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The Energy System Development Plan (ESDP)

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Motivation and Objectives

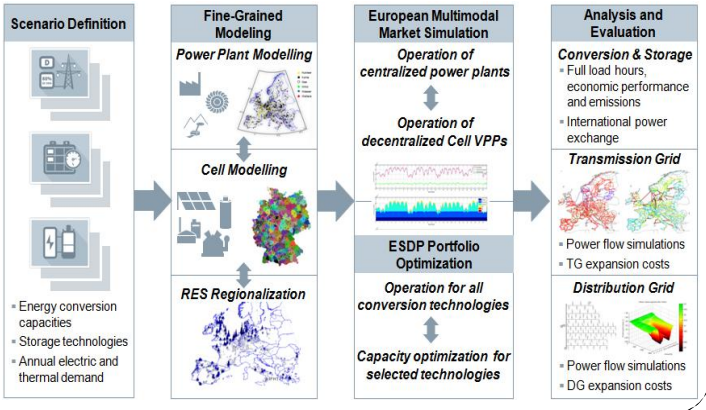
Motivation

- A holistic approach of the electricity, heat and gas sector (multi-modal energy system) leads to affordable and sustainable energy systems with a high penetration of renewable energies
- The increasing number of distributed energy generation and storage units entering the electricity market as part of Virtual Power Plants (VPP) need to be considered in future for a reliable energy supply
- Novel and high performance system modeling (simulation) techniques need to be developed in order to better predict the requirements and penetration for new technologies in future energy systems

Objective and approach

- Objective of the ESDP is to develop a methodology for an integrated assessment and the prediction of realistic multimodal energy systems under different scenarios and regions
- The ESDP introduces the concept of "Energy Cells" in order to take potentially millions of distributed conversion units in the European market into account
- The developed methodology uses a holistic multimodal and Europe-wide market simulation considering centralized and distributed conversion and storage technologies

Methodology Overview



System Modeling

Power Plant Data

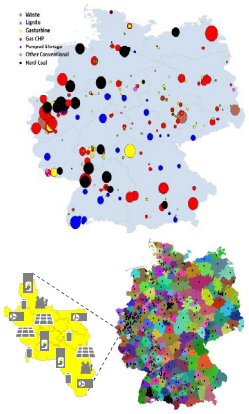
- Power plant (single block) data list with technical and economical parameters for Europe is used
- Regionalization is based on existing power plant locations and planned projects

Regionalization of Renewable Energies and Feed-In Time Series

- Modeling based on consistent meteorological data across Europe as well as potential surfaces and status quo

Cell Modeling

- Database for Distributed Energy Systems (DES) for each residential building, business and industrial site
- Technology-specific aggregation of individual distributed energy systems in regional clusters (Energy Cells)
- Different Cell operation modes with system-wide and local objectives (e.g. self-consumption, peak shaving)

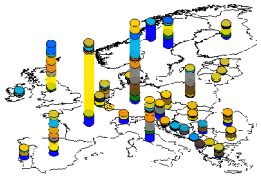


European Multimodal Market Simulation & Portfolio Optimization

- The model is a multi-energy and multi-regional optimization model
- Minimization of total variable system costs using linear programming in the market model:

$$Min \sum_t \sum_i \left(\sum_{pp} P^{PP}_{pp,i,t} \cdot c_{pp,i} - \sum_{p2g} P^{P2G}_{p2g,i,t} \cdot Eff_{p2g,i} \cdot p_{gas,i} + \sum_c \sum_{sc} \sum_{dgs} \dot{Q}^{DGS}_{dgs,sc,c,i,t} \cdot c_{dgs,sc,c,i} \right)$$

- Dispatch calculation of all centralized and distributed conversion and storage units in Europe
- Consideration of multiple opportunities for energy conversion between different energy forms
- Integrated linear network flow model to calculate unrestricted national electricity exchange using NTC (Net Transfer Capacity) approach
- Determination of total system costs, emissions, full-load-hours and primary energy consumption
- Detailed insights in energy flows of the diverse energy carriers are possible
- Portfolio optimization via including fixed costs /CAPEX: $\sum_{pp} Cap_{pp} \cdot c^{inv}_{pp}$



Exemplary Scenarios (operation modes) & Results

- German climate goal scenarios for 2050

Scenario 1.1

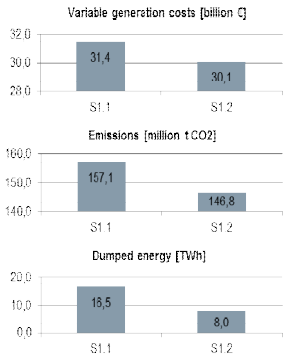
- All heat supplying technologies in the sectors households, CTS and industry are operated in heat driven operation

Scenario 1.2

- All distributed heat supplying technologies are operated in a market driven operation mode
- Central power-to-heat (P2H) units feeding into the district heating networks are installed and simulated at each power plant location

Results

- Variable heat and electricity generation costs for Germany can be reduced by 1.3 billion € (4%)
- Curtailment of renewables is reduced by more than 50% for the considered year (8760h)



Conclusion and Outlook

Conclusion

- Development of a methodology for the simulation and subsequent analysis of multimodal energy systems, modeling electricity, heat, transport and different fuel types
- The model considers energy conversion and storage in centralized and distributed energy systems as well as energy transmission and distribution
- The Energy-Cell approach is introduced as a modeling concept for representing DES in residential, CTS, industrial and transport sector while retaining a regional distinction
- Significant system impact of centralized P2H units in an operation mode controlled by electricity market prices
- Heat and electricity generation costs, emissions and dumped energy can be notably reduced

Outlook

- Analysis of scenarios investigating different technologies, distribution and transmission grid
- Analysis of optimal portfolios and technology consequences
- Taking into account effects of regulatory and micro-economic drivers
- Extension to other regions (US, Asia) and identification of migration paths

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