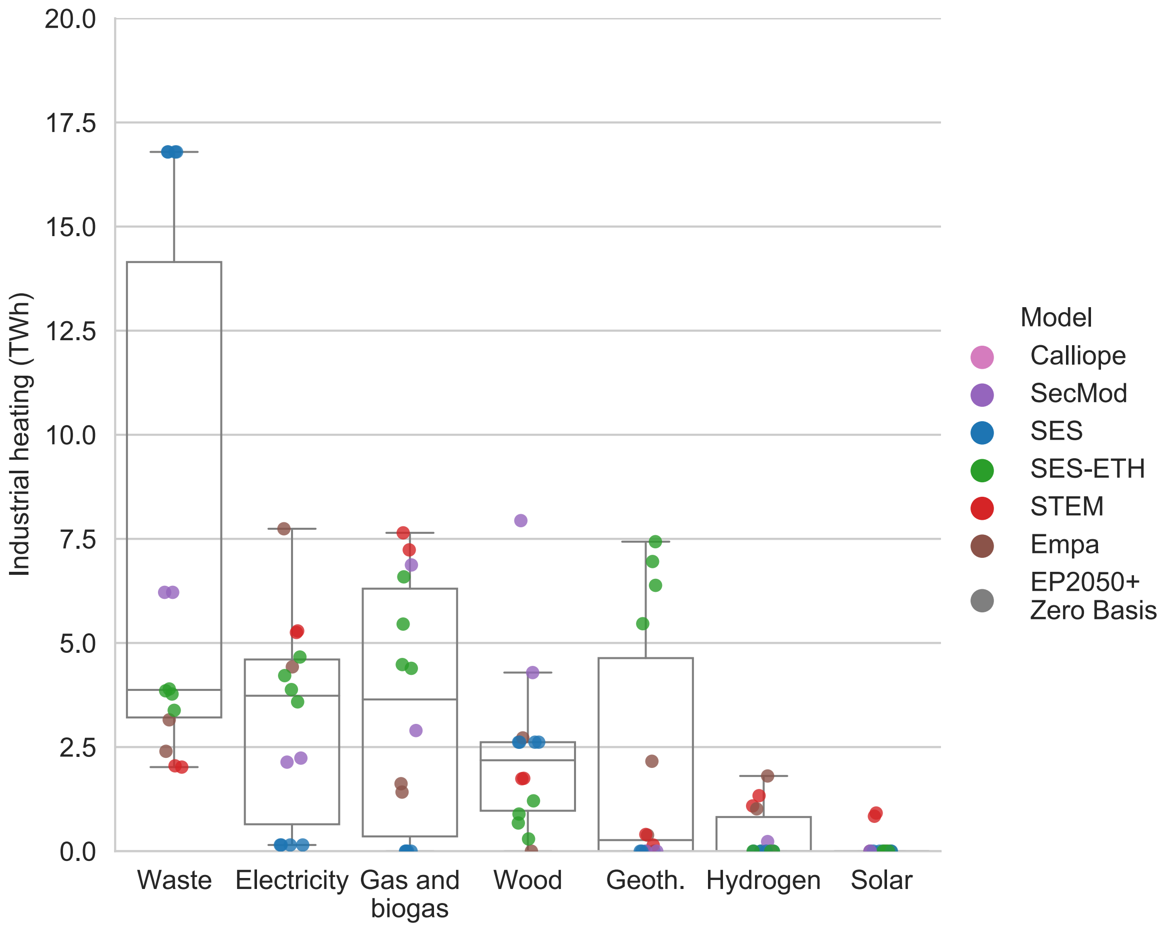
Industrial heat (2050)







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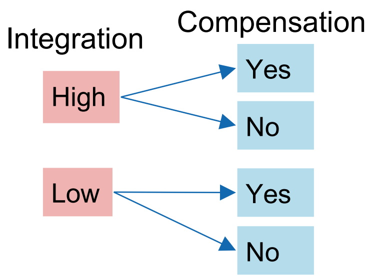
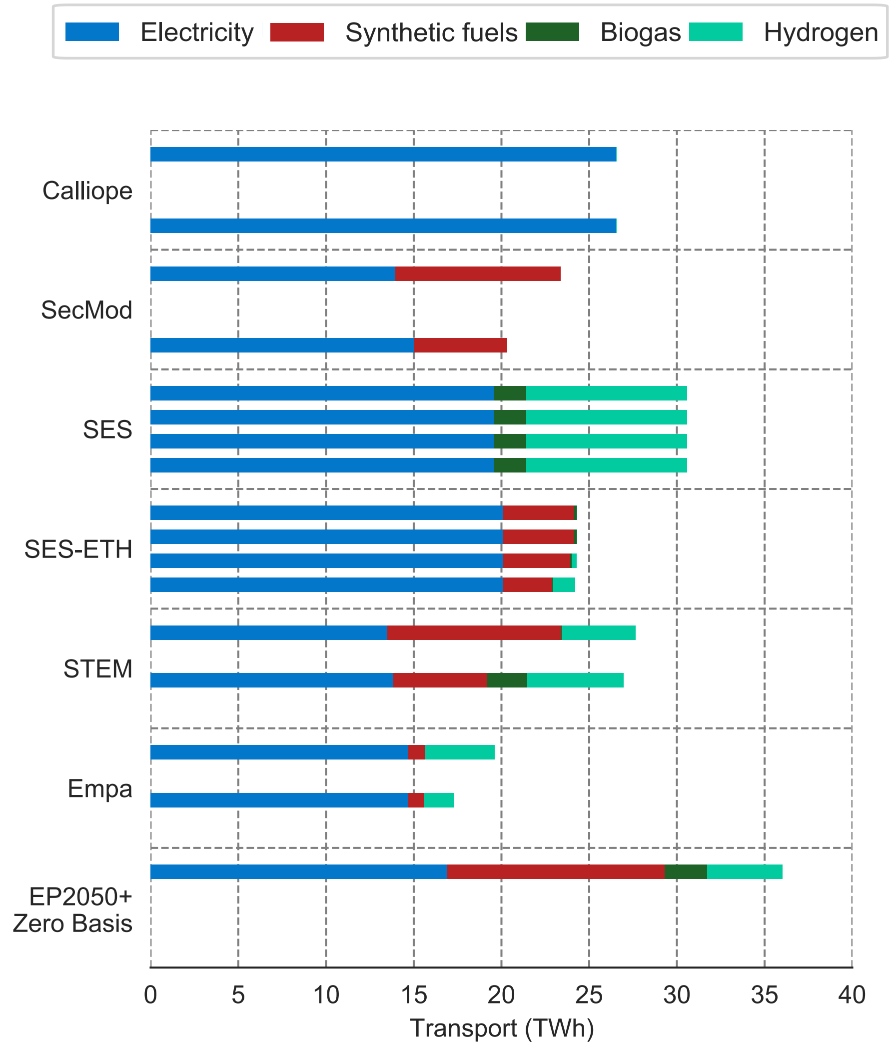
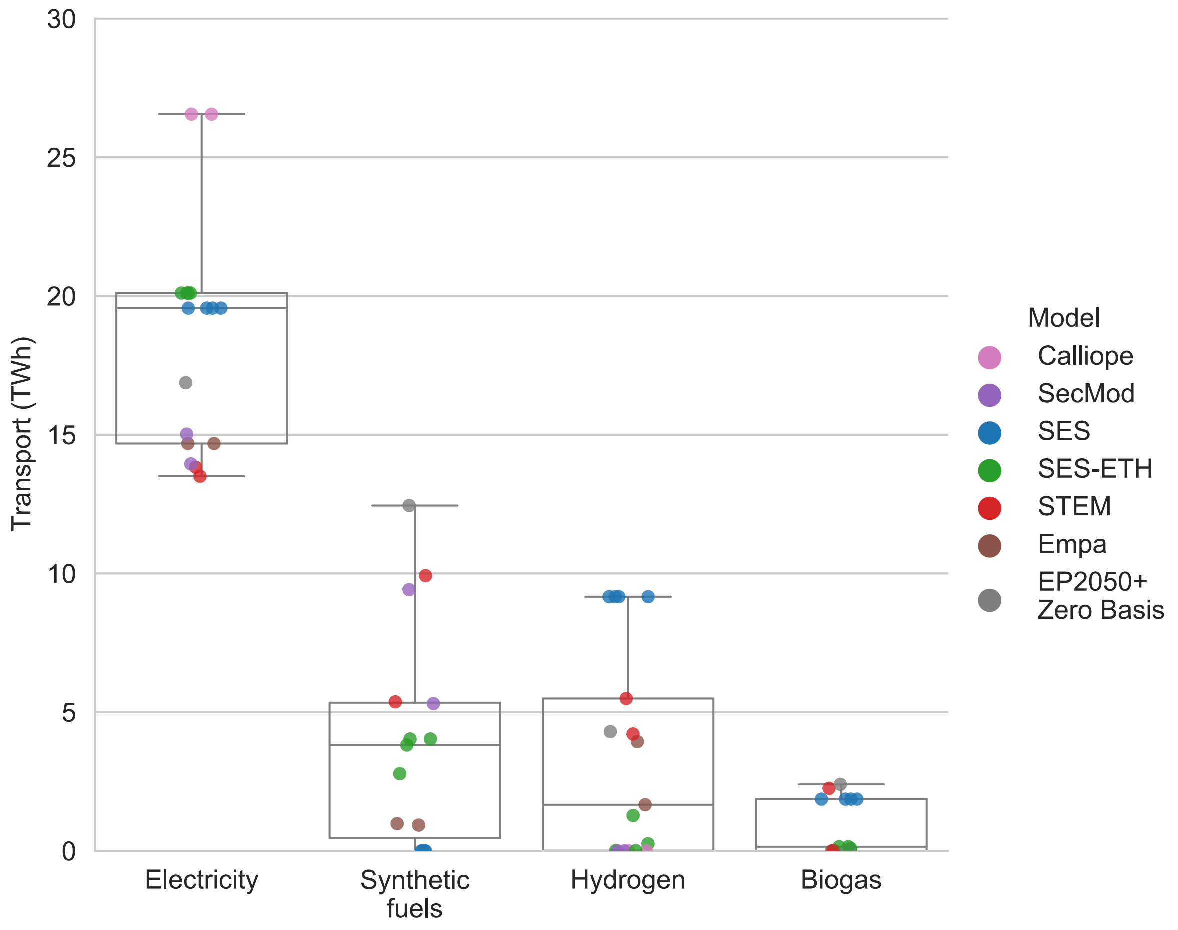
Road transport freight and passengers (2050)







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Learnings, future work, etc.

- Commons and less commons
  - Some of the less commons are driven by model assumptions. E.g. COP of heat pumps, efficiency of electric vehicles
  - Future work: Additional “harmonized” parameters with min and max values
- Scenario definition: Domestic vs. abroad
  - No large differences in energy: innovative, DAC
  - What about the costs?
- Further analysis:
  - H2 production and use
  - Role of flexibility
    - A lot vs. little flexibility in EVs
  - Installed capacities vs. production (not in current data)
  - Biomass use (not in current data)

Thank you for your attention

- Adriana Marcucci, CROSS coordinator, adriana.marcucci@esc.ethz.ch
- Francesco Sanvito, Calliope model, F.Sanvito@tudelft.nl
- Zongfei Wang, EXPANSE model, Zongfei.Wang@unige.ch
- Jared Garrison, Nexus-e model, garrison@fen.ethz.ch
- Florian Baader, SecMod model, fbaader@ethz.ch
- Gabriel Wiest, SES model, gwiest@ethz.ch
- Gianfranco Guidati, SES-ETH model, gianfranco.guidati@esc.ethz.ch
- Evangelos Panos, STEM model, evangelos.panos@psi.ch
- Arijit Upadhyay, Empa model (VSE study), Arijit.Upadhyay@empa.ch

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