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POLYCITY Workshop February 2/3 in Basel

# Energy models as tools for advanced local energy planning

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## **Agenda**

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



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- **The energy model TIMES**
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**ETSAP**

**IEA (International Energy Agency)**

**Implementing Agreements**

***Energy Technology Systems Analysis Programme (ETSAP)***



**Project Head:  
GC Tosato**



**www.etsap.org**

**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)



**Outreach**





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# TIMES

### *Development*

- By ETSAP
- Implementation in GAMS
- Model generator

### *Methodology*

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

### *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

*The Integrated MARKAL EFOM System*

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

### *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



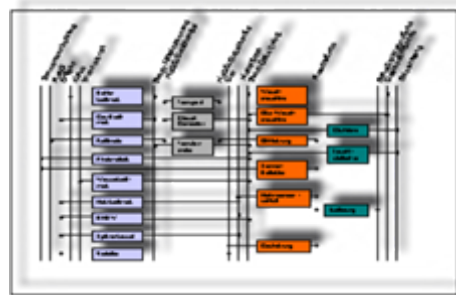
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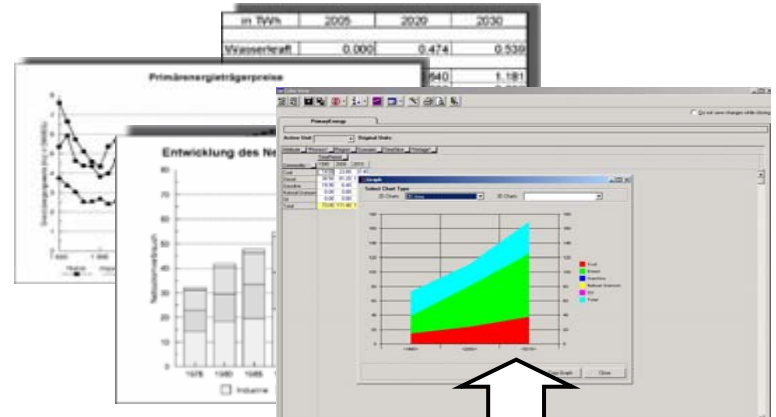
### TIMES



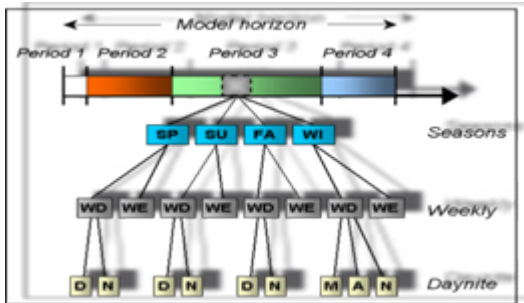
RES



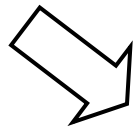
### Analysis of results in VEDA (Versatile Data Analyst)



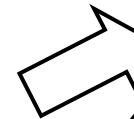
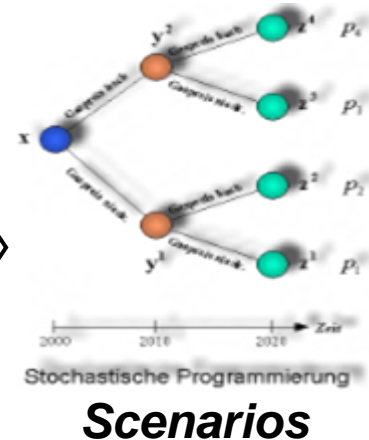
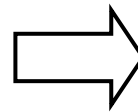
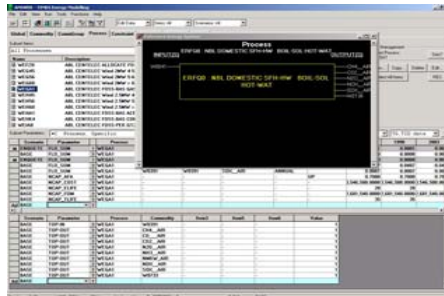
### Specification



### Modeling steps



### Model management / data input in ANSWER



### Solving (General Algebraic Model Structure and solver)



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## Results of TIMES

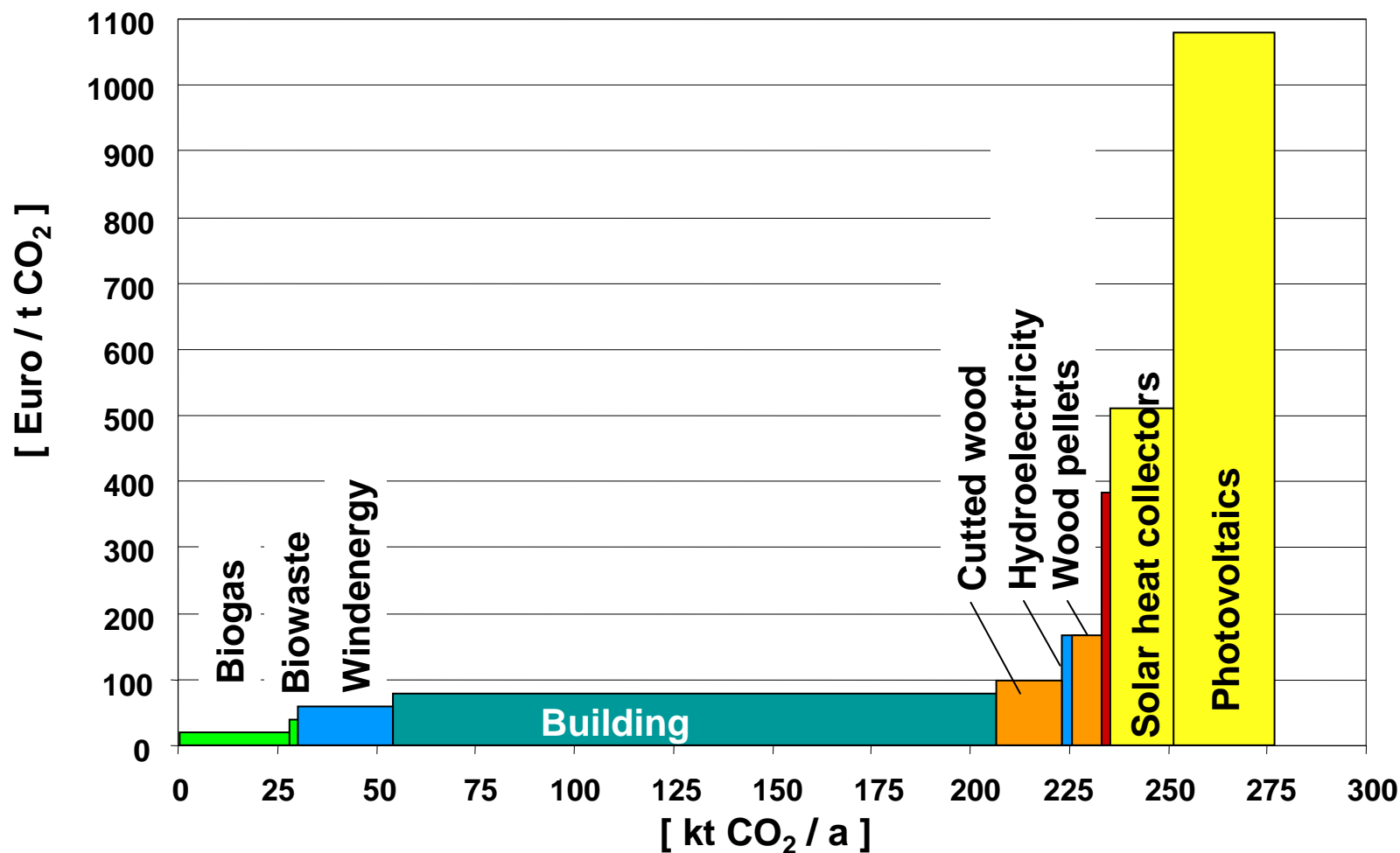
- Optimal structure of the system (supply, distribution and demand)
  - by minimizing the total system costs,
  - under consideration of the energetic framework (biomass / energy supply and demand),
  - with simultaneous balancing of the environmental impacts.
- Cost/Benefit analysis for heat/cold and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



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# Cost-Potential-Curve of different measures in an integrated manner





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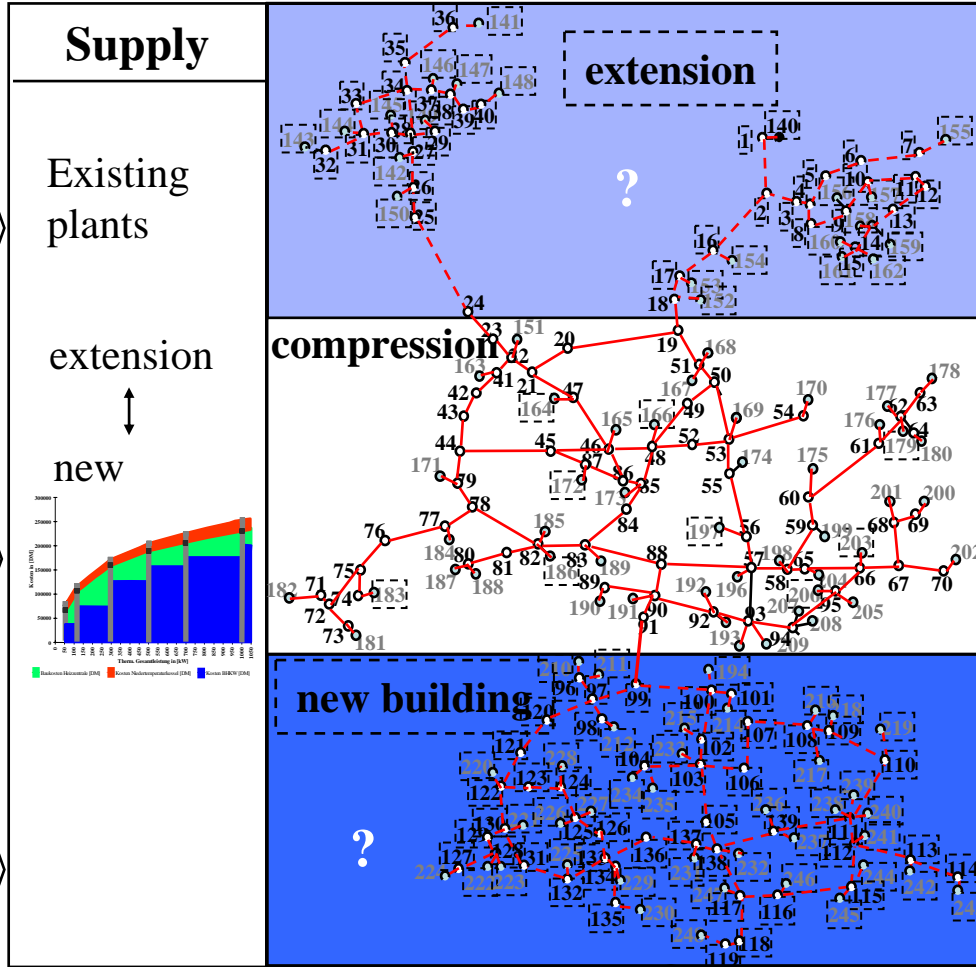
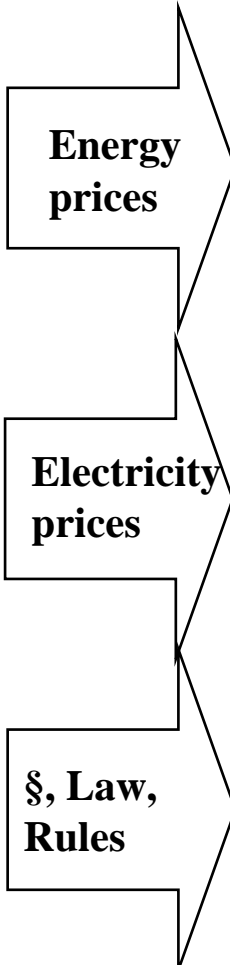
- The energy model TIMES
- **The TIMES area model**
- Exemplary results



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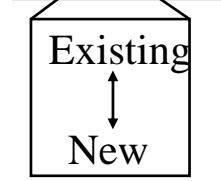
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### The TIMES area model

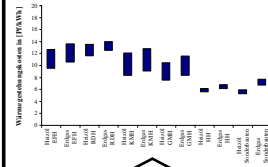


**Application (IER)**

- Baden-Wuerttemberg
- Citymodel – AGFW



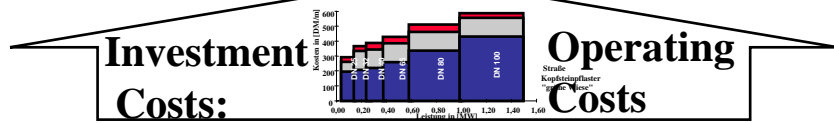
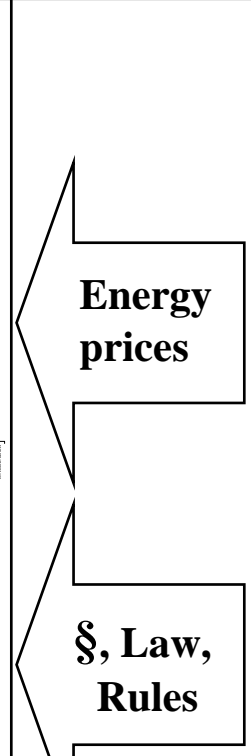
Viability



Saving



Industry



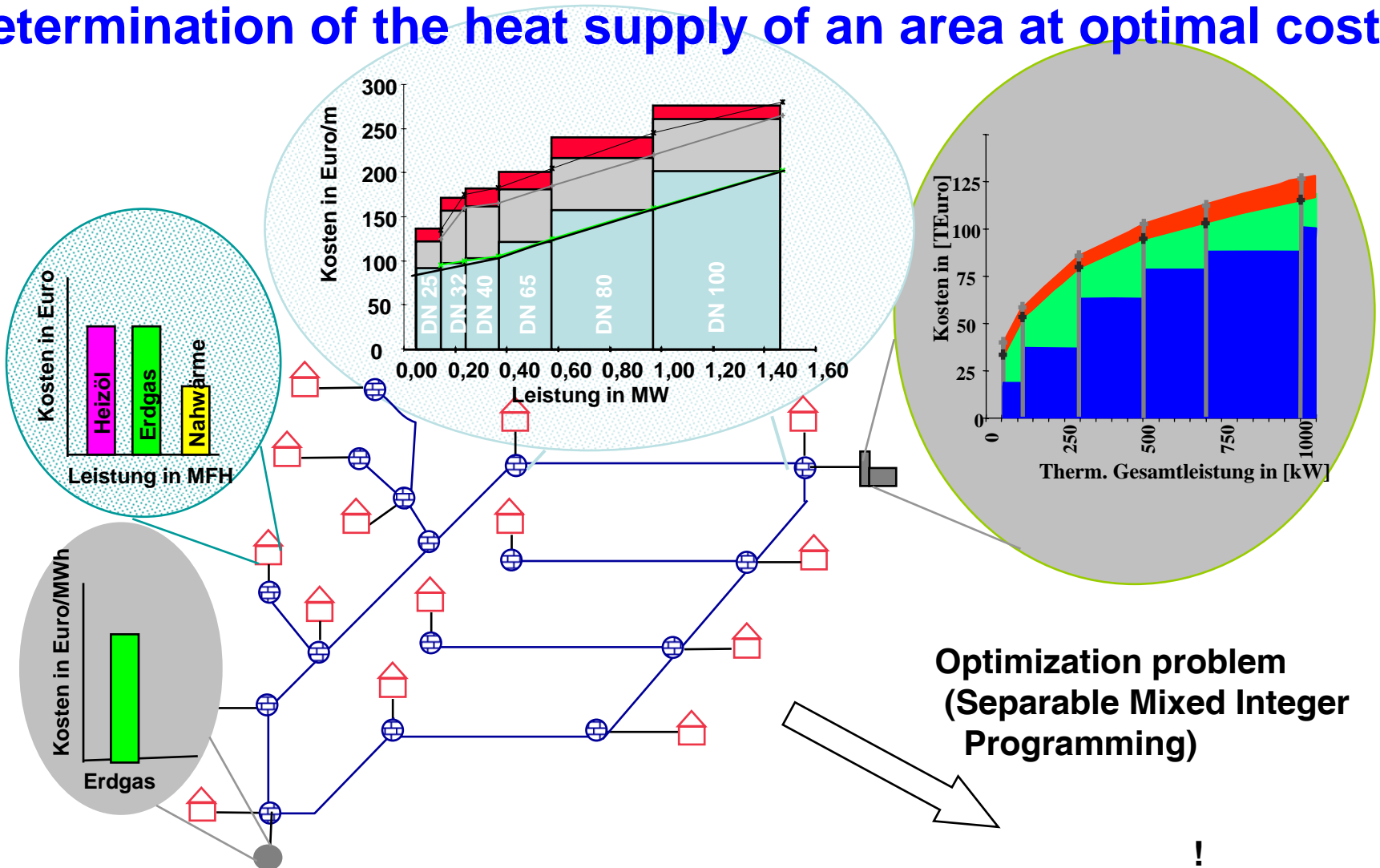




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# Determination of the heat supply of an area at optimal costs



**Optimization problem  
(Separable Mixed Integer  
Programming)**

!

**Total costs = Sum of the costs (Generation + Distribution + consumer devices) = Minimum**



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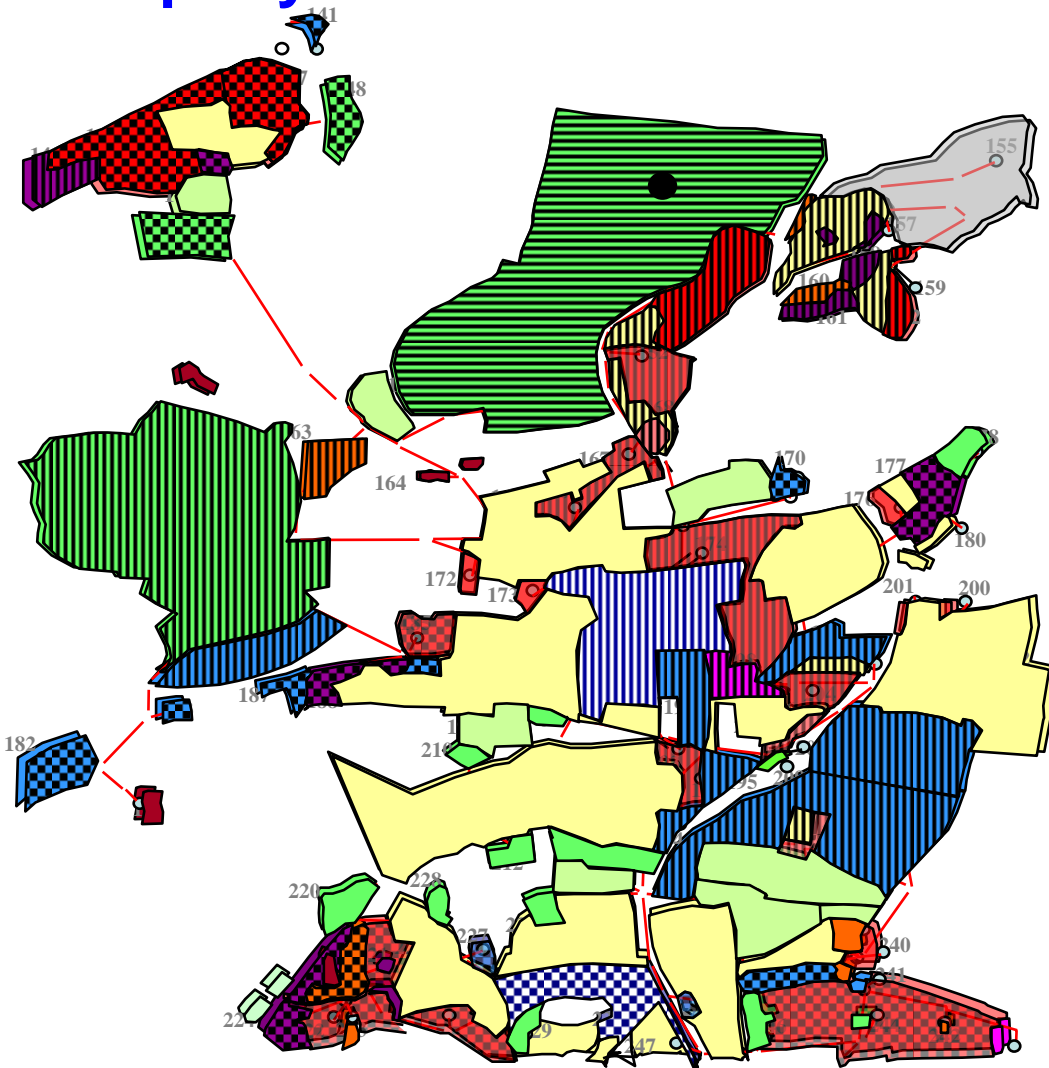
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









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



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## Exemplary results of the area model

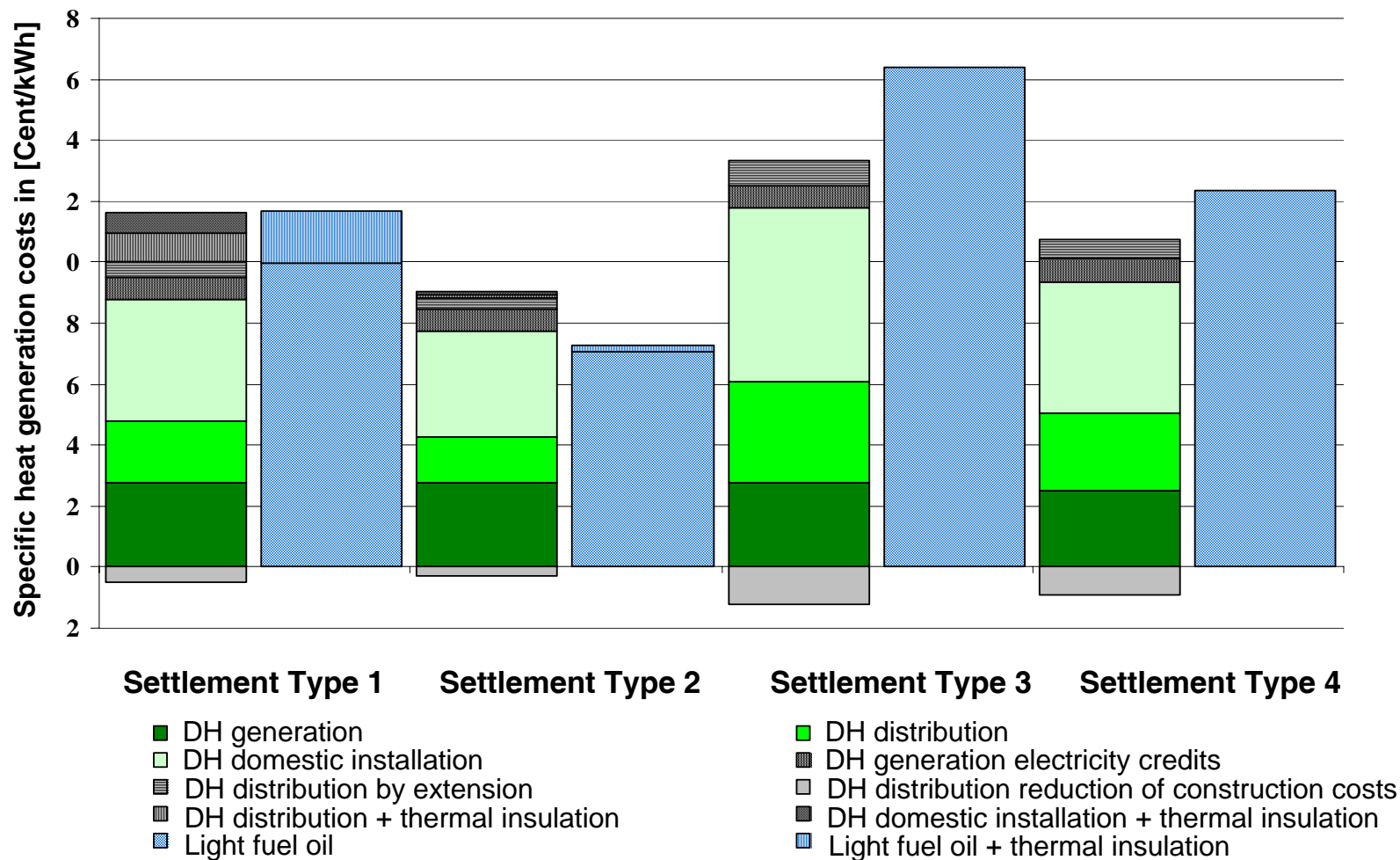


-  district heat (existing)
-  potential of district heat
-  potential of local heat
-  ST0 stand-alone single building
-  ST1 scattering settlement
-  ST2 single and double family houses
-  ST3a urban village core
-  ST4 terraced houses
-  ST5a small apartment buildings
-  ST5b big and small apartment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



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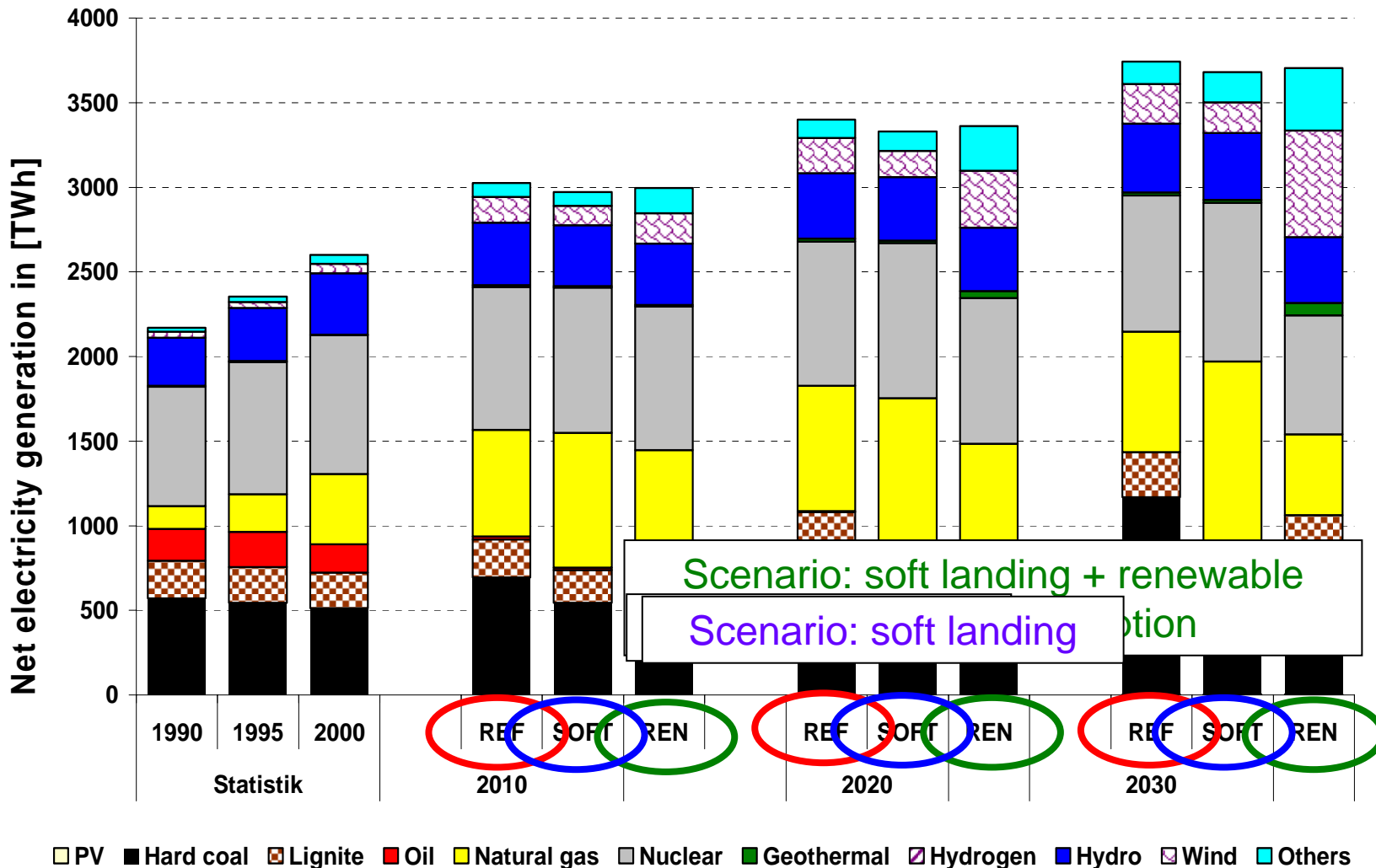
## Comparison of the specific heat generation costs





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## Scenario analysis of the net electricity generation





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## **Synopsis**



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### 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**



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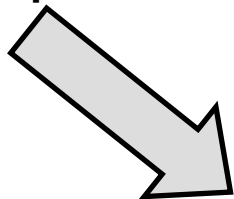
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## TIMES development

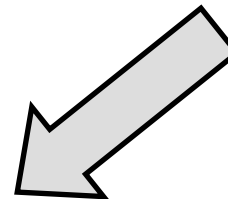
**EFOM-ENV**

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



**MARKAL**

- Dummy processes
- Changing time horizon



**TIMES**

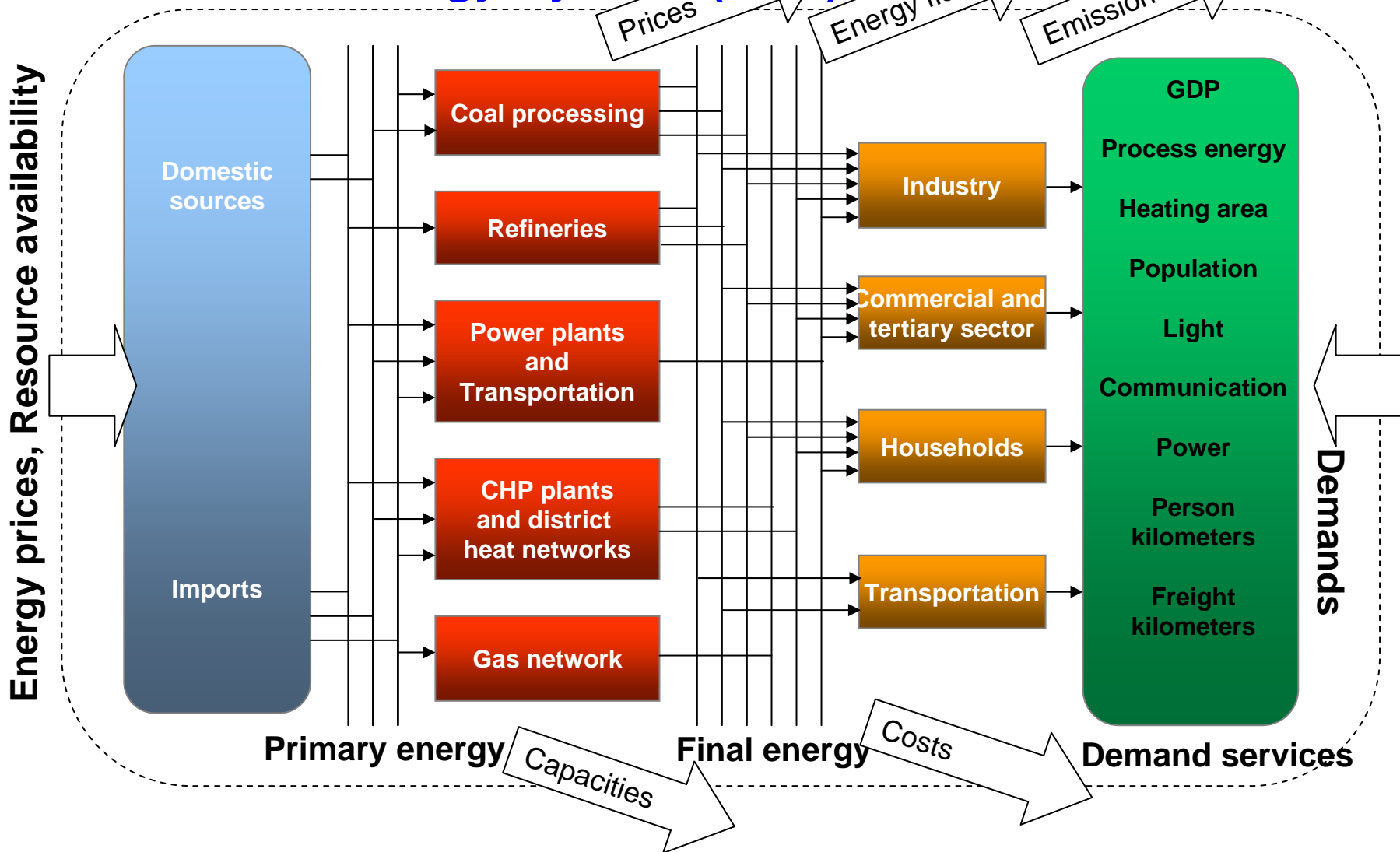
- + Flexible RES description
  - Subdivisions of the year
  - Regions
- + Modularity
- + Expanding application areas
- + Prepare for ongoing research



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# The Reference Energy System (RES)



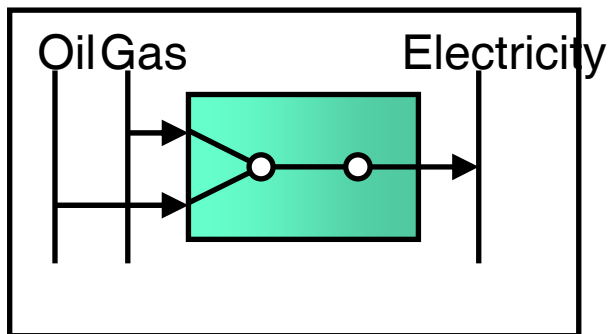


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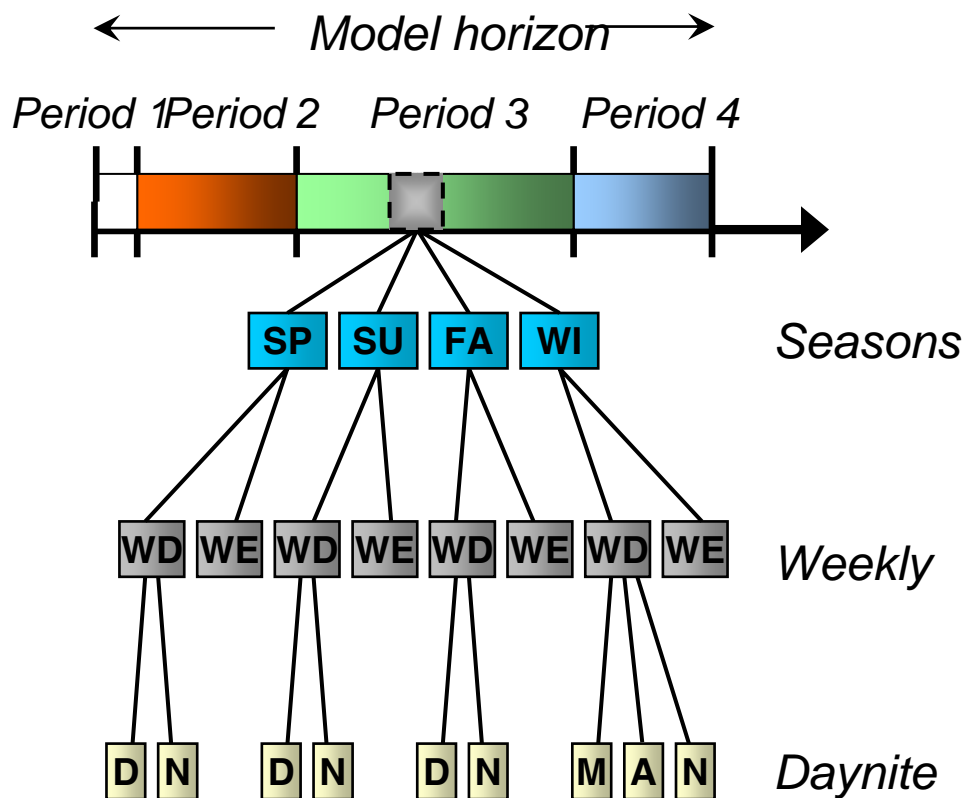
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# Features of TIMES

## 1) Flexible Process description



## 2) Flexibility in time

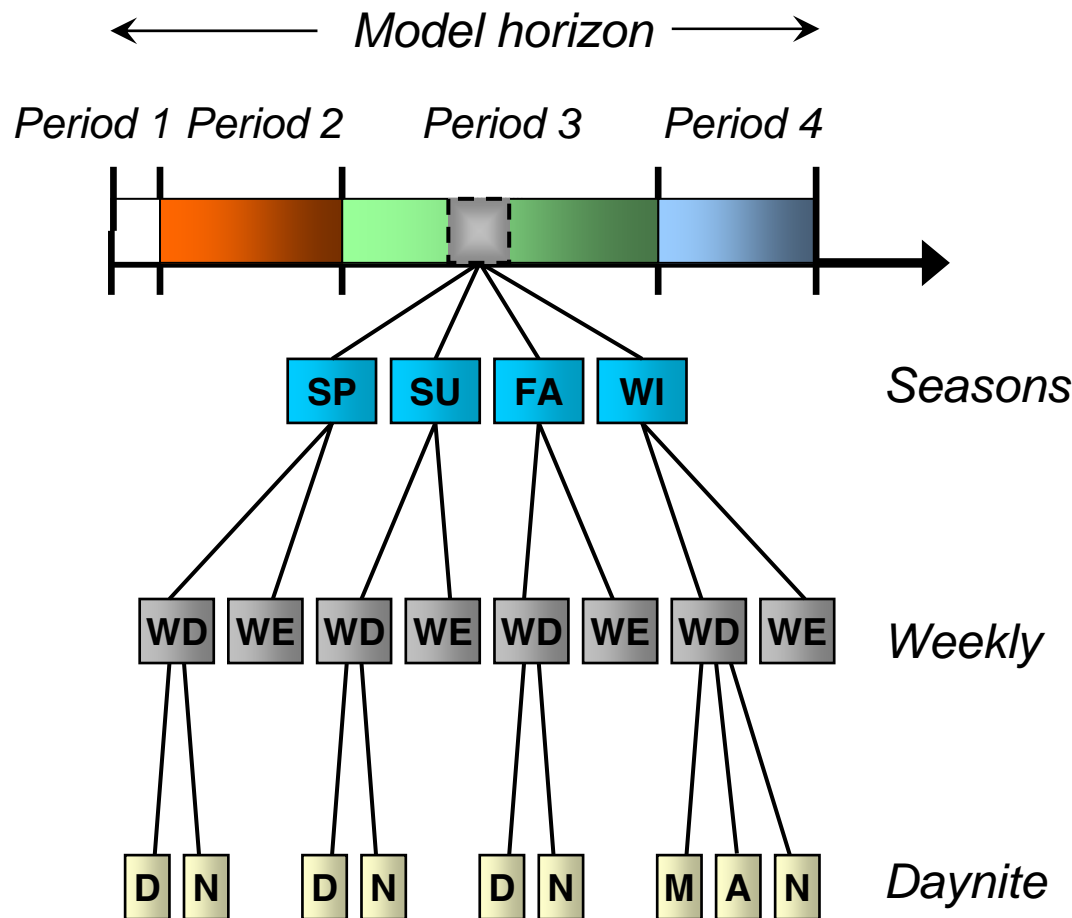




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# Flexibility in time



- 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

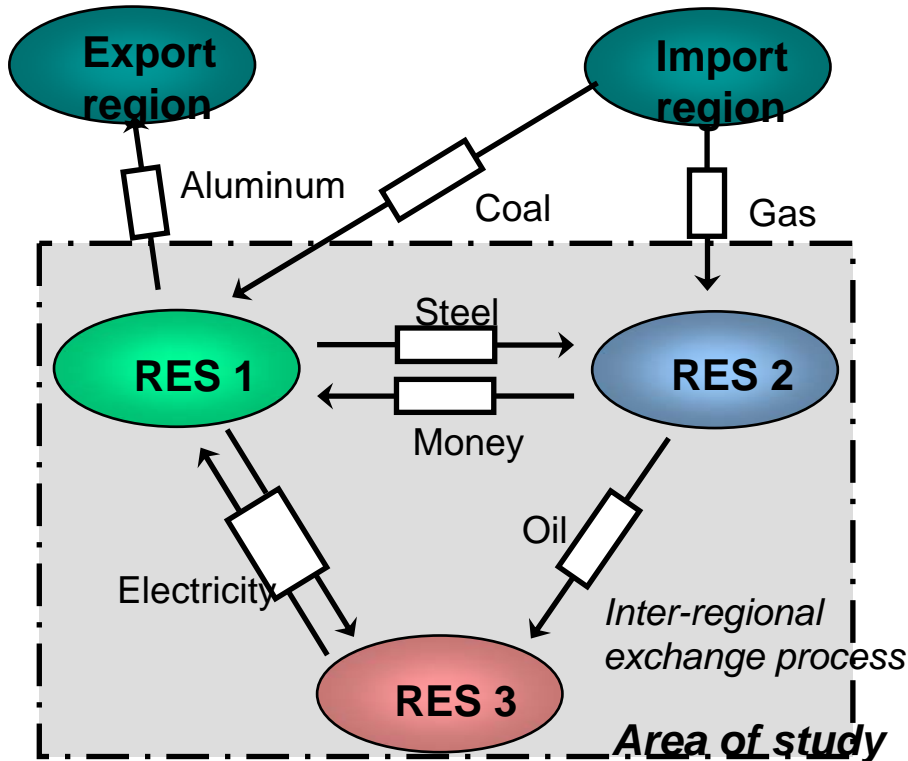


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## User constraints and Inter-regional exchange

Flexible frame work to define problem-specific constraints:

$$\sum_{p=\text{coal plant } c=\text{cosl}} \sum VAR\_FLO(r, v, t, p, c, s) \leq \text{upper\_bound}$$



Process between two internal regions similar to import/export process



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# 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)

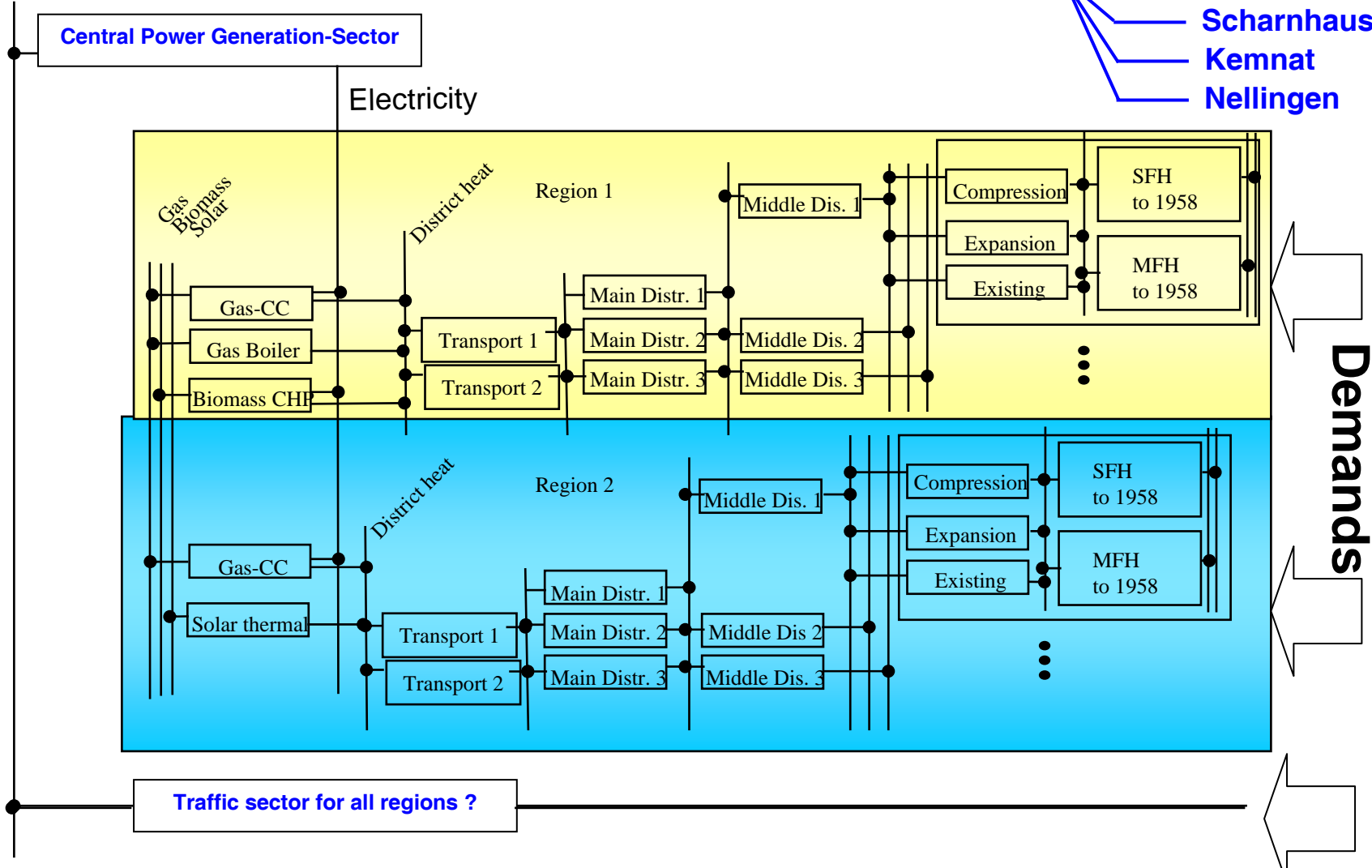


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# Regionalization within POLYCITY

- Parksiedlung
- Ruit
- Scharnhäuser Park
- Scharnhäuser
- Kemnat
- Nellingen





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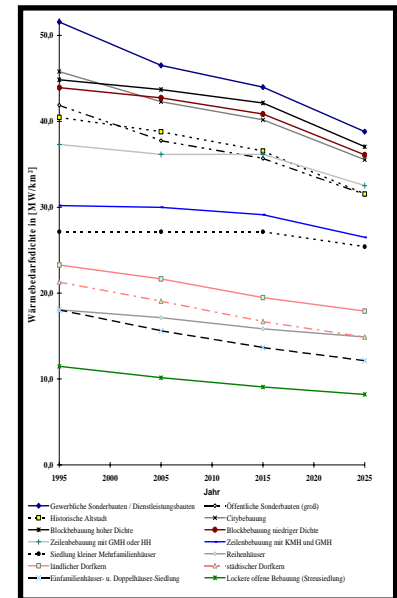
Major Cities & City Regions
Outskirts of City Areas
Medium Size towns
Communities > 2000 Living-units in MFH in towns up to 50.000 inhabitants
Medium / Large cities more than 50.001 inhabitants
Rural area

### Calculation

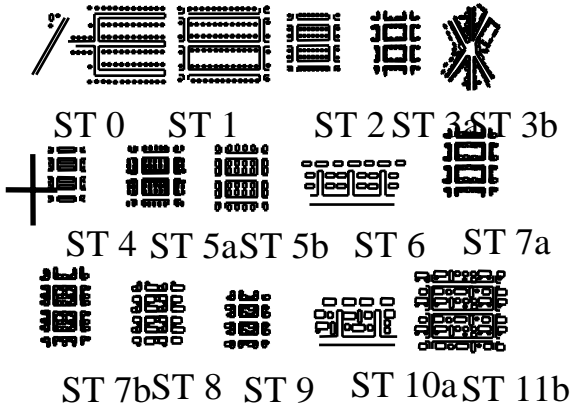
- specific Heat demand
- specific Heat Peak
- specific Heat production costs (decentralized)
- Heat price
- ...

**Building classes**

	1-Familienhaus	Petite n-doppelhaus	Mittlere n-Familienhaus (bis 6 WE)	Größere n-Familienhaus (bis 12 WE)	Hochhaus / Blockbau
Baujahr					
bis 1918	212,0		180,0	181,1	-
1918-18	201,1	118,3	161,5	181,9	-
1919-51	260,3	212,9	139,3	169,5	-
1952-68	163,5	202,3	190,9	111,2	112,6
1969-18	110,2	191,0	169,1	152,1	117,3
1919-83	165,5	111,1	125,2	115,0	-
1984-91	135,1	129,1	101,1	95,1	-
ab 1995	101,3	89,2	93,1	12,0	-



### Types of settlements





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### Vergleich der spezifischen Wärmegestehungskosten

