Energy models as tools for advanced local energy planning

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Agenda

- The energy model TIMES
- The TIMES area model
- Exemplary results
The energy model TIMES
The TIMES area model
Exemplary results
ETSAP

IEA (International Energy Agency)

Implementing Agreements

Energy Technology Systems Analysis Programme (ETSAP)

Technology oriented analysis of energy systems:
- Analysis of national and multinational long-term strategies in the context of economic and sustainable energy supply
- Assessment of perspective of energy technologies
- Technology data review
- Model development (MARKAL, TIMES)

Project Head: GC Tosato

www.etsap.org

Outreach
POLYCITY Workshop February 2/3 in Basel

Features
- Inter-temporal / Long-term
- Flexibility
- Multi-Regions / High spatial resolution
- Elastic demands
- Vintaging
- Load curve
- Endogeneous (technological) learning
- Macro-economic linkage
- Discrete capacity expansion
- Climate extension

Methodology
- Bottom-up Model
- Perfect competition
- Perfect foresight
- Optimisation (LP)

Min/Max Objective function
Equations, User Constraints
Decision Variables $<=$ Solution
Input parameters

Development
- By ETSAP
- Implementation in GAMS
- Model generator

TIMES
The Integrated MARKAL EFOM System

Applications of the model
- IER:
  - Ostfildern
  - Baden-Württemberg, Bavaria, Saxonia, Hessen
  - Germany
  - European electricity and gas sector
  - World
- Other places:
  - Finland (VTT, Helsinki)
  - Belgium (KUL, Leuven)
  - Italy (Turin)
  - EU-NEEDS project
  - Global model (IPP, Munich; GERAD, Canada)
  - South Africa model, Village model (ERC, Cape Town)
TIMES

RES

Specification

Modeling steps

Model management / data input in ANSWER

Analysis of results in VEDA (Versatile Data Analyst)

Solving (General Algebraic Model Structure and solver)

Scenarios
Results of TIMES

- Optimal structure of the system (supply, distribution and demand)
  - by minimizing the total system costs,
  - under consideration of the energetic framework (biomass / energy supply and demand),
  - with simultaneous balancing of the environmental impacts.

- Cost/Benefit analysis for heat/cold and electricity generation.

- Determining of policies and measures by carrying out scenario analysis and sensitivity analysis.

- Comparison of the results with benchmark values and/or with similar situations in other European cities.
Cost-Potential-Curve of different measures in an integrated manner
The energy model TIMES
The TIMES area model
Exemplary results
The TIMES area model

Supply

Existing plants

extension

New

Energy prices

Electricity prices

§, Law, Rules

Investment Costs:

Operating Costs:

Application (IER)
- Baden-Wuerttemberg
- Citymodel – AGFW

Energy prices

Viability

Existing

New

Saving

§, Law, Rules

Industry
Construction of the model topology –

Heat demand density 65.96 GWh/km²
Heat capacity density 38.8 MW/km²
Total area 22.5 ha
Determination of the heat supply of an area at optimal costs

Optimization problem
(Separable Mixed Integer Programming)

Total costs = Sum of the costs (Generation + Distribution + consumer devices) = Minimum
The energy model TIMES
The TIMES area model
Exemplary results
Exemplary results of the area model

district heat (existing)
potential of district heat
potential of local heat
ST0 stand-alone single building
ST1 scattering settlement
ST2 single and double family houses
ST3a urban village core
ST4 terraced houses
ST5a small apartment buildings
ST5b big and small apartment buildings
ST6 multi-story building
ST8 city housing
ST10b public special buildings
ST11a service buildings
ST12 other supply areas
Comparison of the specific heat generation costs

Settlement Type 1  Settlement Type 2  Settlement Type 3  Settlement Type 4
- DH generation
- DH domestic installation
- DH distribution by extension
- DH distribution + thermal insulation
- Light fuel oil
- DH distribution
- DH generation electricity credits
- DH distribution reduction of construction costs
- DH domestic installation + thermal insulation
- Light fuel oil + thermal insulation
Scenario analysis of the net electricity generation

Net electricity generation in [TWh]


Scenario: soft landing + renewable

Scenario: soft landing
Synopsis
Synopsis

For integrated planning the energy model TIMES can play an essential role for the advanced local energy planning to...

- provide a consistent long-term sustainable energy plan that analyses the behaviour of the entire energy system.
- see the implications of current decisions in future.
- find among different alternatives the way which satisfies best to the market allocation of limited resources by considering different exogenous constraints and decision criteria.
- assess the overall energetic, economic and environmental effects and results of the municipality performance.
- show the conflict potential of different goals and objectives.
- develop an overall energy and sustainability strategy.
- cost-benefit analysis.
Thank you for your attention
POLYCITY Workshop February 2/3 in Basel
TIMES development

- Limited subannual resolution
- Changing time horizon
+ Flexible process description

- Dummy processes
- Changing time horizon

+ Flexible RES description
Subdivisions of the year
Regions
+ Modularity
+ Expanding application areas
+ Prepare for ongoing research
The Reference Energy System (RES)
Features of TIMES

1) Flexible Process description

2) Flexibility in time

- Model horizon
- Period 1 Period 2 Period 3 Period 4
- Seasons
- Weekly
- Daynites
Flexibility in time

- Variable period length and unlimited # of periods
- Easy shifting of model horizon
- Timeslice tree with three sub-levels
- User-defined time-segment resolution for commodities and processes
- Inheritance and aggregation of parameters along the tree
- Time-slice storage as well as inter-period storage
- Load curve
User constraints and Inter-regional exchange

Flexible frame work to define problem-specific constraints:

\[ \sum_{p=\text{coal plant}} \sum_{c=\text{cost}} \text{VAR}_FLO(r, v, t, p, c, s) \leq \text{upper_bound} \]

Process between two internal regions similar to import/export process
Characteristics of the TIMES area model

Objective function:
Integration over time
(Minimization of the total system costs)

Cost functions:
- Variable and fixed operation costs, taxes
- Credits (e.g. electricity credits, feed in tariffs)
- Investment (Consideration of the cost degression),
- Distinction between lifetime and amortization period
- Different interest rates (Households, industry, utilities)

Energy and demand balances:
- Transformation balances
- Separate demand balances for generation, distribution and consumption
- Consideration of losses
- Storage

Temporal resolution:
Variable (Duration curves, load curves, type days, periods)

Spatial resolution:
Variable (Single building, streets or settlements)
Regionalization within POLYCITY

Central Power Generation-Sector

Electricity

District heat

Region 1

Main Distr. 1

Middle Dis. 1

Region 2

Main Distr. 2

Middle Dis. 2

Traffic sector for all regions?

Gas-CC

Gas Boiler

Biomass CHP

Gas-CC

Solar thermal

Transport 1

Transport 2

Transport 1

Transport 2

District heat

SFH to 1958

MFH to 1958

Compression

Expansion

Existing

Demands

Parksiedlung

Ruit

Scharnhauser Park

Scharnhausen

Kemnat

Nellingen
Calculation
- specific Heat demand
- specific Heat Peak
- specific Heat production costs (decentralized)
- Heat price
- ...
Vergleich der spezifischen Wärmegestehungskosten

Spez. Wärmegestehungskosten in [Cent/kWh]

<table>
<thead>
<tr>
<th>Siedlung Reihenhäuser</th>
<th>Siedlung kleiner neuerer Mehrfamilienhäuser</th>
<th>Neubau Reihenhaussiedlung</th>
<th>Neubau Kleiner Mehrfamilienhaussiedlung</th>
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<td>NW-Erzeugung</td>
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Legende:
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