High-detail energy system modelling to support VRE technology representation in IAMs

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In order to model variable renewable energy (VRE) integration into the power system, Integrated Assessment Models (IAM) need aggregated information on VRE availability and balancing requirements. We present exemplary applications of the high resolution energy system model REMix designed to support the representation of VRE technologies and integration costs in IAMs.

Linear bottom-up optimization model REMix [1-4]

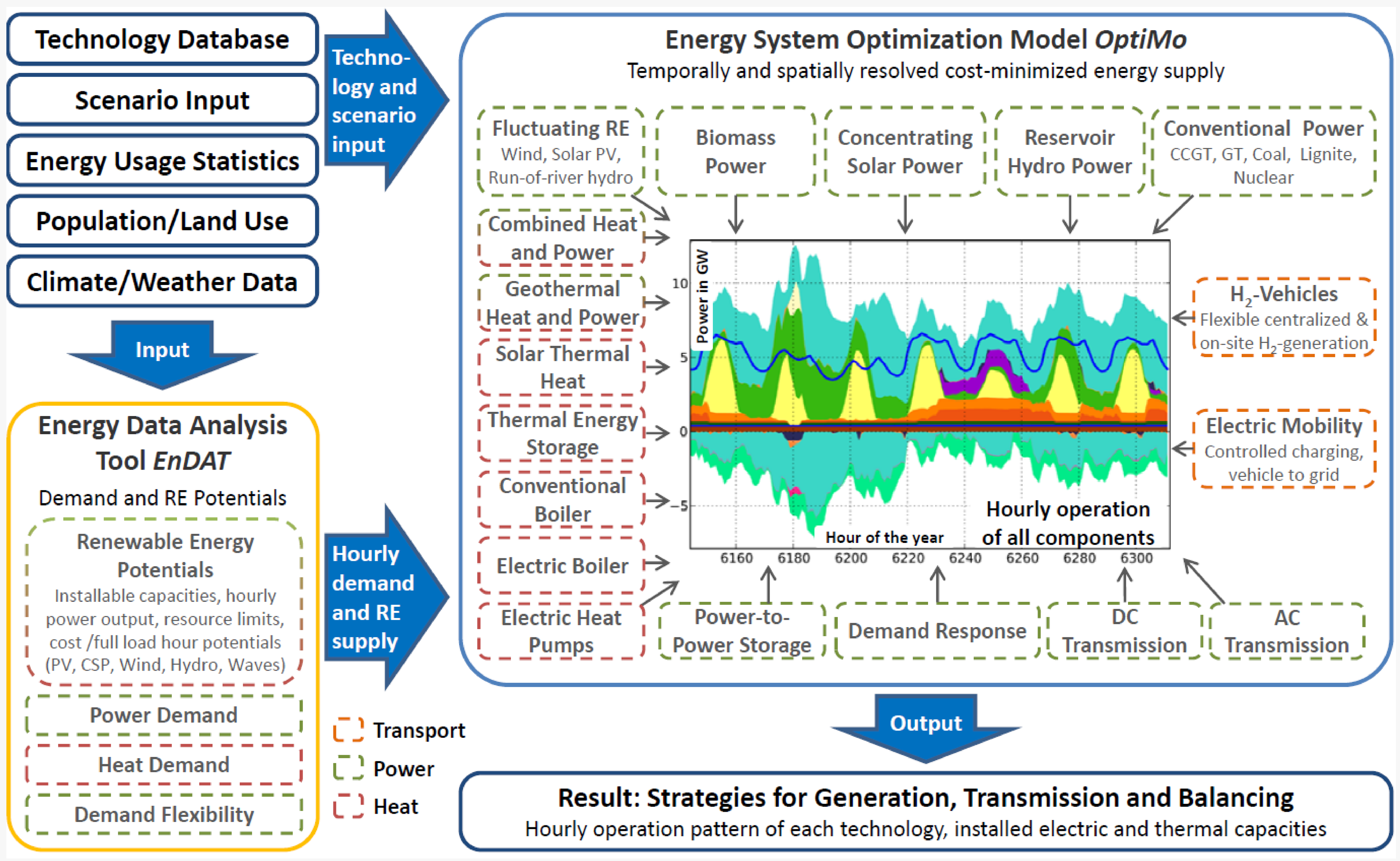

Figure 1: REMix model overview.

- REMix identifies least-cost supply systems and optimizes their hourly operation
- REMix relies on a global high resolution renewable energy resource assessment
- REMix is focused on modelling flexible electric loads in all demand sectors

Case study Demand Response and Thermal Storage

Recent REMix studies [4,6] show that consumer demand response (DR) and thermal energy storage (TES) can reduce VRE integration costs in Germany.

Methodology

Evaluation of 7 scenarios with 85% RE power supply share in the year 2050.

Assessment of the ability of DR and TES to reduce costs and CO_2 emissions.

50Base	**Base Scenario**, peak load 88 GW, annual power demand 522 TWh, VRE capacities in Germany: PV 76 GW, Wind onshore 55 GW, offshore 35 GW
$50H_2T$	**Hydrogen fuel usage**, peak load 91 GW, annual power demand 586 TWh VRE capacities in Germany: PV 80 GW, Wind onshore 62 GW, offshore 37 GW
$50H_2St$	50Base with endogenous capacity expansion of **hydrogen storage**
50Grid	50Base with endogenous capacity expansion of **power transmission** lines
50PV	50Base with **increased PV capacity** of 114 GW, wind offshore reduced to 25 GW
50Wind	50Base with **increased wind onshore capacity** of 83 GW, wind offshore reduced to 19 GW
50CSP	50Base with **dispatchable power import** from CSP plants, VRE capacities in Germany: PV 67 GW, Wind onshore 51 GW, offshore 31 GW

Highlights

- DR and TES are in all scenarios competetive with alternative balancing options
- They are not competing but complementary measures
- In Germany, costs can be reduced by up to 2 billion €, CO_2 emissions by 5 Mt
- DR suited for reducing capacity demand, TES for cutting VRE curtailments

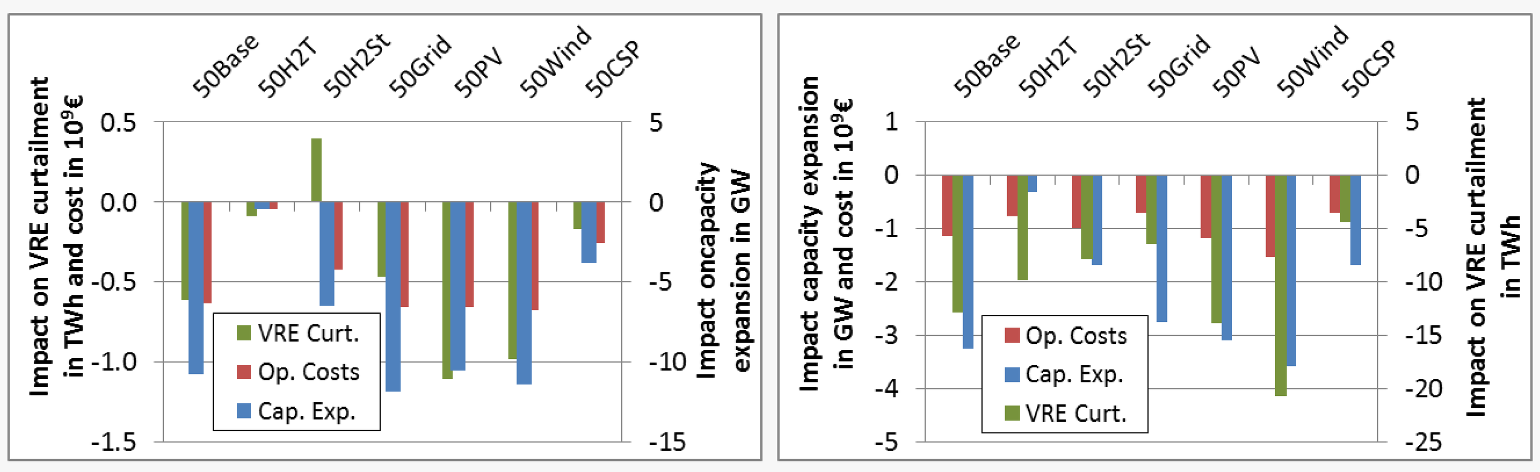

Figure 2: Reductions in cost, curtailment and back-up capacity achieved by DR (left) and TES (right)

Case study VRE Integration Costs in Europe

The research leading to these results has received funding from the European Union's Seventh Framework Programme [FP7/2007-2013] under grant agreement n° 308329

ADVANCE

Methodology

Parametric study of balancing needs associated with VRE penetration and composition in Europe [5], done in the framework of the ADVANCE project

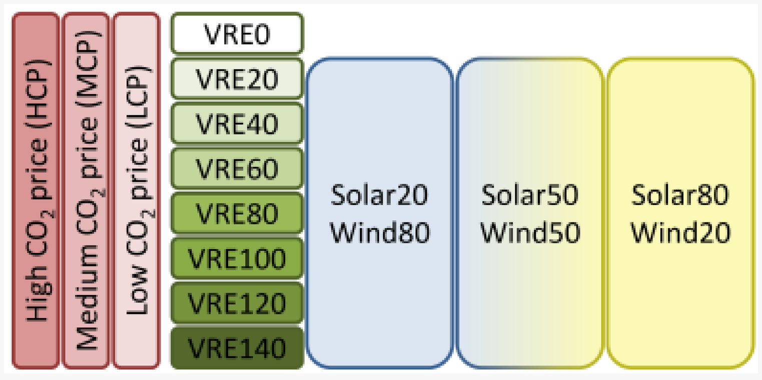

Figure 3: Analyzed scenarios. Numbers indicate corresponding shares in percent of overall supply. VRE shares range between 0% and 140%, solar and wind shares in VRE supply between 20% and 80% each.

- Total system costs are minimized
- Concentrating solar power (CSP) is included in the solar share
- Output: backup capacity and energy, storage and transmission needs, curtailments, emissions, LCOE and integration costs

Results

All results for MCP (medium CO_2 price). LCP and HCP show similar patterns.

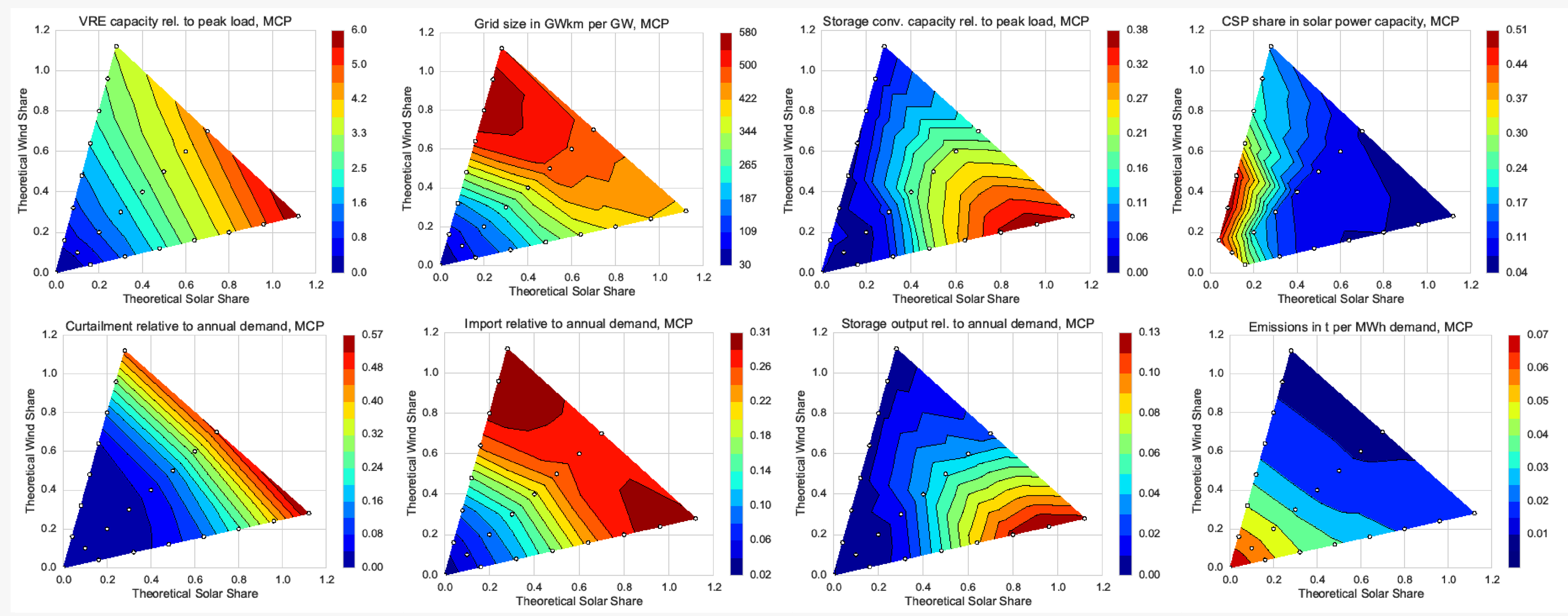

Figure 4: Exemplary results: capacity relative to peak load, energy relative to annual demand.

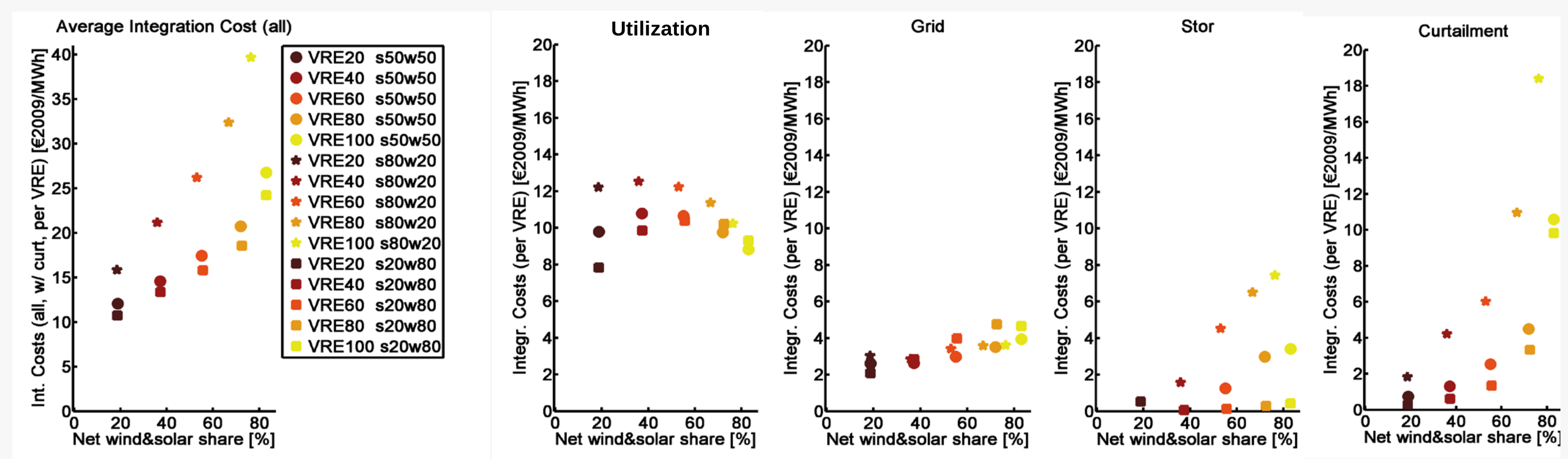

Figure 5: Total average integration costs for the four categories utilization, grid, storage and curtailment. First term in the legend: theoretical VRE share before curtailment; second term: ratio of solar to wind in the theoretical contribution; x-axis: net VRE share after curtailment.

Highlights

- Total VRE capacity of up to 4 x peak load at 100%, 6 x peak load at 140% VRE
- Storage capacity of up to 38% of peak load, especially with high solar shares
- Grid capacity up to 580 $GWkm/GW_{peak}$, higher for wind-dominated systems
- Curtailments < 6% of annual load at 50% VRE and <24% at 100% VRE
- Up to 13% of power delivered to consumers comes from storage units
- Up to 31% of power delivered to consumers is imported
- CSP plant capacity reaches 24 - 152 GW and is limited by available potential
- Least system costs in wind dominated systems
- Least system costs at 40% / 60% / 80% VRE share for LCP / MCP / HCP

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