Energy systems modelling for renewable energy integration and policy design

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Energy system models by DLR

REMix Modelling Framework

REMix-EnDAT

Calculation of global potentials and hourly availability of RE technologies

REMix-OptiMo

LP optimization model with focus on sector-coupling and flexibility options for large interconnected RE dominated energy systems

REMix-CEM

MILP optimization model with focus on identifying **concerted** transition pathways for national power systems with strongly growing electricity demand

Modelling detail →

← System size

EnDAT: Energy Data Analysis Tool
OptiMo: Optimization Model
CEM: Capacity Expansion Model

Questions of national energy planning authorities

- **Capacity expansion planning:**
  - Which?
  - When?
  - Where?
  - How much?
  - Associated costs?
- **Integration of RE:**
  - Where are favorable sites?
  - How can RE be integrated into the existing system efficiently?
  - How will RE influence conventional generators and transmission grids from a long-term planning and short-term operation perspective?
- **Support by REMix-CEM:**
  - Identifying concerted and reliable transition pathways for a sustainable energy supply

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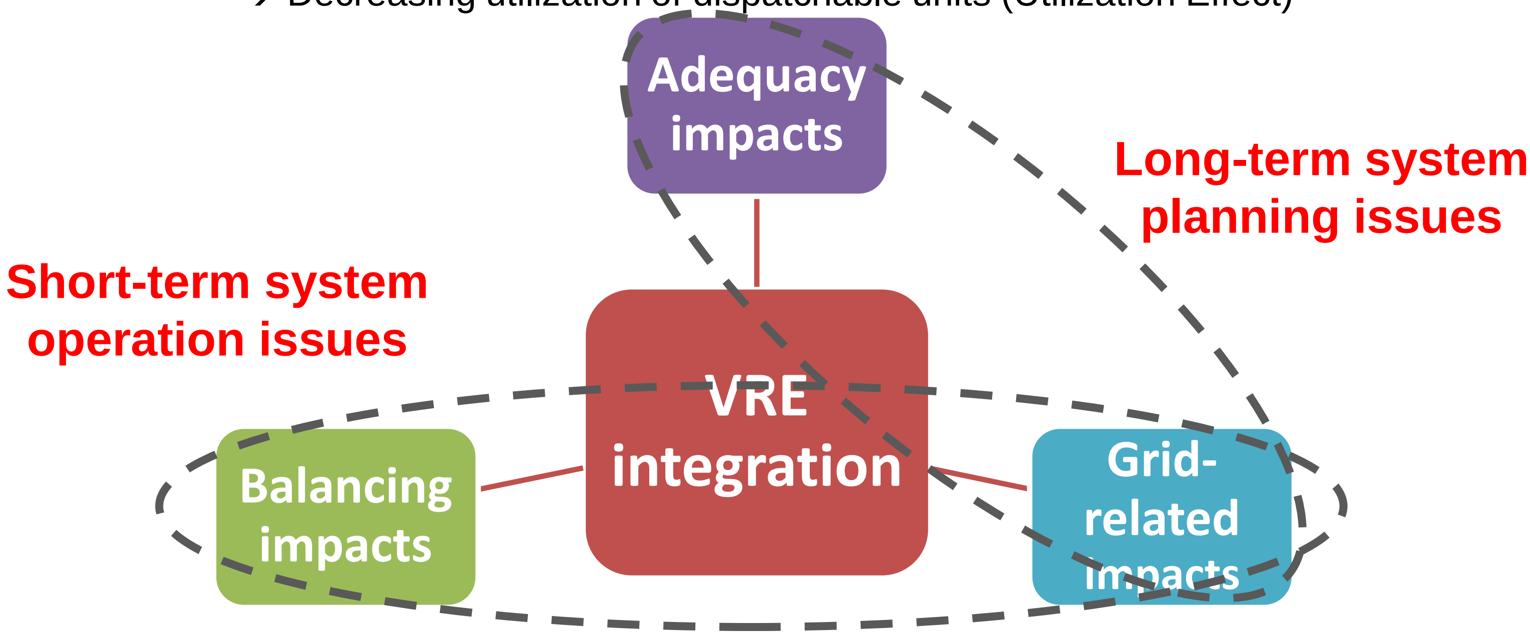
Impacts of large-scale integration of variable renewable energies (VRE)

- LCOE of VRE are very competitive today
- Low capacity credits of VRE
- Low variable generation costs of VRE

→ Decreasing utilization of dispatchable units (Utilization Effect)



- Higher variability of residual load

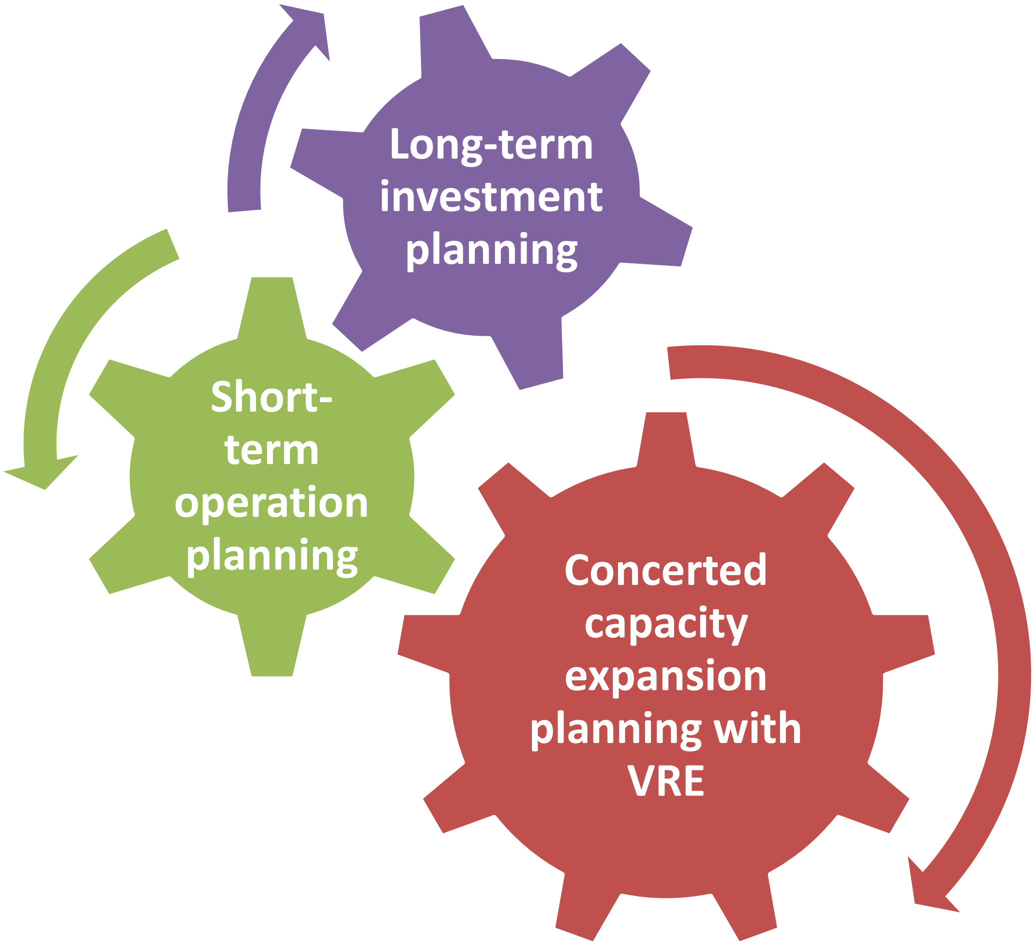
→ More cycling of dispatchable units (Flexibility Effect)

→ Higher needs for operating reserve

- Site-specific characteristics
- (V)RE often far away from demand centers

→ Grid extensions and reinforcements necessary

REMix-CEM combines…



- Path-optimization over planning horizon to consider utilization effects caused by VRE
- Adequacy and operating reserve restrictions to maintain a reliable system design
- High temporal resolution to account for the time-of-delivery energy value of VRE
- High spatial resolution to consider site-specific nature of VRE (multi-node model)
- Unit commitment constraints of dispatchable units to consider balancing impacts caused by VRE

Modelling approach

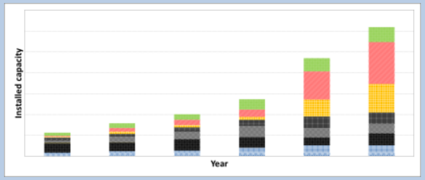
Input

Climate and weather data, techno-economic parameters, scenario assumptions

Capacity Expansion Model REMix-CEM

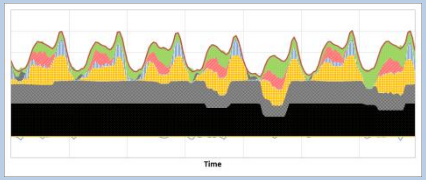
Capacity Expansion Planning

Multi-annual least-cost capacity expansion optimization with selected unit commitment constraints and representative hourly time-slices



Unit Commitment Optimization

Annual dispatch optimization with full set of unit commitment constraints (rolling horizon)



Output

Capacity expansion plan, hourly system operation, system and single unit costs, GHG emissions

Policy Design

Long-term and short-term RE targets, design of power purchase agreements, feed-in-tariffs, etc.

Process of scientific based policy advise for national energy planning authorities

Science	International Cooperation	Policy (Decision makers energy sector)
Deutsches Zentrum für Luft- und Raumfahrt German Aerospace Center	giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH	
Identification of appropriate model		Data and scenario workshop
Model adaption and calculation of full scenario set		Select "Main Scenarios" and concretize boundary conditions
Calculation of "Main Scenarios"		Select "Lead Scenario" and finalize boundary conditions
Calculation of "Lead Scenario"		Implementation of policy/regulatory strategy

Broad View

Detailed Strategy

Does detailed modelling matter…

- A small case study:

Generation expansion optimization for conventional thermal generators in a 50% VRE scenario until 2050

Objective: Identification of least cost generation expansion plan to meet residual demand over planning horizon

Run 1: without unit commitment constraints (UCC)
Run 2: with UCC

Planning horizon: 2015 – 2050 (demand increases by a factor of 3)

Candidate units: COAL, CCGT, OCGT, ICE (motors)

Temp. resolution: 672 time-slices per year
(4 seasons, 1 week per season with hourly time-slices)

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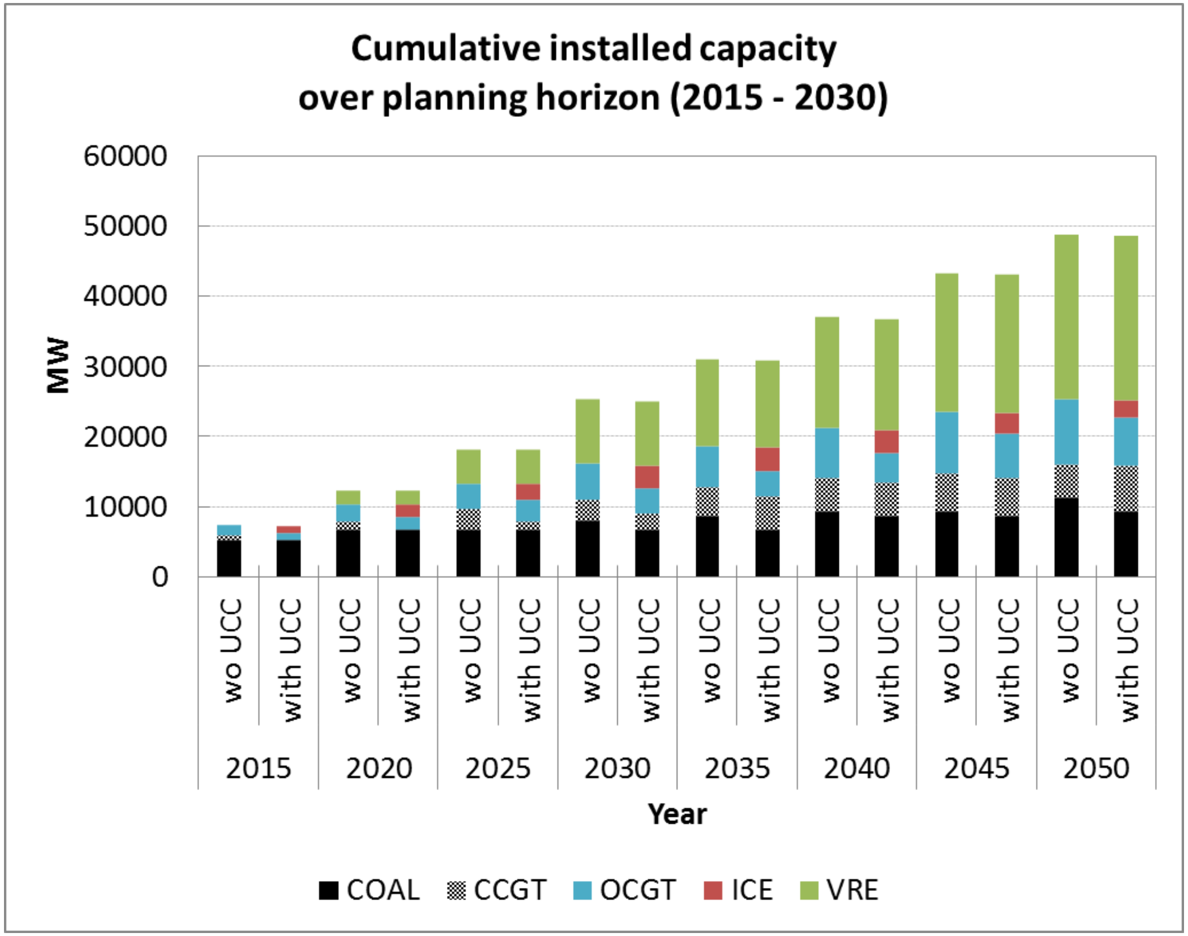
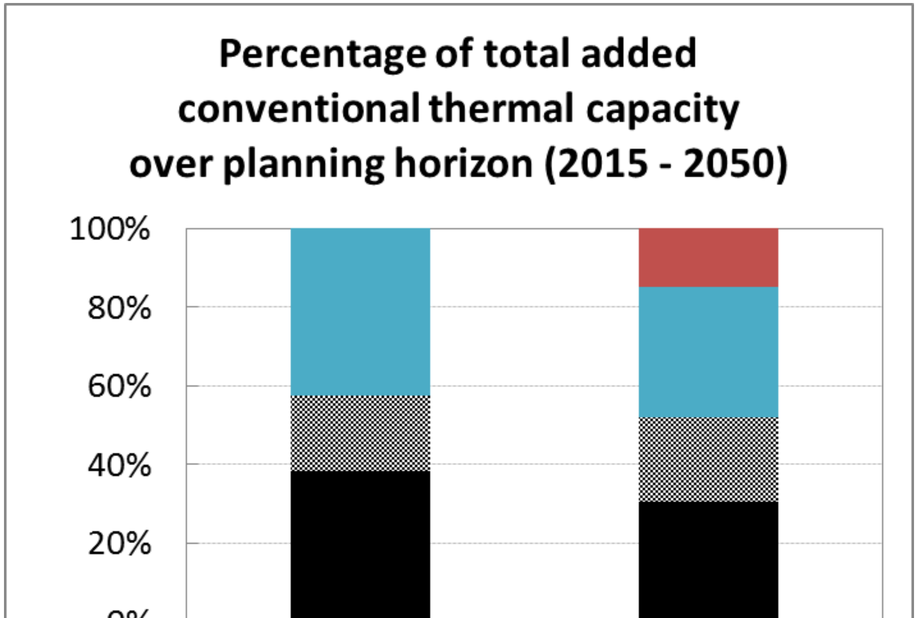
Results case study 1: Cumulative installed capacity



- Significant expansion of conventional thermal power plants despite large-scale integration of VRE (50% until 2050)

Results case study 1: Investments in conventional thermal power plants



	wo UCC	with UCC
ICE	0	15
OCGT	43	33
CCGT	19	22
COAL	38	30

- Share of investments in less flexible coal decreases significantly when UCC are considered directly in least-cost capacity expansion planning
- Share of investments in more flexible technologies increases significantly when UCC are considered
- OCGT preferred option to back-up VRE due to lowest investment costs

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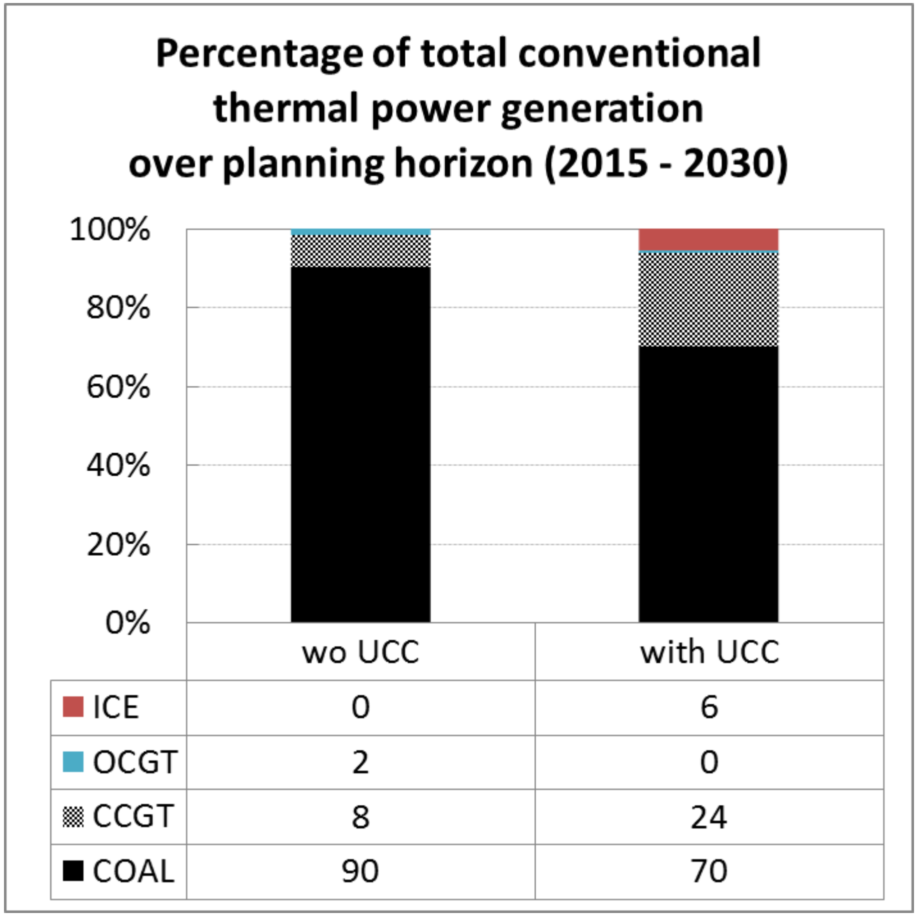
Results case study 1



	wo UCC	with UCC
ICE	0	6
OCGT	2	0
CCGT	8	24
COAL	90	70

- Share of power generation by coal to meet residual demand over planning horizon decrease from 90% to 70% when UCC are considered

Conclusions and challenges

- Energy system models can support policy makers to identify concerted and reliable transition pathways for a sustainable energy supply
- In order to identify concerted transition pathways, energy system model must combine long-term system planning and short-term system operation issues
- Energy system models require a high modelling detail (high temporal & spatial resolution, inter-temporal constraints on system and single unit level) in order to take into account impacts of VRE
- Detailed models are computational demanding - Innovations in the field of energy system modelling are required to apply detailed modelling approaches also for large interconnected systems
- Detailed models rely on detailed input data – A big challenge in many cases

Thank you very much!

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Does detailed modelling matter…

- Two small case studies

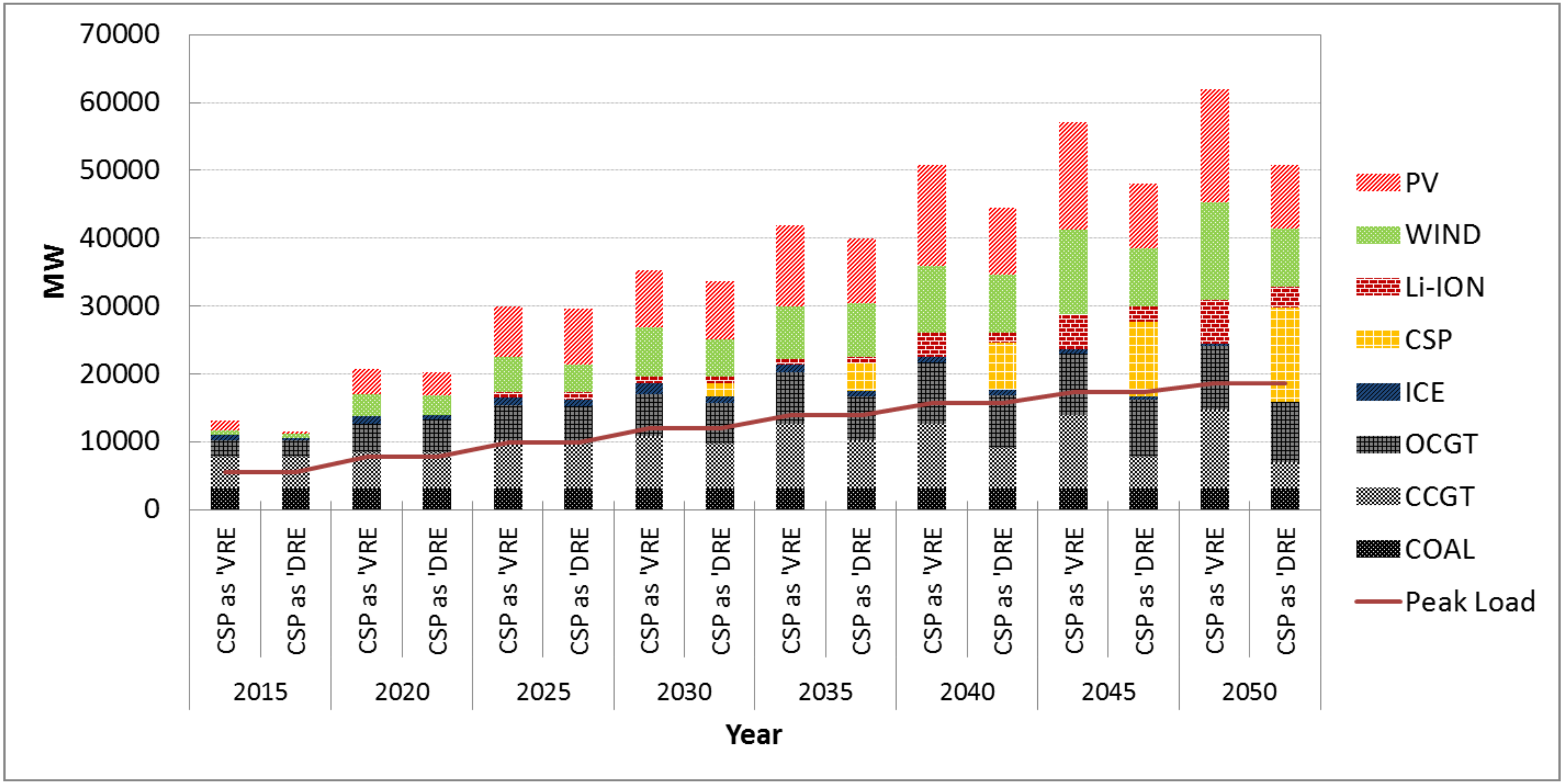
1. Generation expansion optimization for conventional thermal generators in a 50% VRE scenario until 2050.

   Run 1-1: w/o unit commitment constraints (UCC)
   Run 1-2: with selected UCC: start-up costs, min. generation level
   Run 1-3: with full set of UCC

2. Considering technical capabilities of CSP in capacity expansion planning

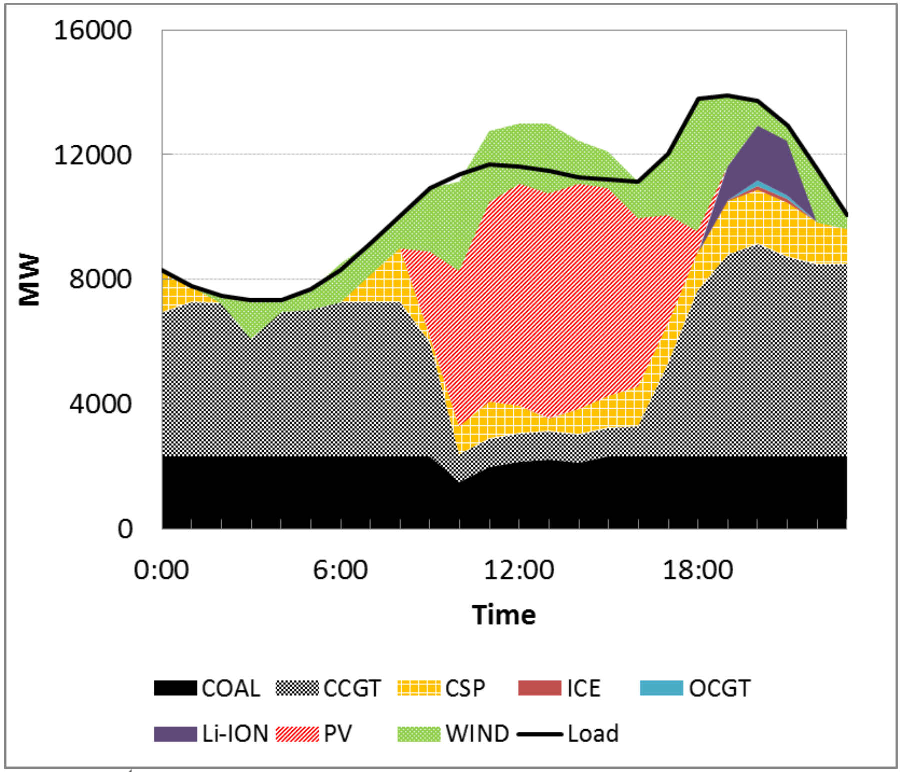
   Run 2-1: Modelling CSP as VRE
   Run 2-2: Modelling CSP as DRE (dispatchable renewable energy)

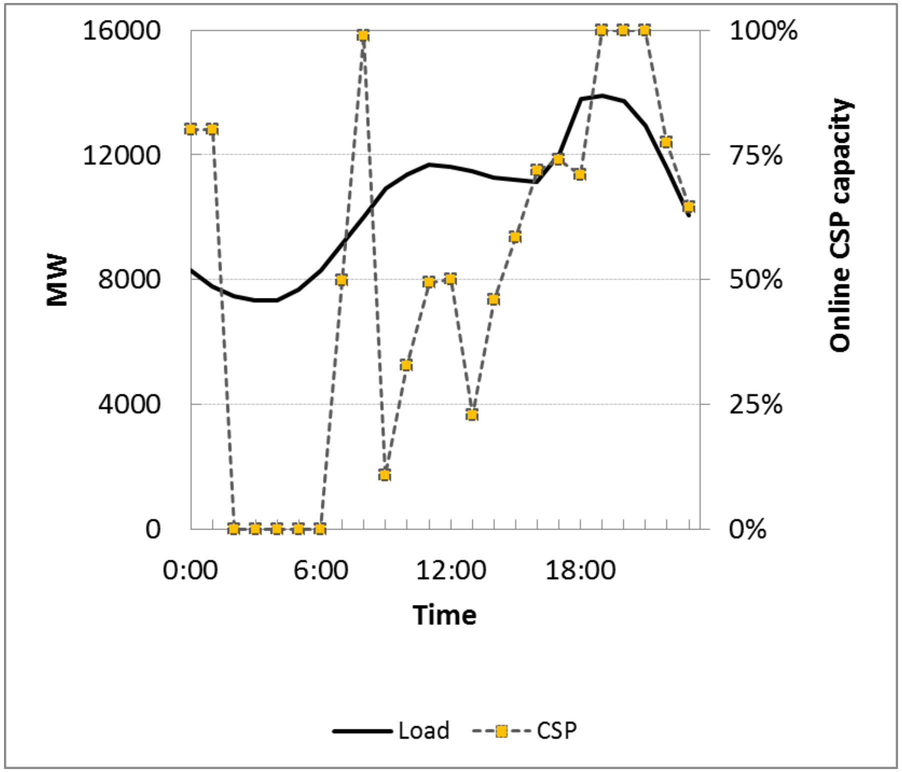
Results case study 2: Considering technical capabilities of CSP



Results case study 2:

- CSP complements power generation from VRE and offers dispatchable and firm capacity





Model set-up

- Planning horizon: 2015 – 2050, path-optimization with five year steps
- Temp. resolution: 4 seasons per year x 1 week per season x 168 h per week = 672 time-slices per year
- Candidate units: Coal, CCGT, OCGT, ICE (motors)
-

	2015	2020	2025	2030	2035	2040	2045	2050
Demand [TWh]	35	49	62	76	88	99	110	118
VRE Share [%]	0	10	20	30	35	40	45	50

- Objective: Least cost generation expansion plan to meet residual demand over planning horizon

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