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# FRAUNHOFER INSTITUTE FOR SOLAR ENERGY SYSTEMS ISE

Energy expansion planning model ENTIGRIS

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# Details on the modelling approach ENTIGRIS

The tool is an **expansion planning model (GAMS software, CPLEX)** which uses a reduced numbers of hours for an hourly economic dispatch in the expansion optimization (LP approach). The number of dispatch hours can be varied depending on the size of the problem.

## Objective:

- Minimizing total system cost which includes new investments plus cost for operation and fuel use (transmission grid, power plants and storages)

## Key variables in the model:

- Capacities of new generation and transmission (including size of CSP-SF and CSP-TES)
- Generation of each hour (which is dispatched by the system)

## Constraints in the optimization:

- Energy balance at each model node (electricity zone)
- Maximum capacities of PP and lines
- Restrictions for potential of new power plants
- Operational constraints (must-run, load change, storage level, reserve capacity etc.)
- Use of natural gas from pipelines
- Targets (such as RES targets)

System cost are optimized for the years 2020, 2025 and 2030.

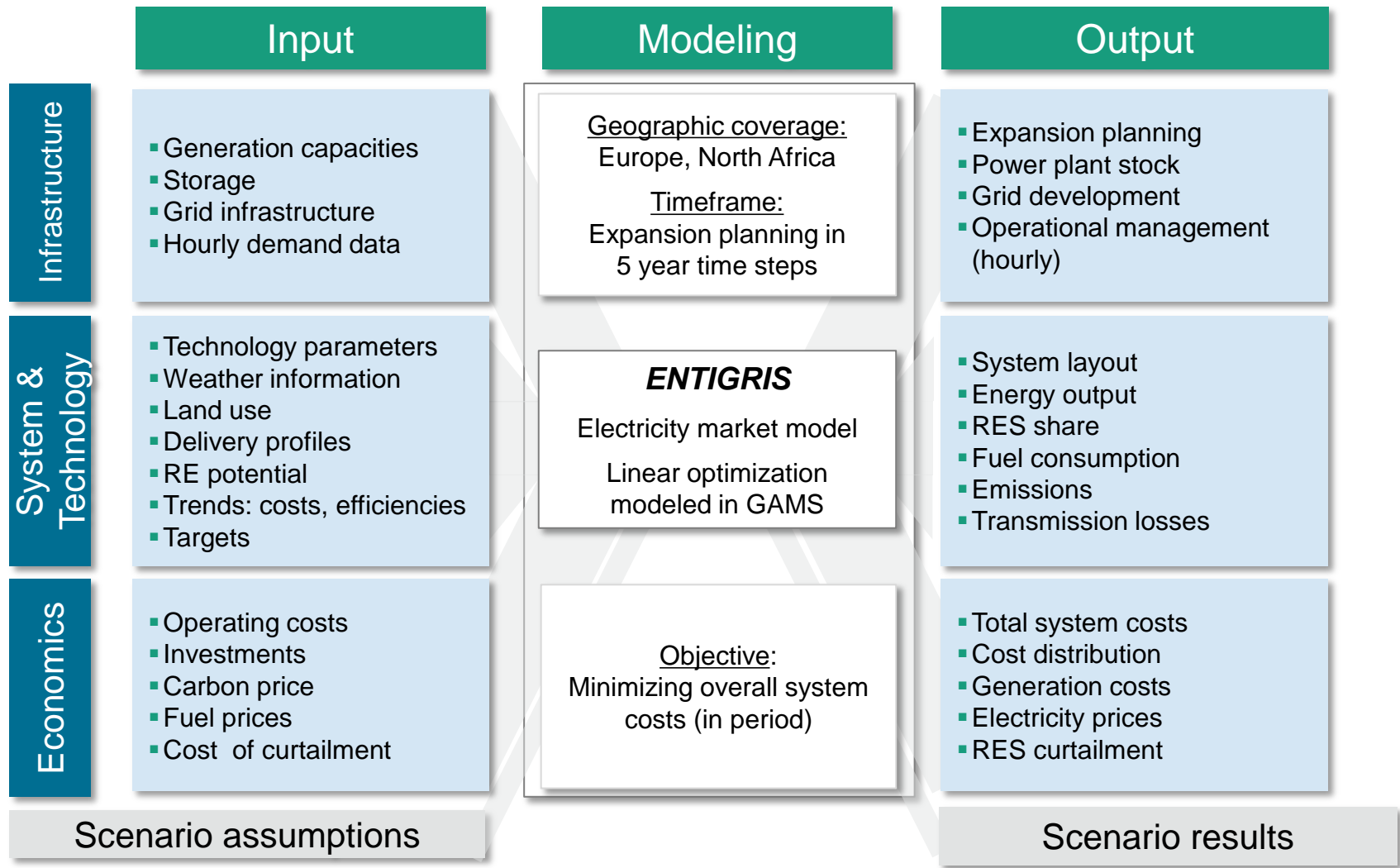
The model uses a deterministic approach with perfect foresight.

# Details on the modeling approach

- Demand is distributed over **electrical zones** in the country. Balance of demand is a key target for each modelled hour. Electricity exchange between zones is possible.
- **Grid capacities** are considered in the expansion planning tool and also optimized.
- **Location** of new technologies are given endogenously based on the optimization.
- **Generation of renewable** is modelled by using weather data from different locations. Potential for new power plants can be limited for each zone.
- Generation of electricity per technology is depending on different technology parameter such as efficiency, installed capacity and operational cost.
- CSP storage sizes can be optimized endogenously. Batteries can be placed everywhere in the system.

# ENTIGRIS

## Overview



# ENTIGRIS-Europe

## Characteristics und References

### Focus

- Electric energy system incl. CHP
- Integration of RES, combination with fossil fuel plants
- Suitable grid extension
- Linking expansion planning and operational management
- Minimization of system costs

### Strengths

- ✓ Linking future grid expansion with power plant development
- ✓ Detailed, integrated German/ European power plant stock
- ✓ RES potential integrated using Europe-wide GIS analysis
- ✓ 27 grid areas modeled in Germany

#### *References and publications:*

- *Kost, C.; Junne, T.; Senkpiel, C.; Hartmann, N.; Schlegl, T.; Zampara, M.; Capros, P. (2015): Renewable Energy Expansion and Interaction in Europe: High Resolution Modeling of Germany and Greece. 12th International Conference of the European Energy Market 2015 20.05.2015-22.05.2015 in Lisboa.*
- *Kost, C. (2015). Renewable energy in North Africa: Modeling of future electricity scenarios and the impact on manufacturing and employment. Dissertation, Universität Dresden.*

# ENTIGRIS-Europe

## Application – RES-DEGREE project

Challenge: Optimization of the electric energy system in GER & Greece

GER & GR

RES & conv.  
Grid extension  
High level of detail  
27+8 knots

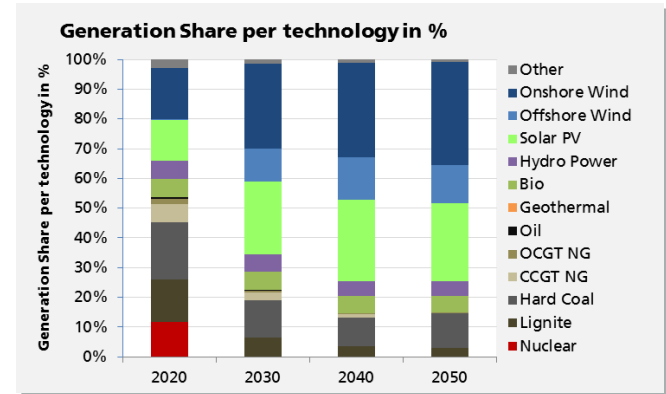
Grid

EU

RES potentials: PV,  
wind, biomass  
Interconnectors  
CO<sub>2</sub> targets

Analysis of  
different  
scenarios  
targeting 2050

**Objective:**  
assessment of  
electricity  
exchange, opt.  
utilization of RE  
and fossil fuel  
plants



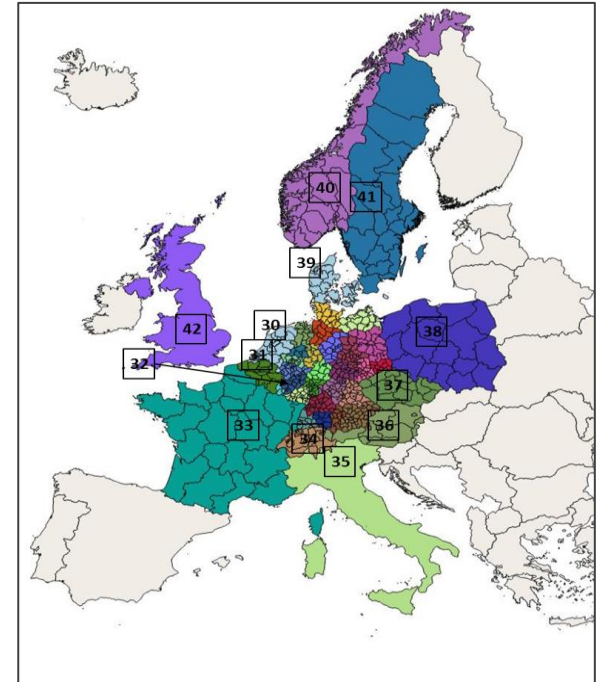
- Recommendations on national and international level
- Action plan
- Implementation strategy

RES-DEGREE project: Towards an Energy System in Europe Based on Renewables,  
Duration: 01.01.2014 - 30.11.2015, German Federal Ministry of Economics and Technology BMWi

# ENTIGRIS-Europe

## Motivation and Challenges

- Integration of renewable energy sources
- Volatile electricity generation increasing
- Large extension of power plant capacities and transmission grid required
- Activation of unused market flexibilities
- **Analysis of the European electricity system focusing 2050 needed**



Modeling the German, European and North African electric energy system for a profound analysis of the future development and affordable expansion

# Thank you for your attention!



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