EIGHTH GOVERNMENT BUILDING ENERGY EFFICIENT TECHNOLOGY WORKSHOP
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Energy Systems Optimization Tool with Linköping University

Swedish case studies

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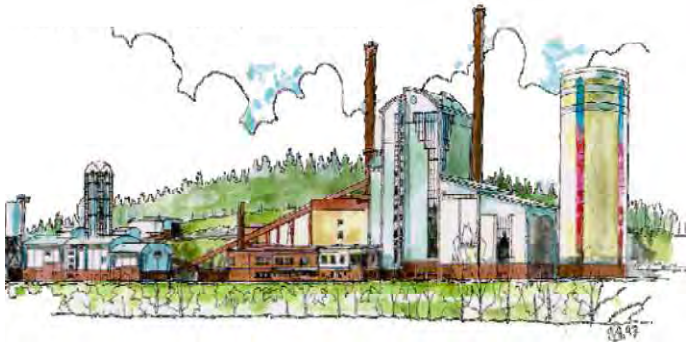
Definition of Energy Systems

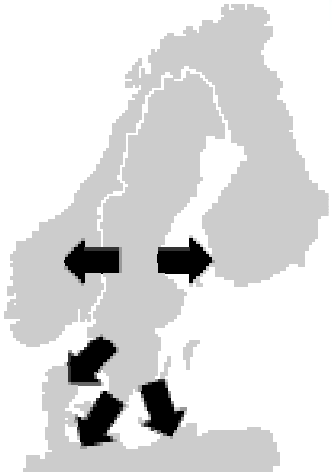
Energy systems consist of **technical artefacts** and processes as well as actors, organizations and institutions which are linked together in the **conversion**, **transmission**, **management** and **utilization** of energy.

The view of energy as a **Socio-technical** system implies that also **knowledge**, **practices** and **values** must be taken into account to understand the on-going operations and processes of change in such systems.

Levels of the Energy Systems

- Global energy systems
- National energy systems
- Regional energy systems
- Local energy systems
- Industrial energy systems
- Building as an energy system



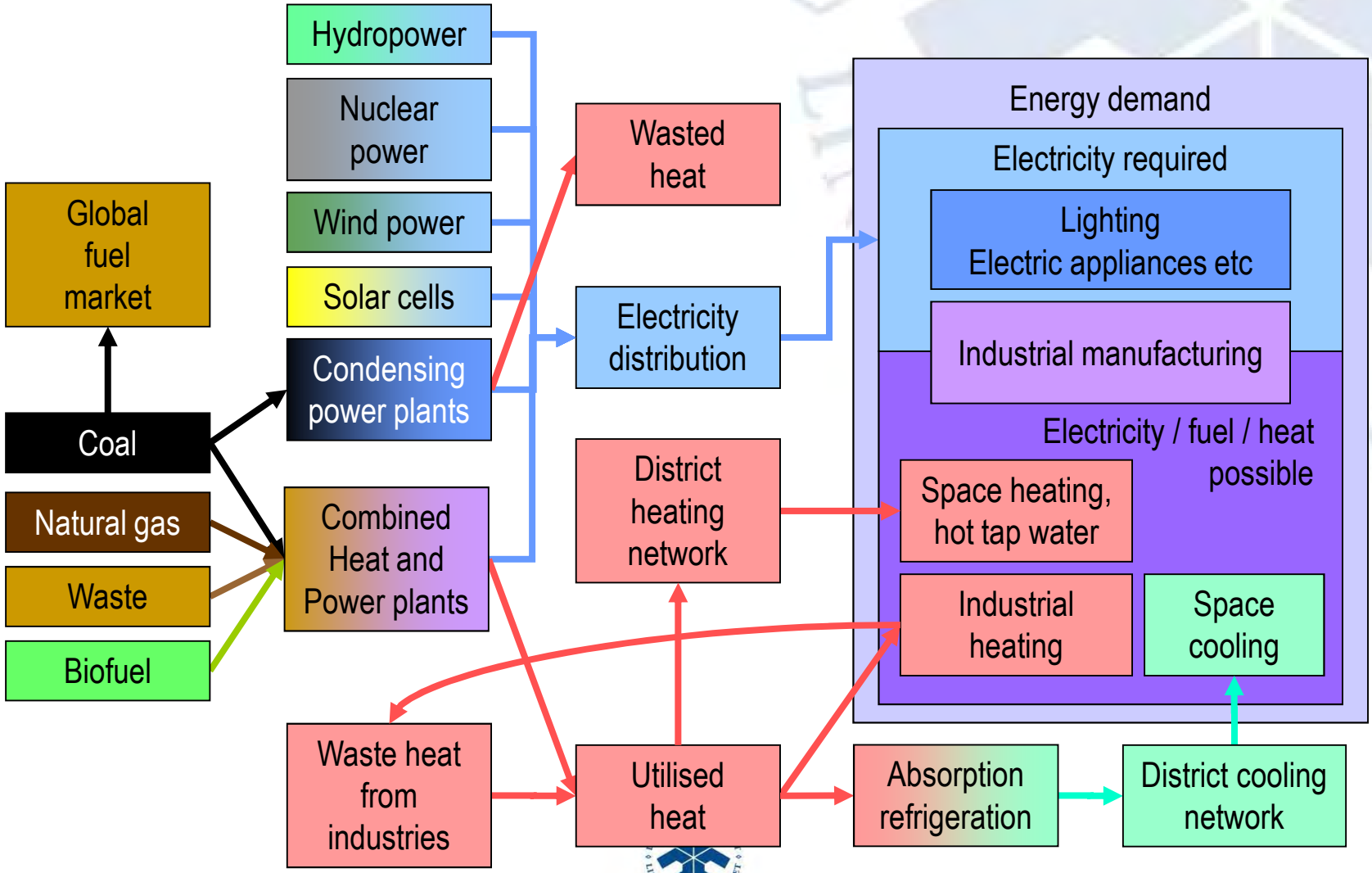


Sources, transport, resources, distribution, history-future, policy, rules, etc.

Energy Systems Analysis

Interplay and optimisation of energy supply, use and conservation

Many possibilities to satisfy energy demand



Enhanced coal utilisation

- Increasing energy demand
  makes coal more valuable.

- Better to use coal in an efficient CHP plant
  that uses the heat than
  in a condensing plant that wastes the heat

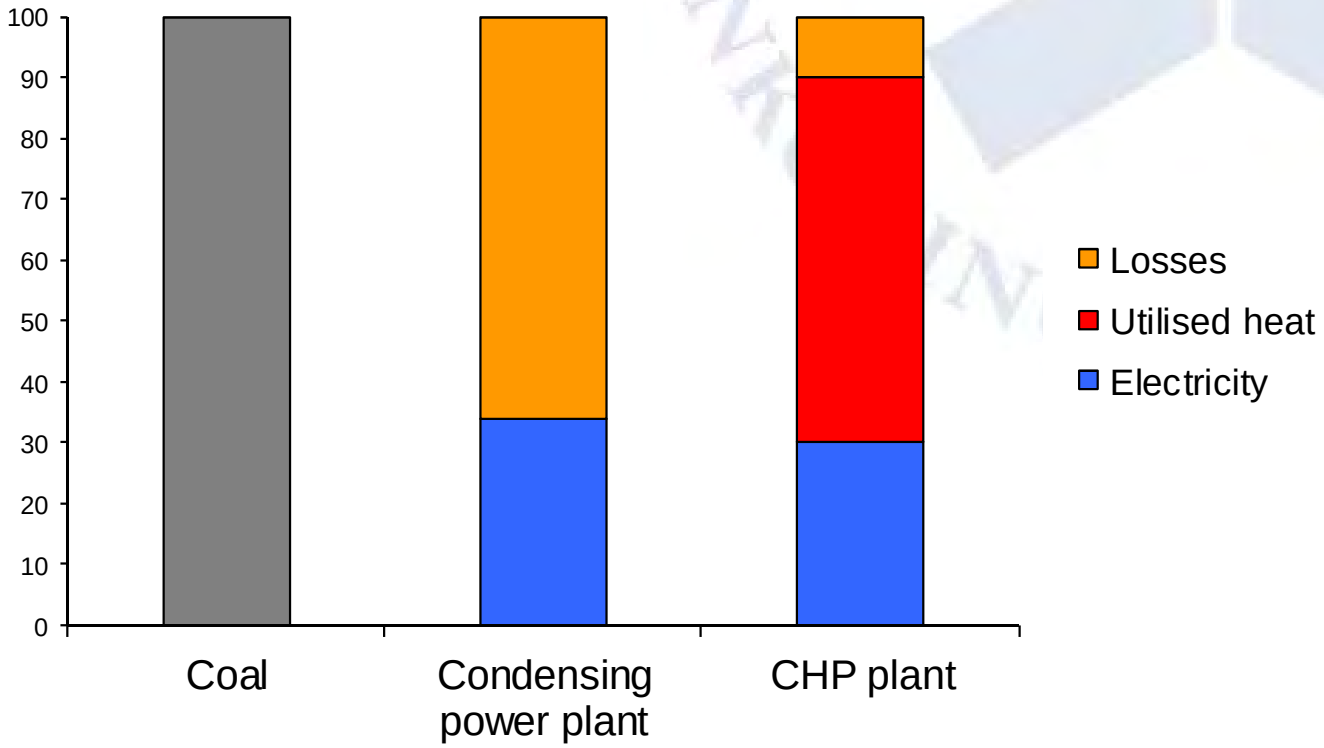
- If the heat is used:

  Less coal needed to satisfy energy demand

  Lower CO_2 emissions caused by
  satisfying energy demand

  Incomes from electricity *and* heat sales,
  which may reduce electricity price

Condensing power plant and Combined Heat and Power (CHP) plant



Sustainable electricity utilisation

- Electricity is valuable
- Minimised electricity consumption
- Heat can be used instead of electricity
  in many cases, e.g. for heating and cooling.
- Heat from
  combined heat and power (CHP) plants
  or boilers that produce only heat

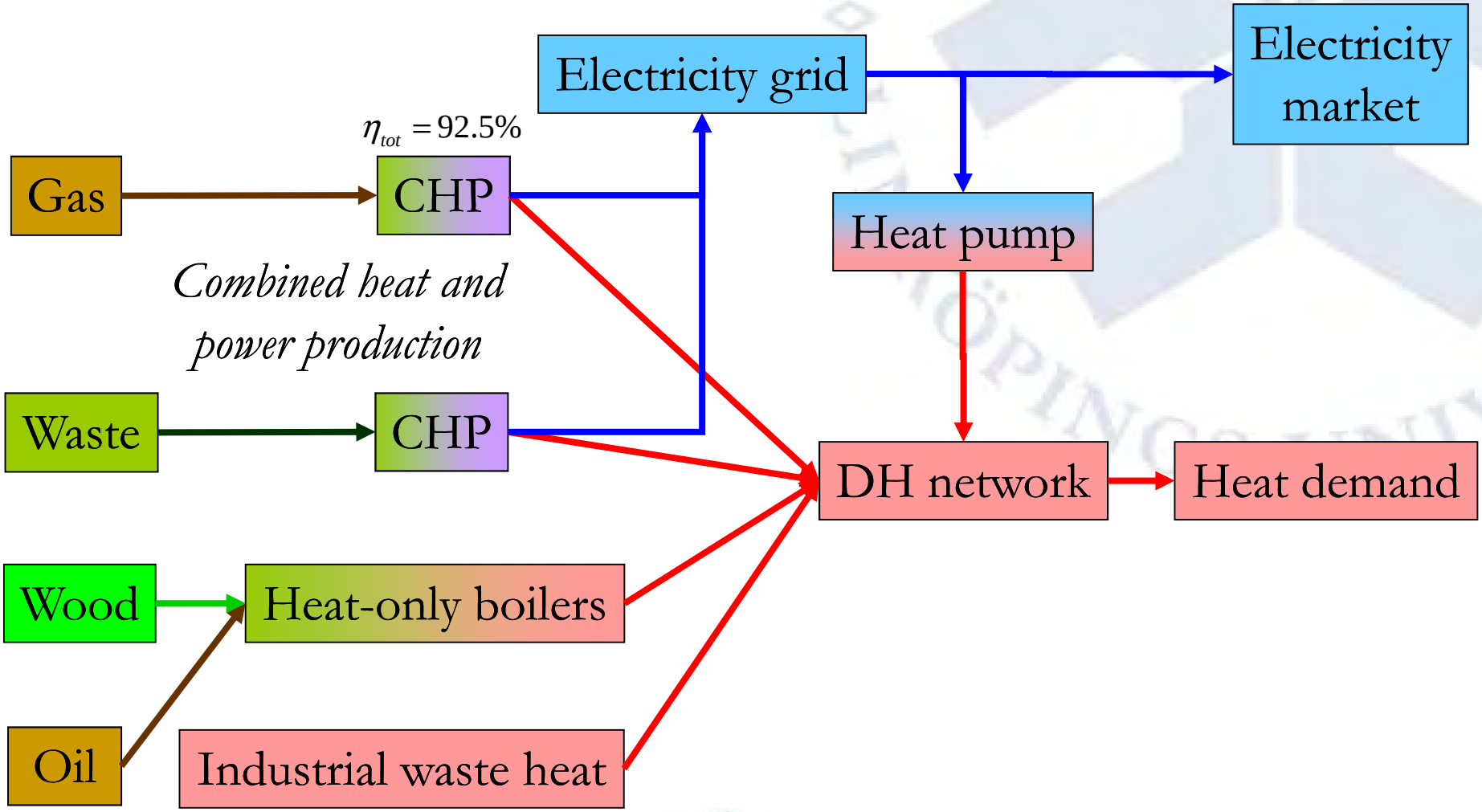
District heating and cooling systems

- Networks for hot and cold water are built from plants to industrial premises, commercial centres, houses etc when a district is built.
- Convenient for inhabitants

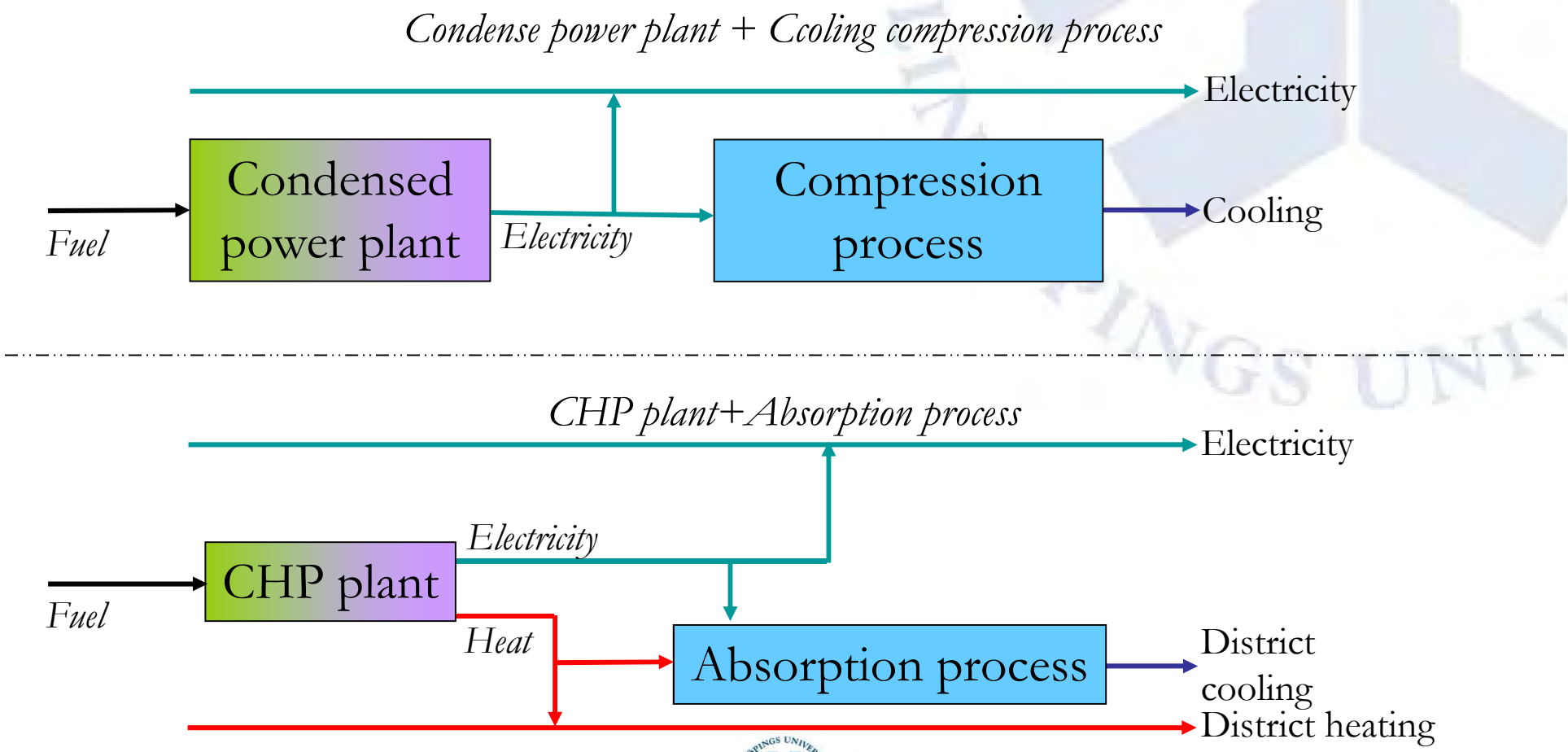
District heating enables

- Utilisation of resources that otherwise might be wasted, e.g. industrial waste heat, municipal waste
- Cogeneration of electricity, heat, steam and cooling

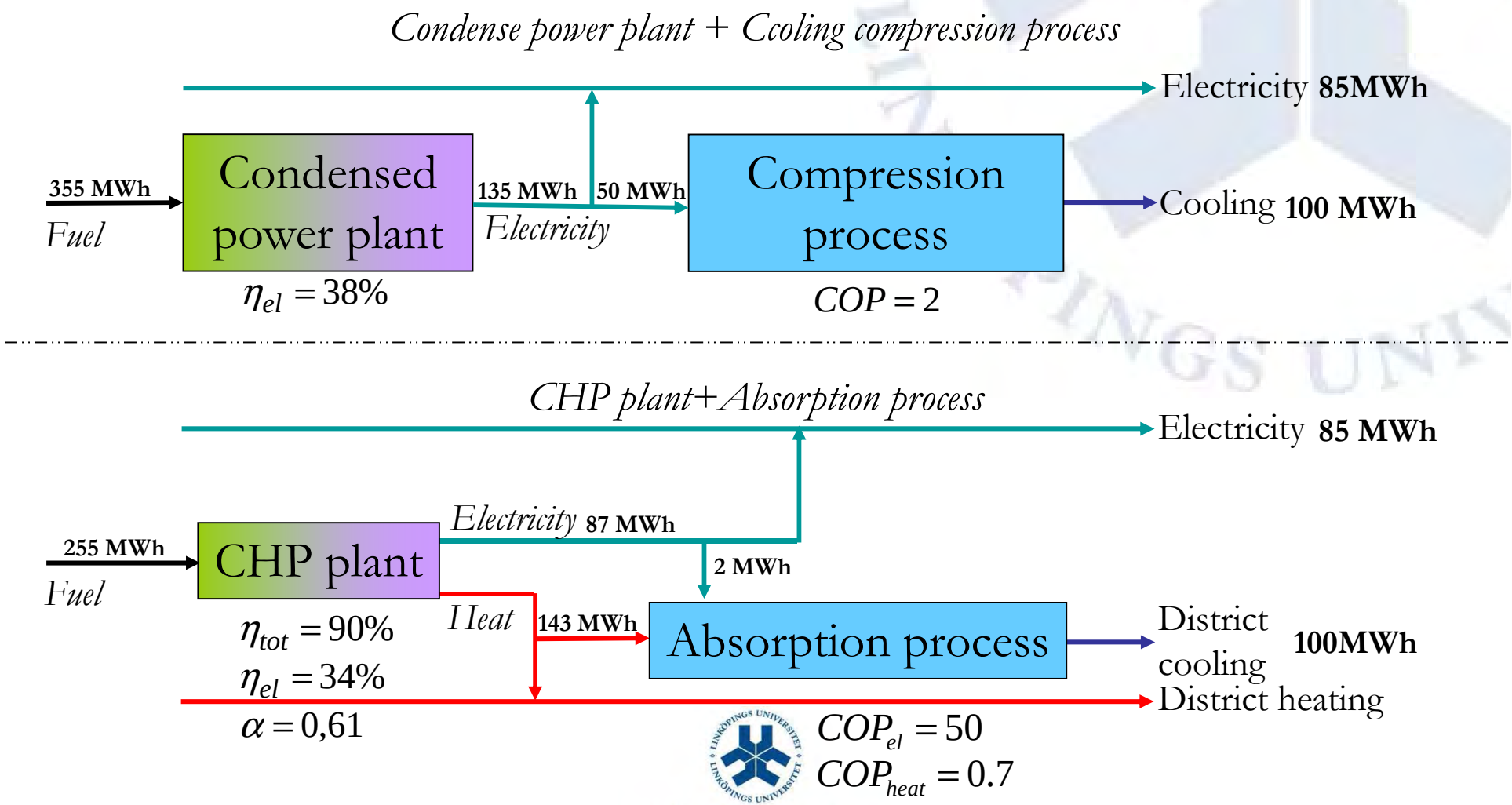
District heating supply



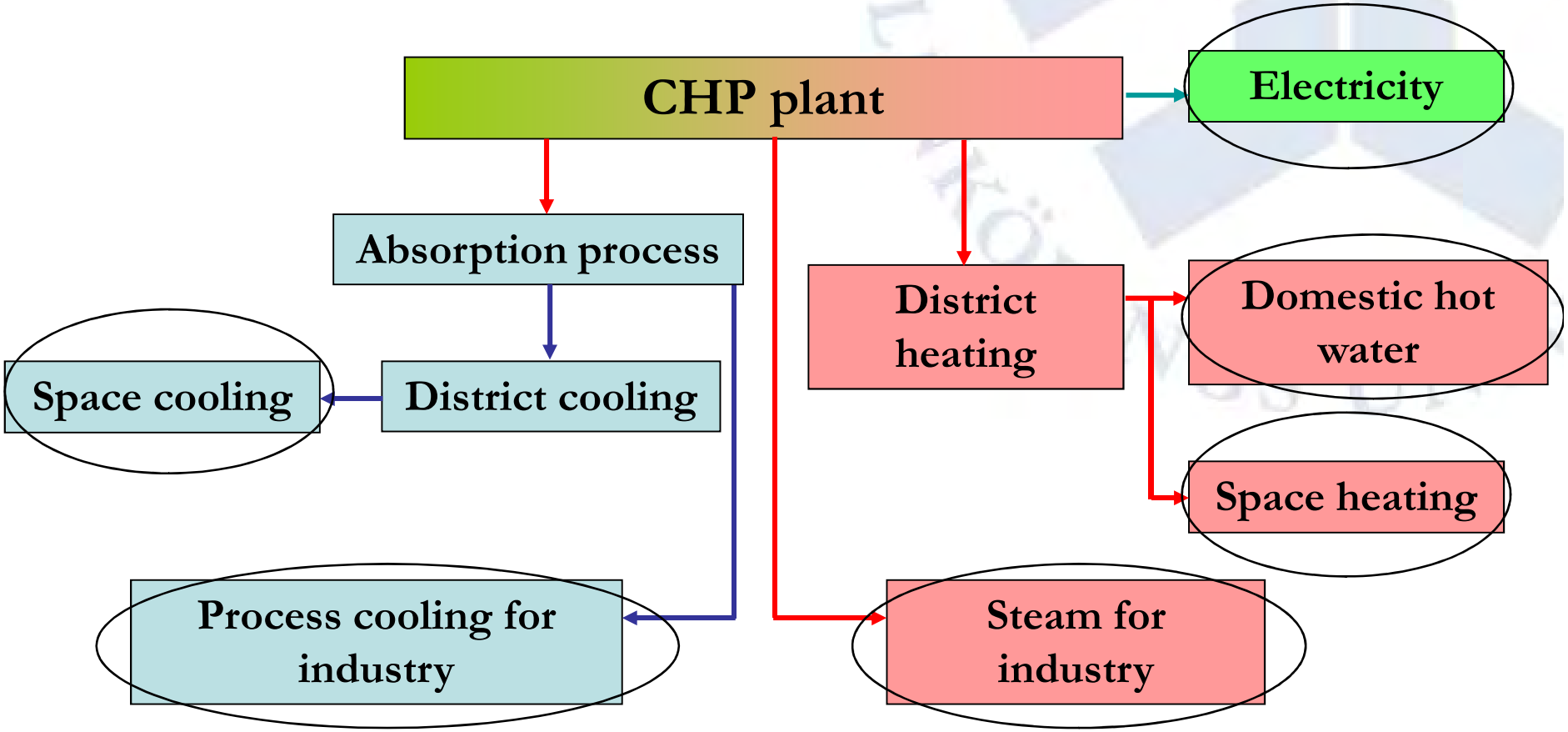
Absorption vs vapour compression process



Absorption vs vapour compression process



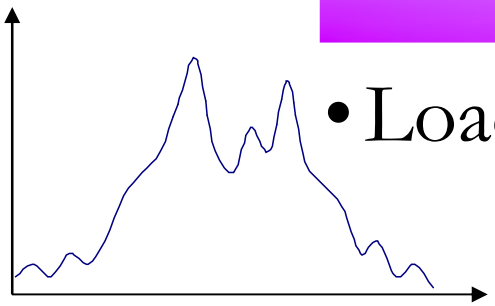
Combined Heat and Power plant



Demand-side measures

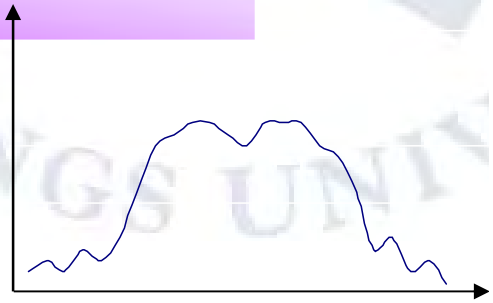
- Energy conservation

  reduces energy demand



- Load management

  reduces capacity demand

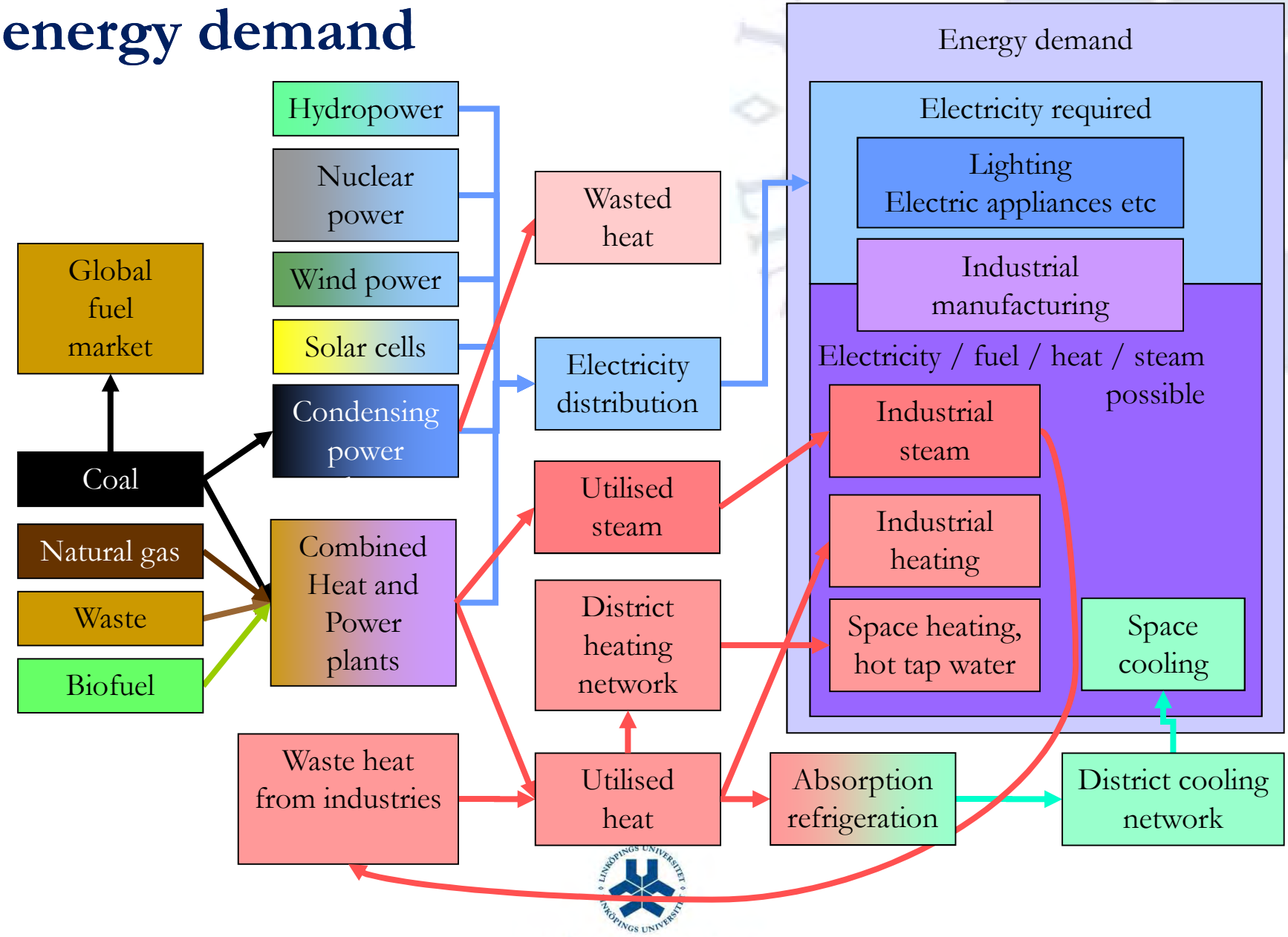


- Energy carrier switching

  e g from electricity to fuel

  or district heating

Many possibilities to satisfy energy demand



System analysis

Energy system

Photo source: Siemens

System boundary

Management

Aim: Supply energy at low cost
Components: Available capacity
Resources: Limited supplies

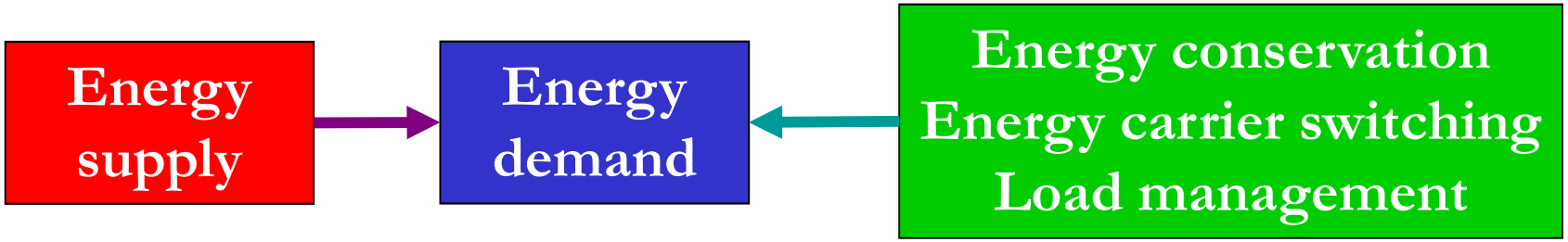
Boundary conditions

Fuel prices, Laws, Demand ?

How to use components and resources to achieve aim best?
Use a model that describes important properties of the system.

Energy system optimisation model

- Country, region, municipality, district-heating system
- Electricity and heat production
- Short and long-term variations
- Cost minimisation
- Optimisation method: Linear programming
- Investments in new plants: type, size, occasion
- Given energy service demand



MODEST

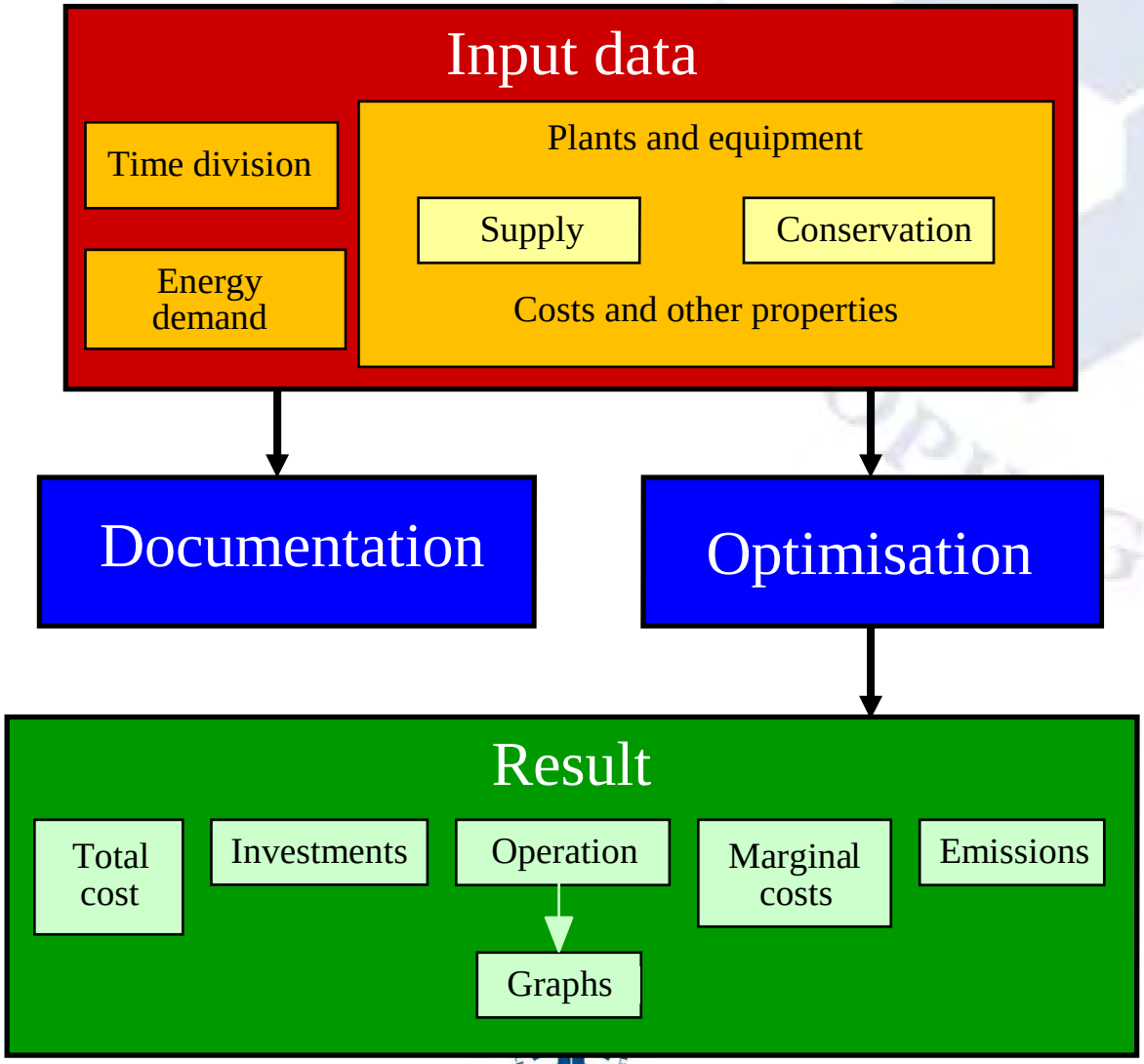
an energy system optimisation model

Model for Optimisation of Dynamic Energy Systems with Time dependent components and boundary conditions

- MODEST calculates how energy demand should be satisfied at lowest possible cost.
- MODEST can handle many kinds of energy sources, forms, plants and demand
- MODEST has been used for more than 50 Swedish district heating systems, regional biofuel supply and use and national electricity supply and conservation

MODEST

Information flow

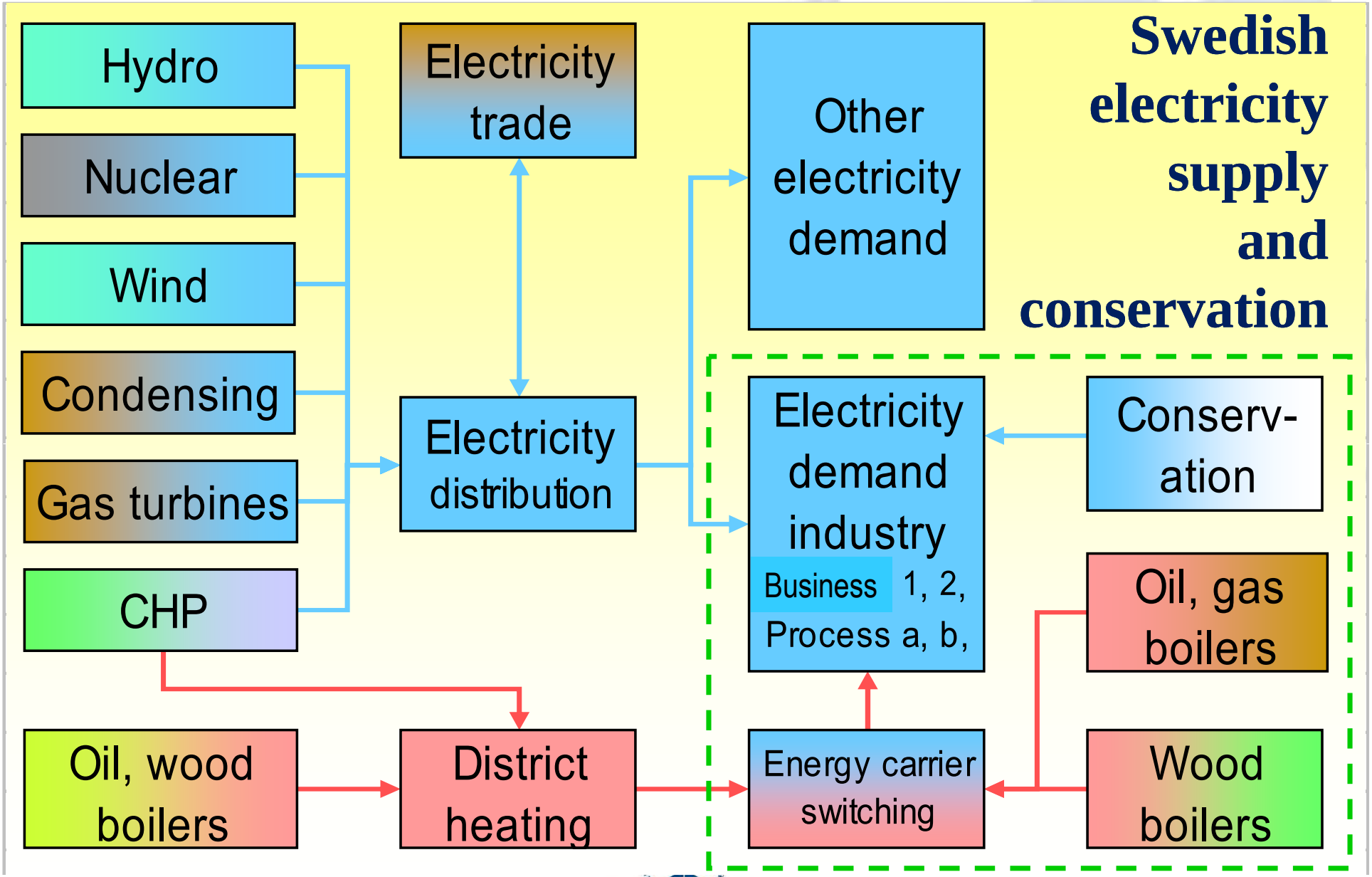


MODEST

Some of the parameters that can be defined

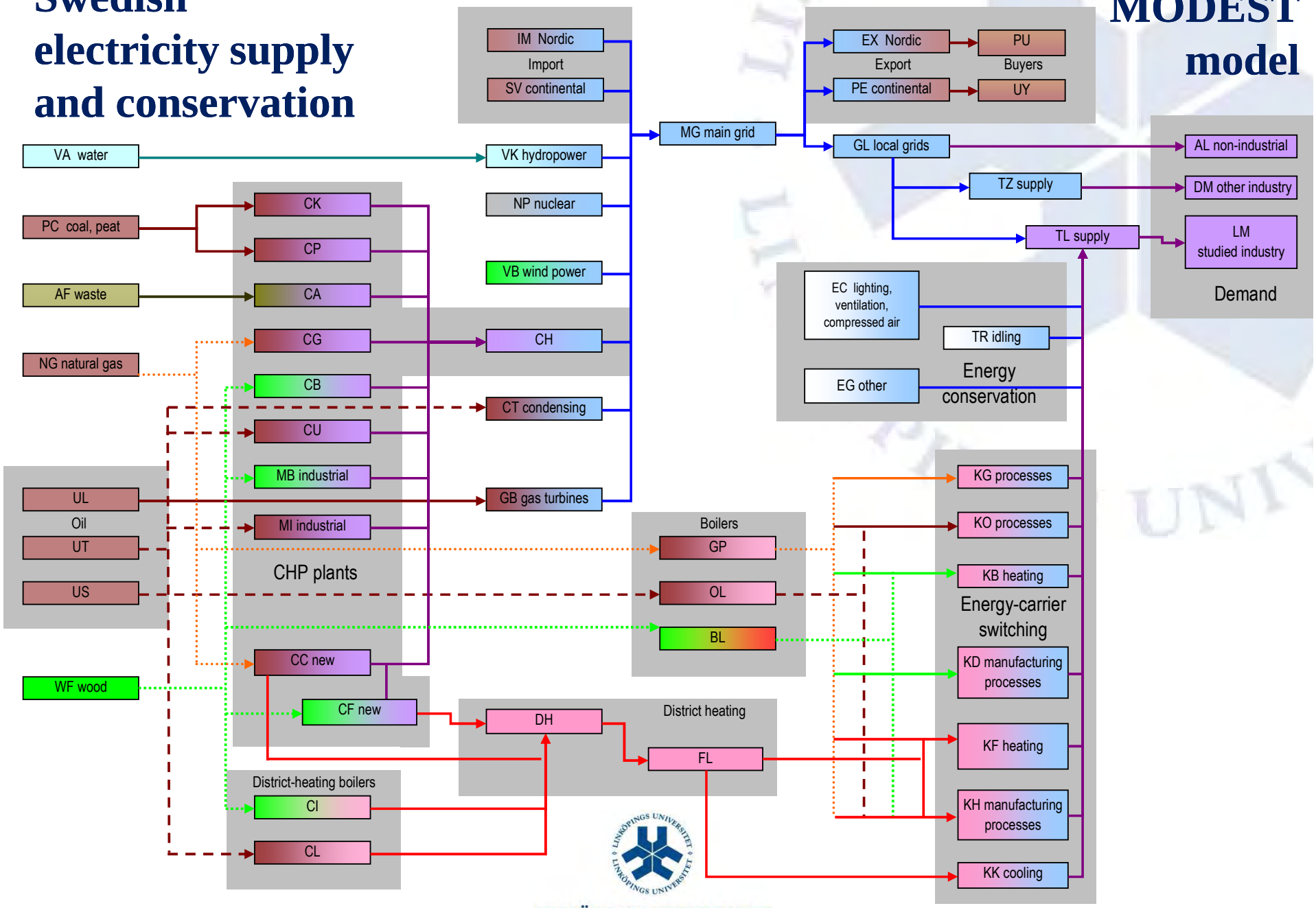
- Available capacity for plants
- Max & Min / fix energy per year, season
- Efficiency
- Power to heat ratio for CHP plants
- Storage capacity
- Energy demand
- Sales
- Emission coefficients and limits
- Energy costs
- Investments costs
- Electricity prices, fuel prices
- Depreciation time
- Taxes and policy instruments

Swedish electricity supply and conservation

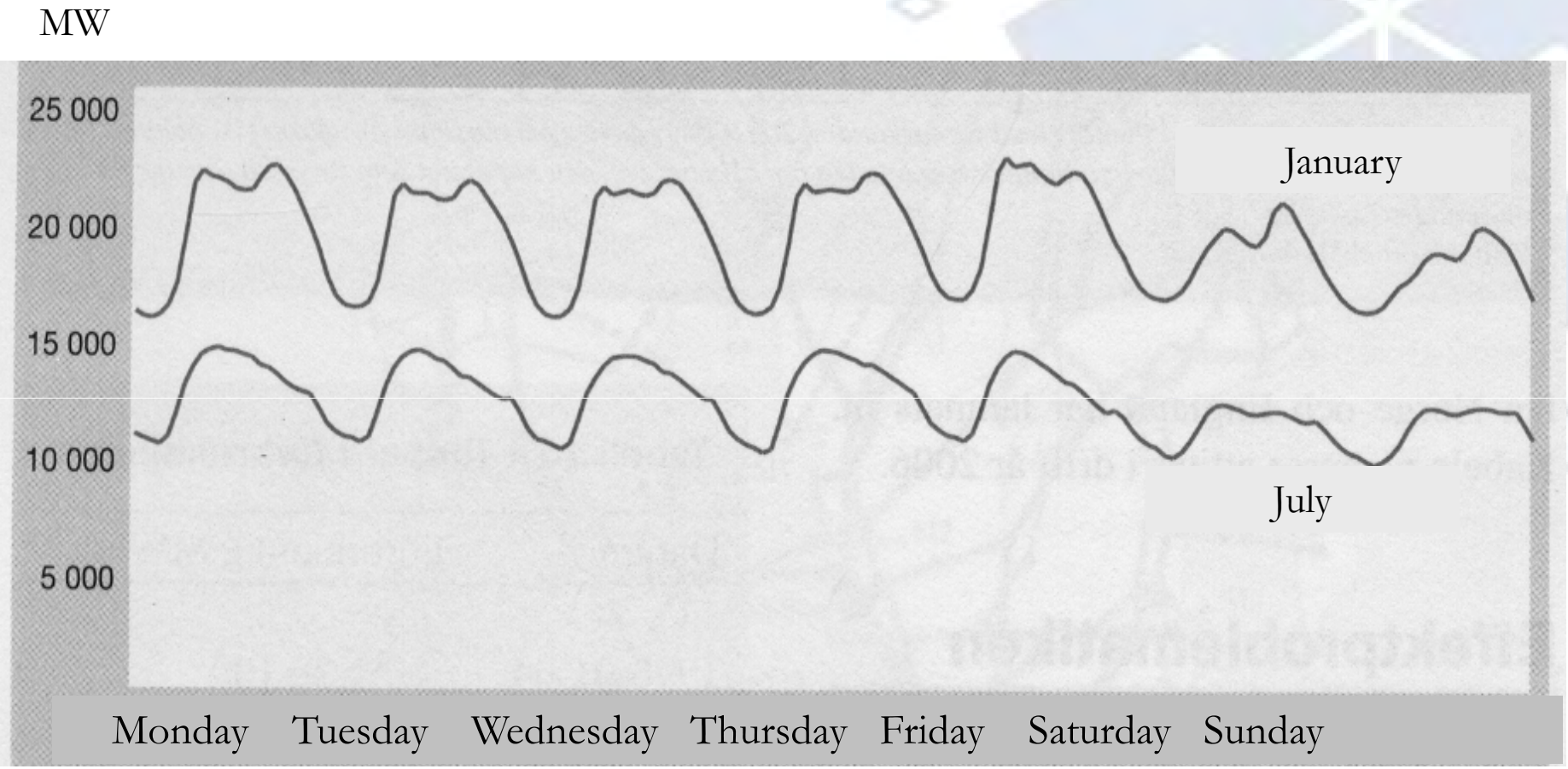


Swedish electricity supply and conservation

MODEST model



Electricity capacity demand



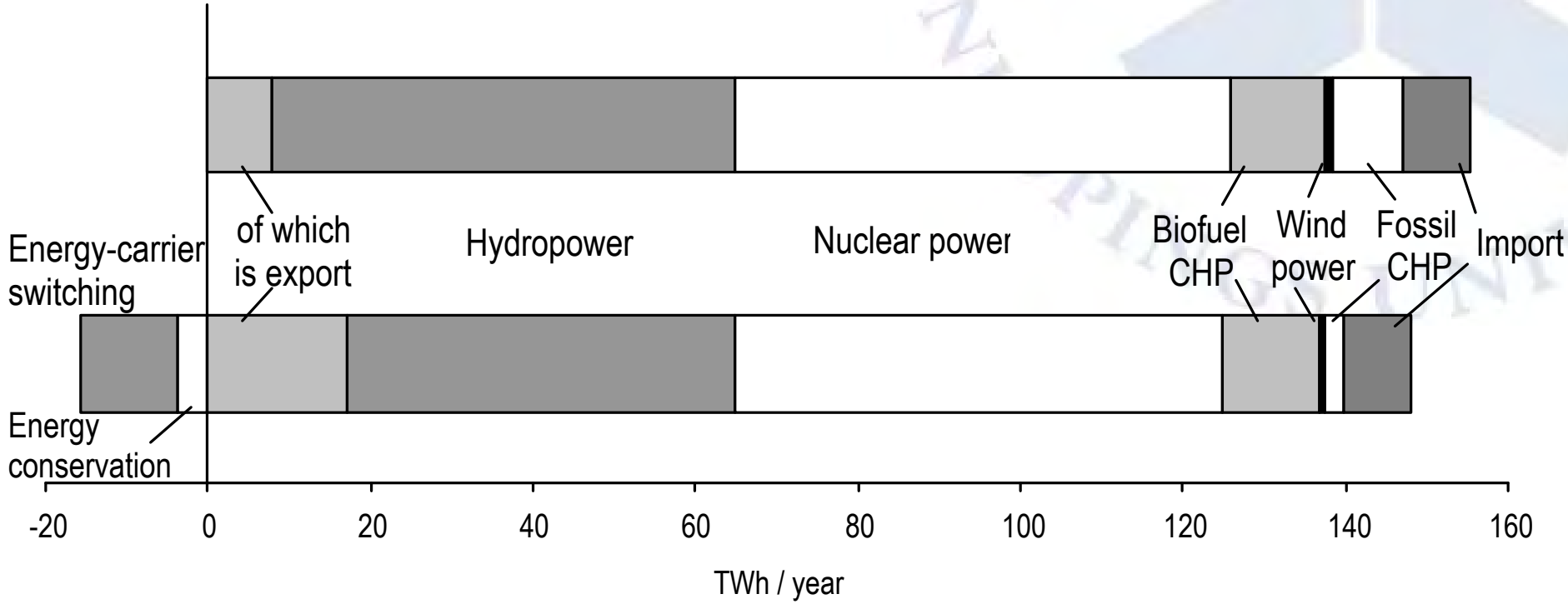
Sweden

2000

Season i	Diurnal period j	Days	Hours	Hours a year t_{ij}
1 November - March	1	Weekdays	22-06	840
	2		06-07	105
	3		07-08	105
	4		08-12	420
	5		12-16	420
	6		16-22	630
	7	Weekend	22-06	328
	8		06-22	656
	9	Peak days	22-06	40
	10		06-07	5
	11		07-08	5
	12		08-12	20
	13		12-16	20
	14		16-22	30
2 April September October	1	Weekdays	22-06	512
	2		06-22	1024
	3	Weekend	22-06	216
	4		06-22	432
3 May - August	1	Weekdays	22-06	712
	2		06-22	1424
	3	Weekend	22-06	272
	4		06-22	544

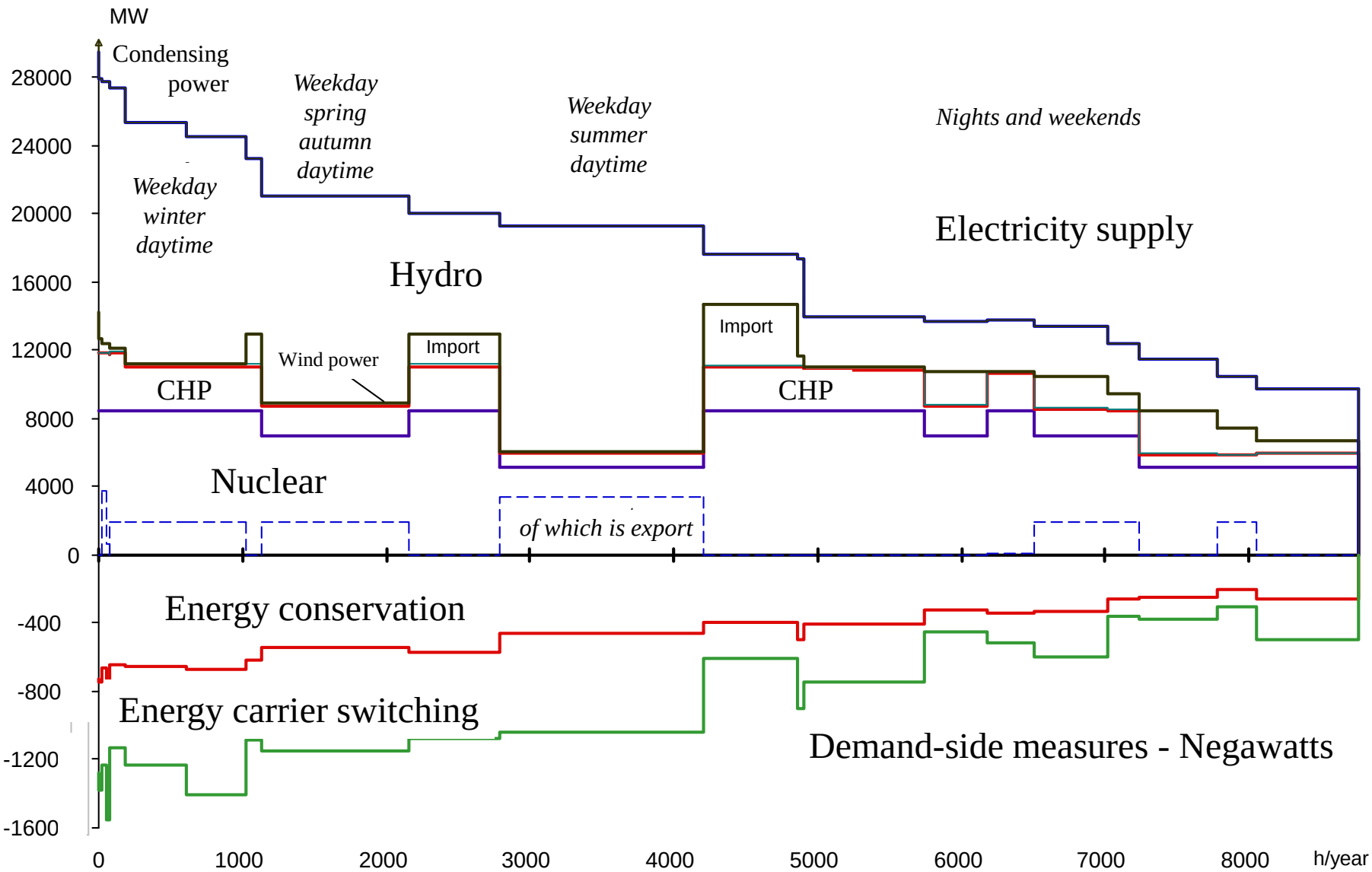
MODEST time division example

Electricity supply without and with electricity conservation



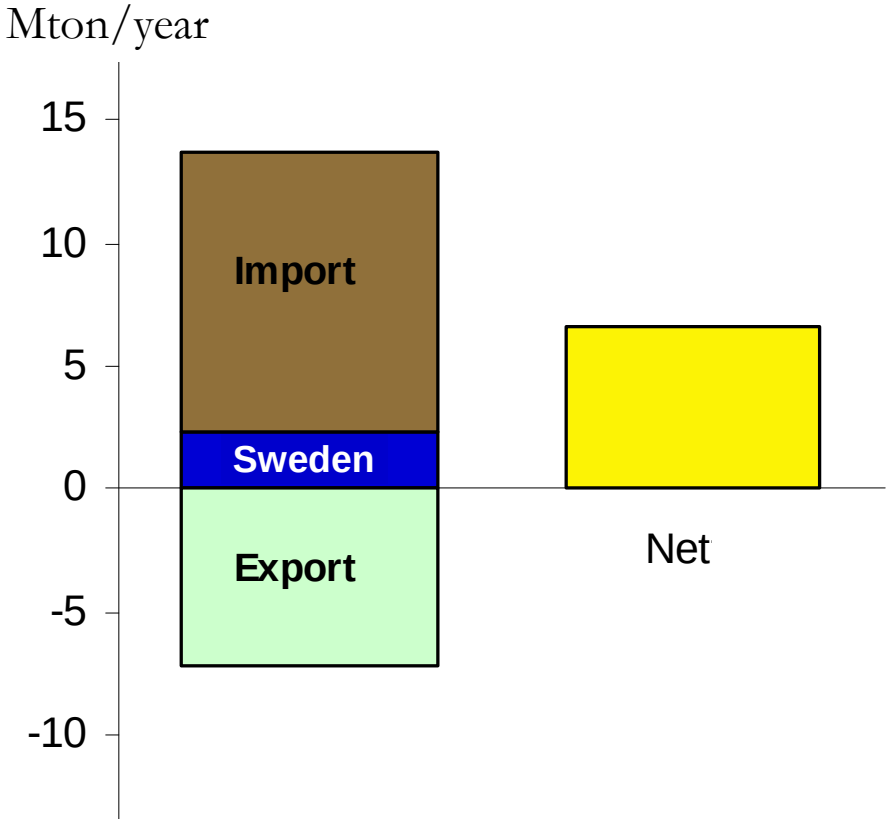
MODEST optimisation result

Electricity supply and conservation in Sweden during one year

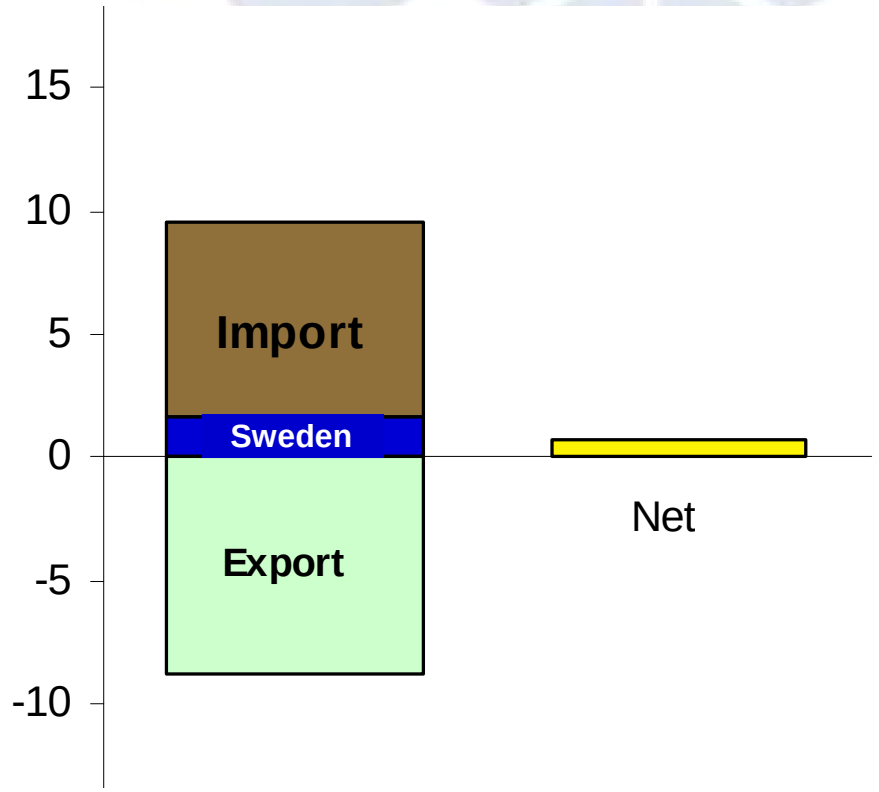


MODEST optimisation result - Duration graph

CO_2 emissions due to Swedish electricity demand



Without electricity conservation



With electricity conservation

Regional Energy System Optimisation

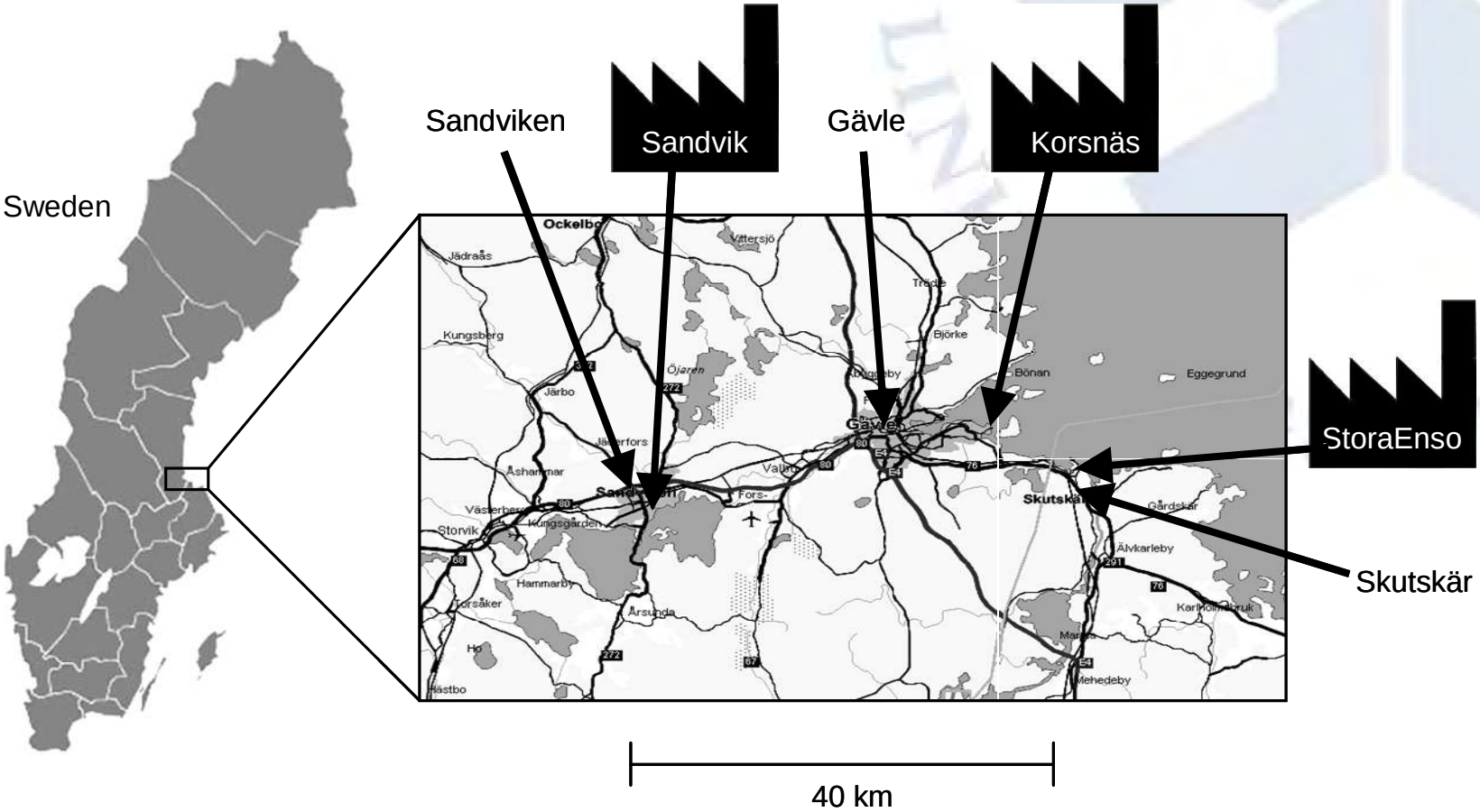
"Potential for a local heat market"

Project idea

- Is to investigate and analyze the economical potential for

regional collaboration in the energy field between different companies by means of establishing a joint heat market where several companies can buy and sell heat

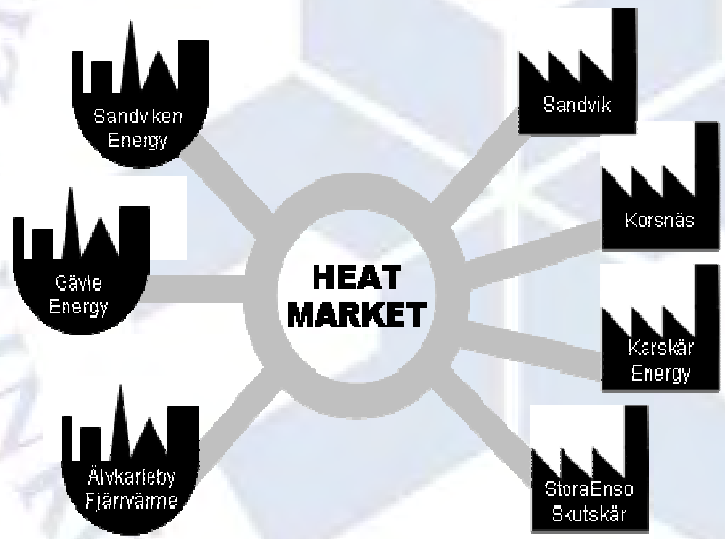
RESO - Studied region



Distance is about 50 km

Heat demand is about 7 TWh/year

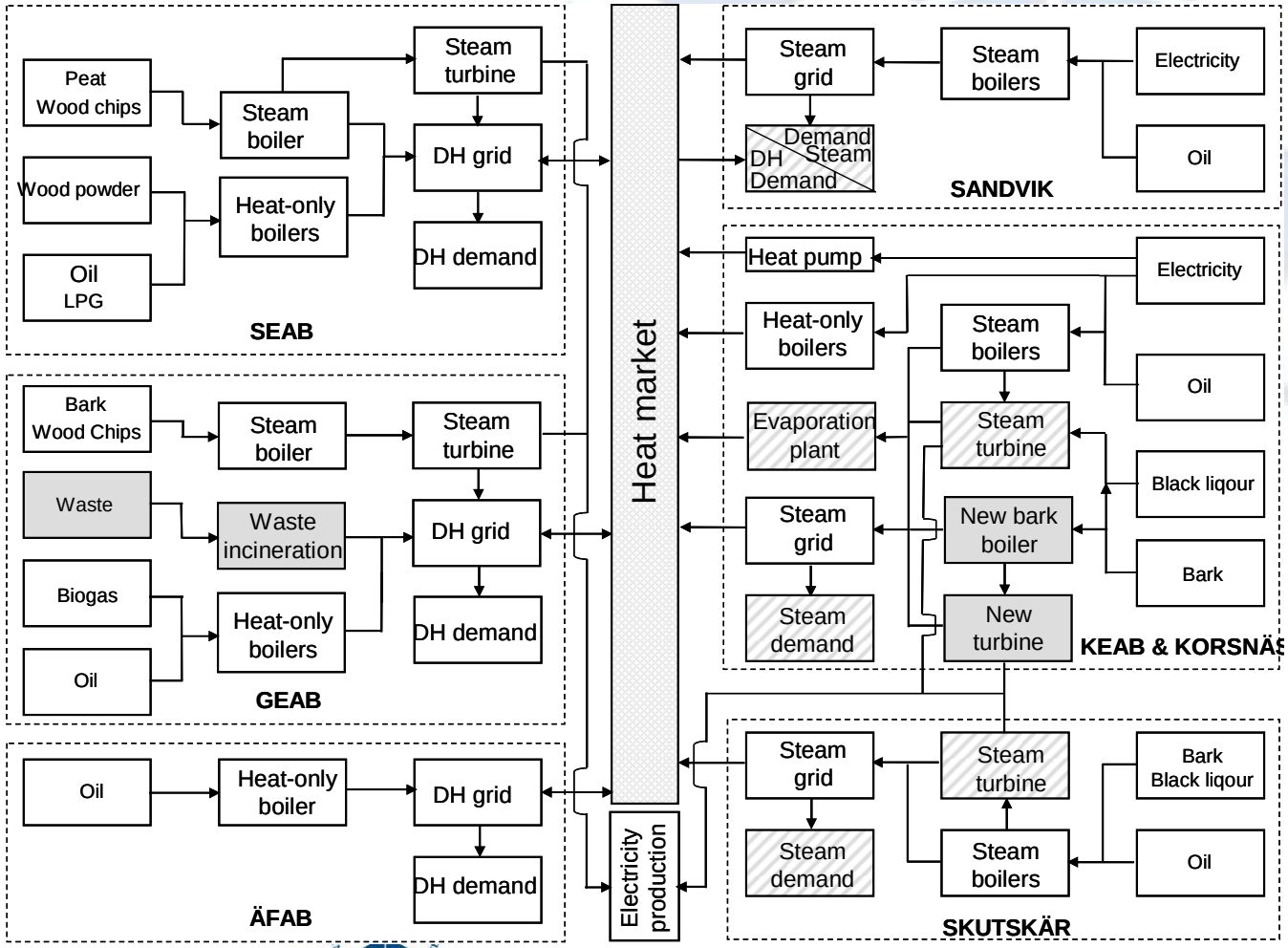
Aim of the project



- Connecting the district heat systems
- Use of excess heat from industries
- Possibilities, difficulties, influences
- Optimal design of the energy systems
- Win-Win benefits
- How the present and new utilities should be used?
- How the energy demand should be provided?
- How the results will be influenced by the
  - fluctuations in electricity
  - fuel prices
  - CO2-tax
  - electricity certificates trading
  - emission rights trading

Schematic representation of the modeled system

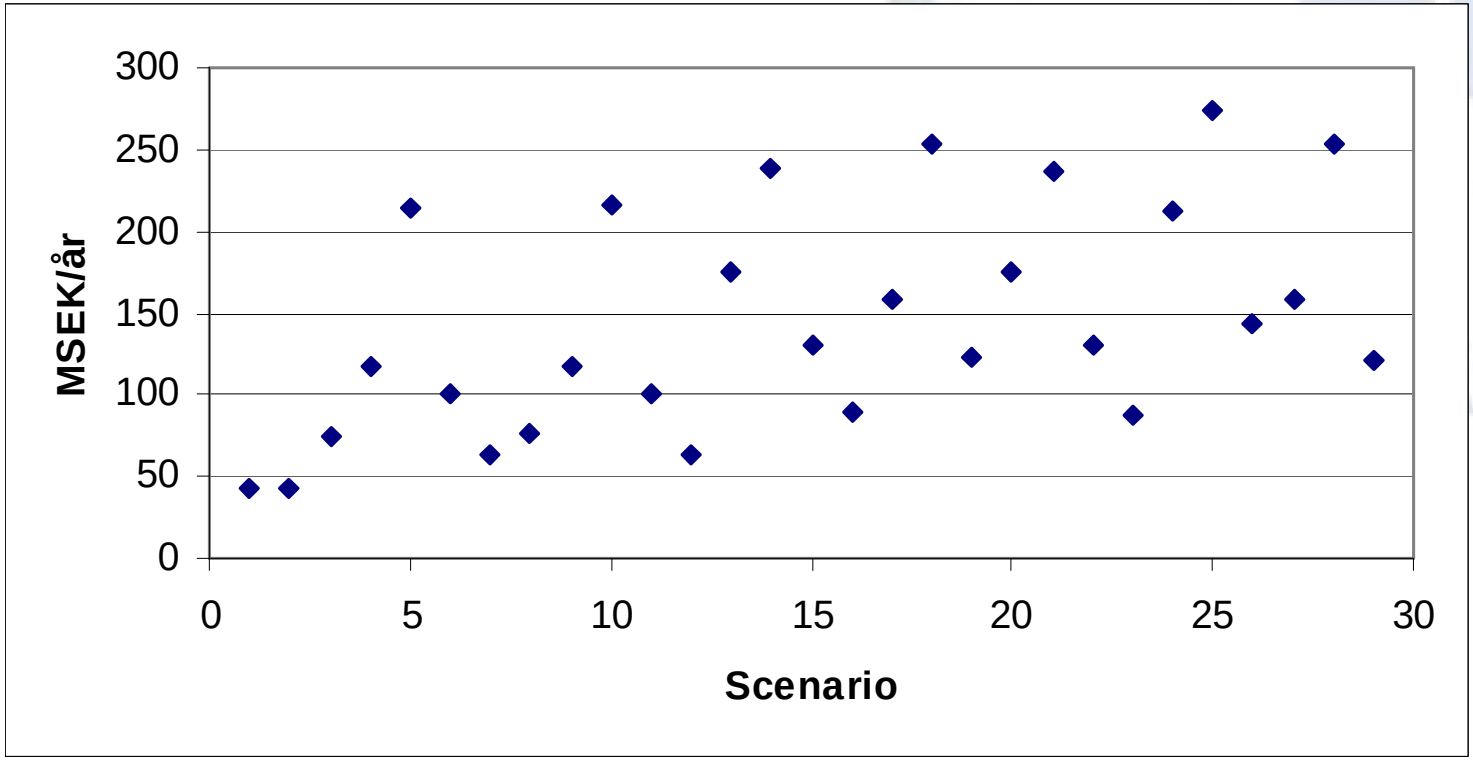
- Approach
  - System perspective
  - Optimization



Possible investments and changes within the system

- 30 cases:
  - Usage of excess heat
  - Process integration
  - Waste incineration plant
  - New bio-fuel CHP plant
  - Upgrading the turbines
  - Increasing the district heating demand

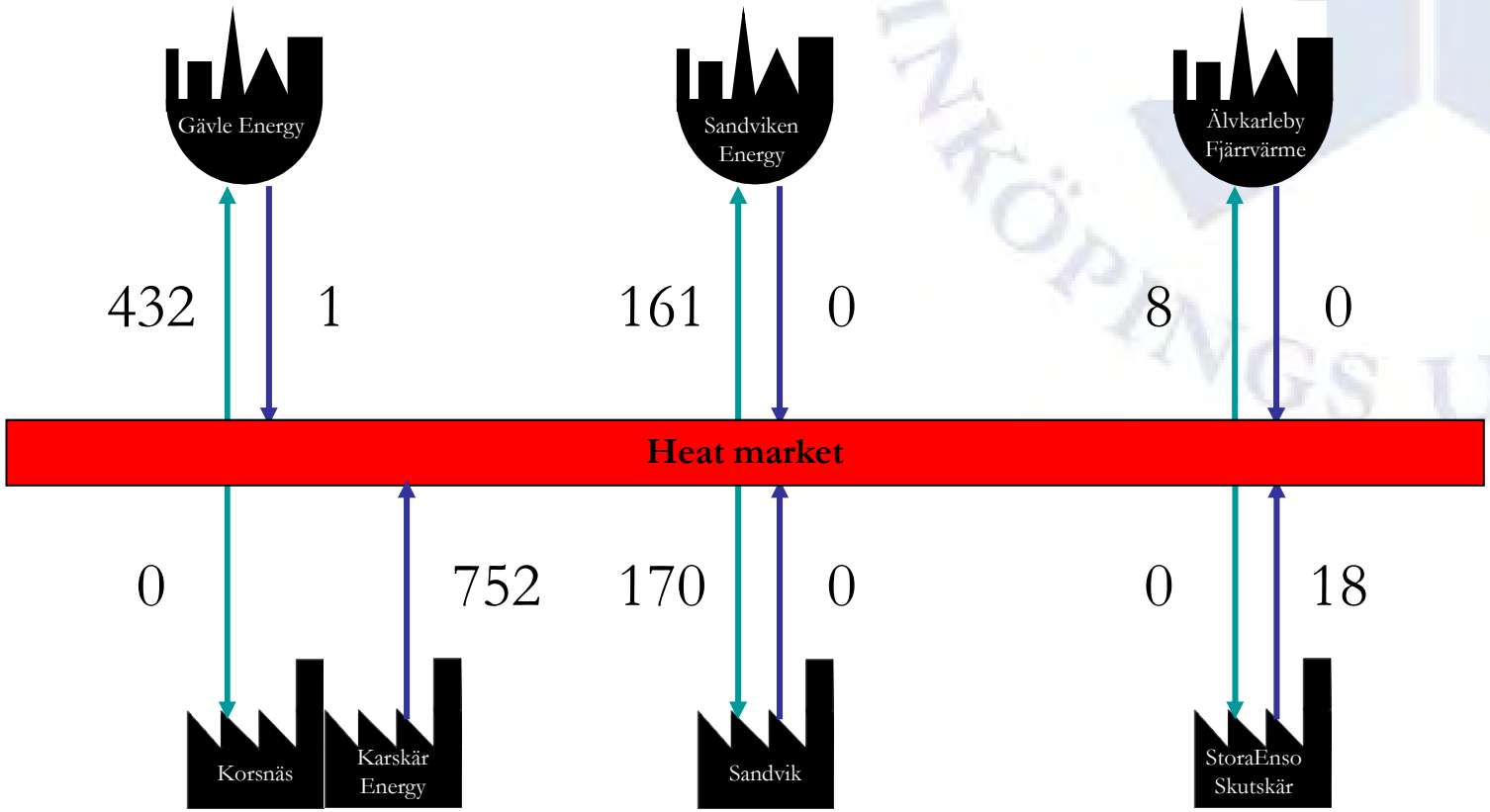
Possible reduction in costs compared to ref. Scenario



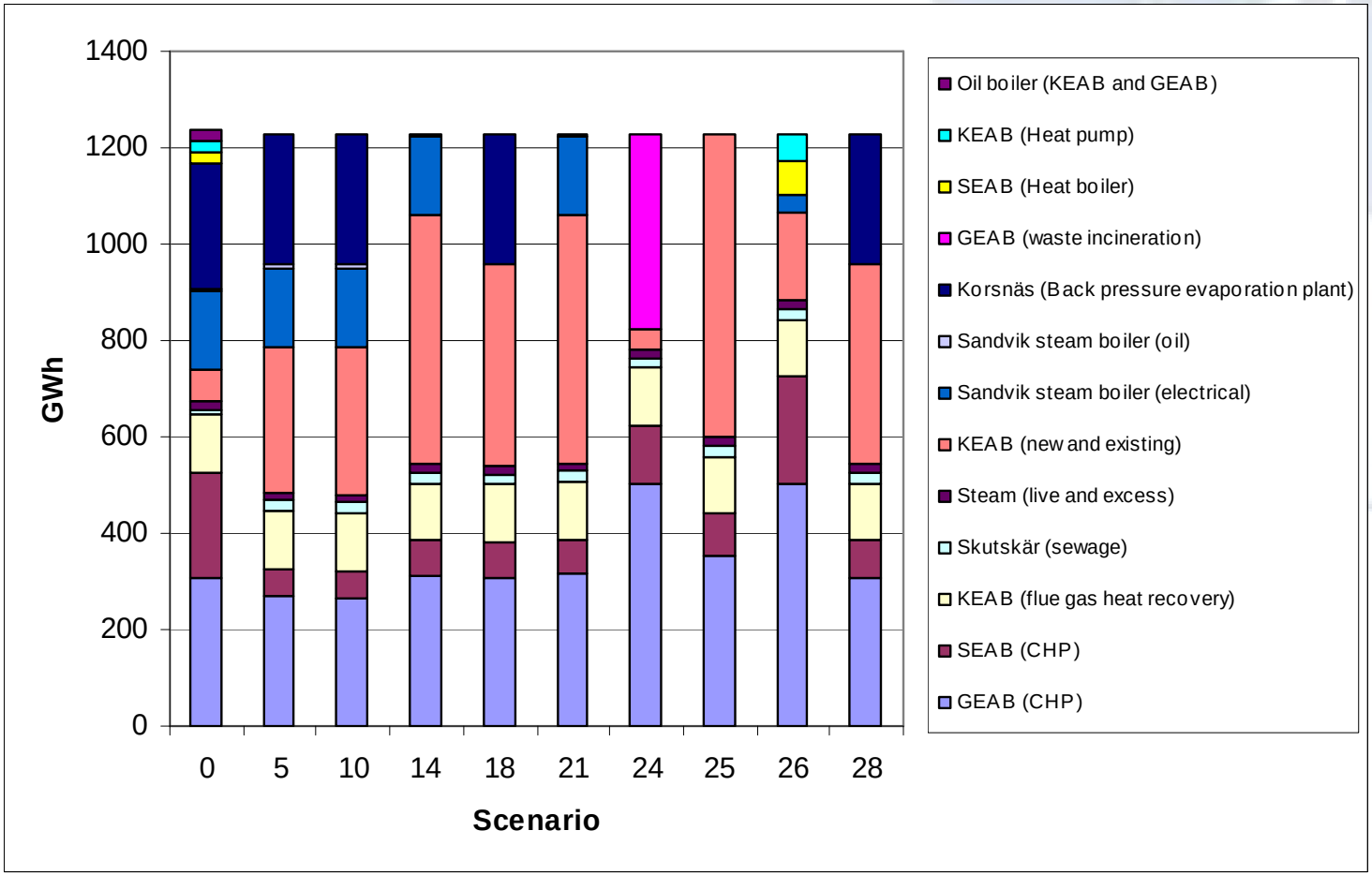
Solution with the highest revenue, compared to the present system

- 270 MSEK/year saving which can be used for the investment
- Investments in the following measures
  - Process integration
  - New bio-fuel CHP plant
  - Increasing the capacity of the heat market
- District heating market 770 GWh/year
- Electricity production 980 GWh/year

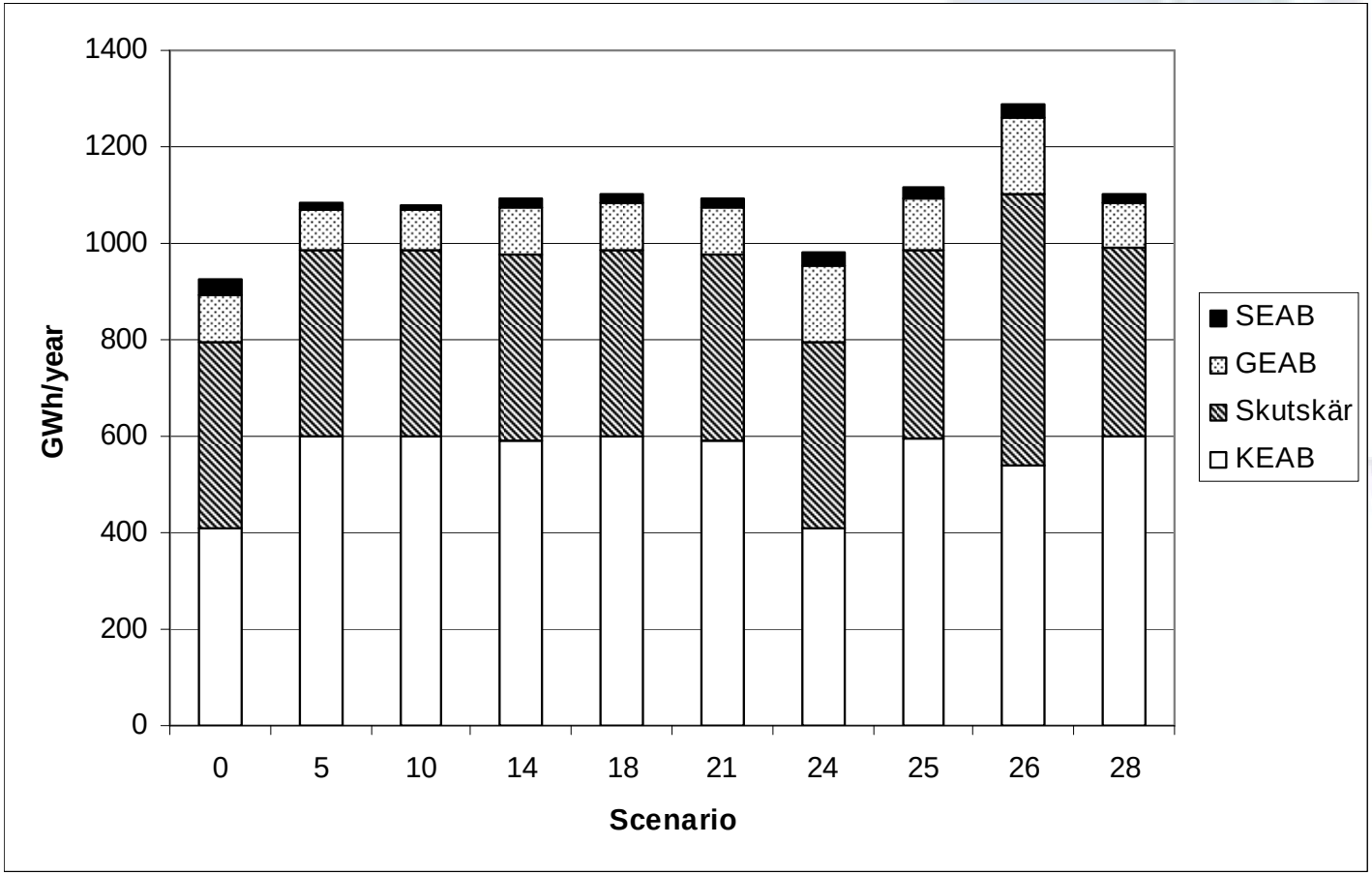
Results with highest revenue compared to the ref. scenario (GWh)



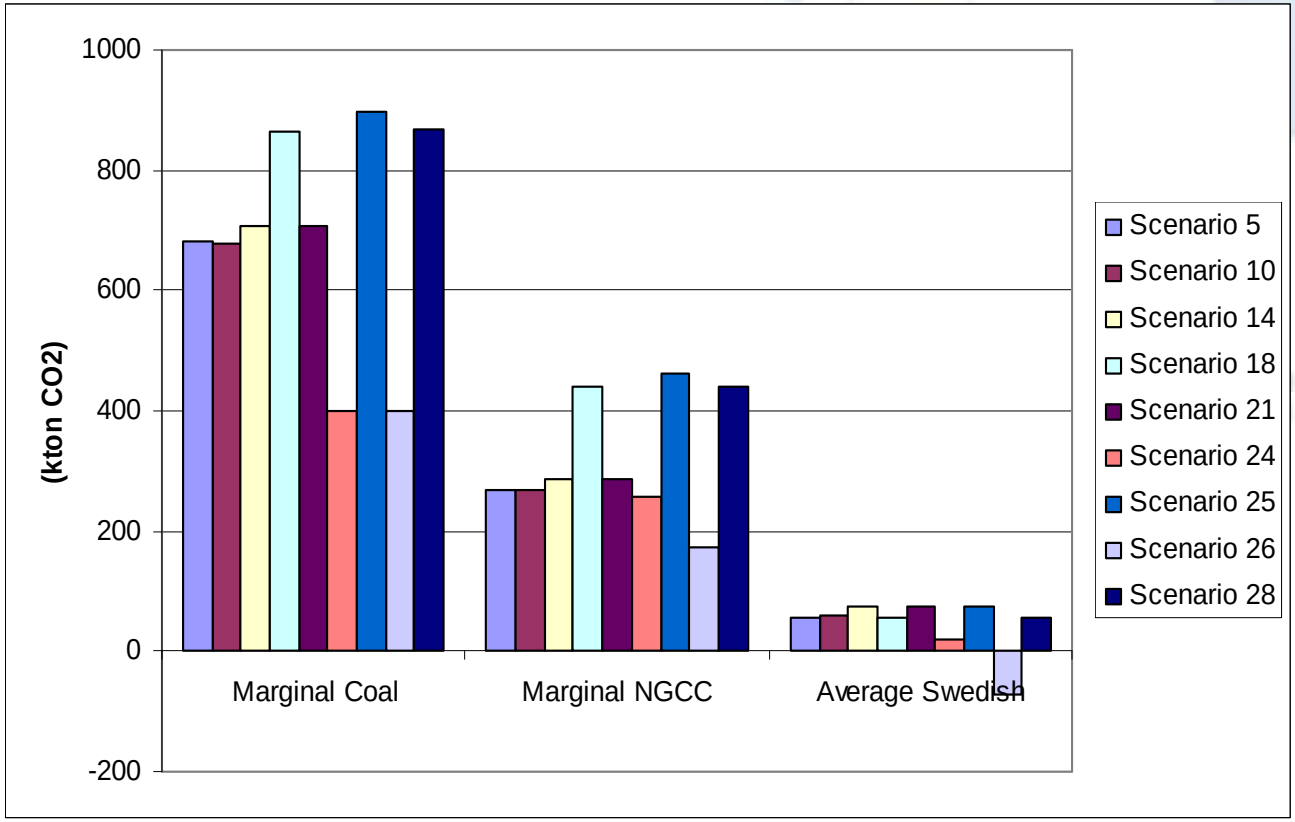
Heat production



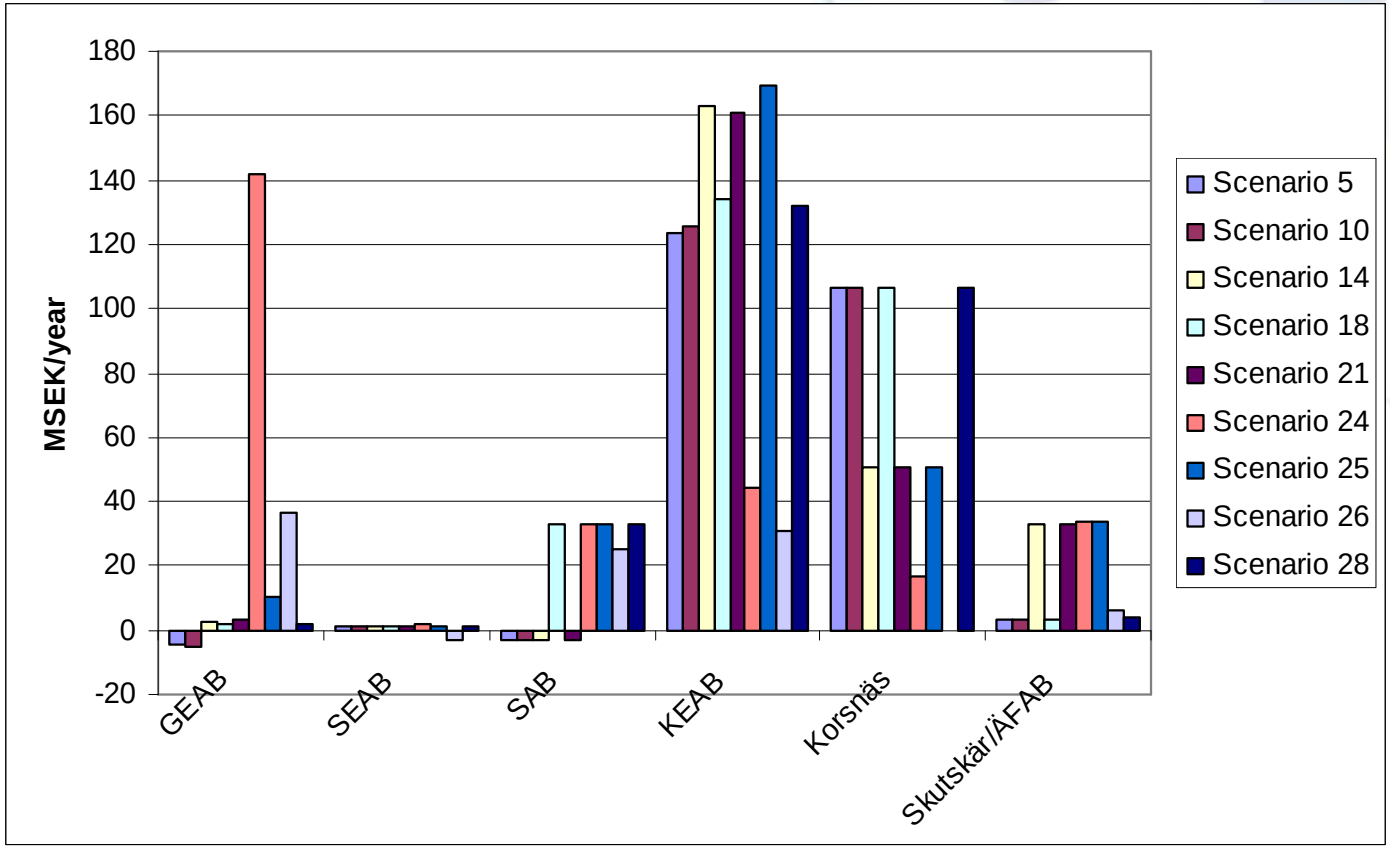
Electricity production



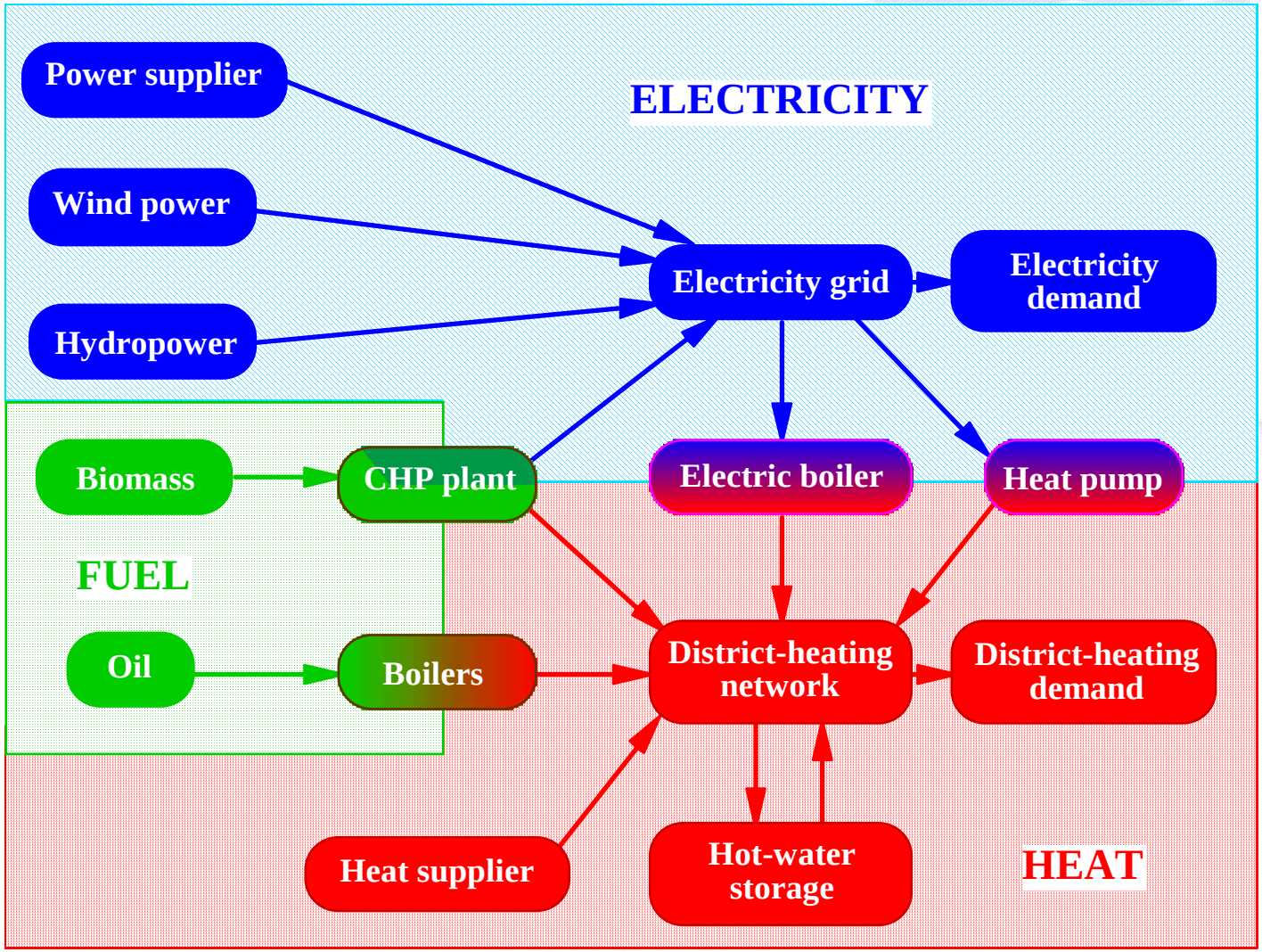
CO_2 emissions, compared with the ref. scenario



Influence on each actor, compared with the ref. scenario



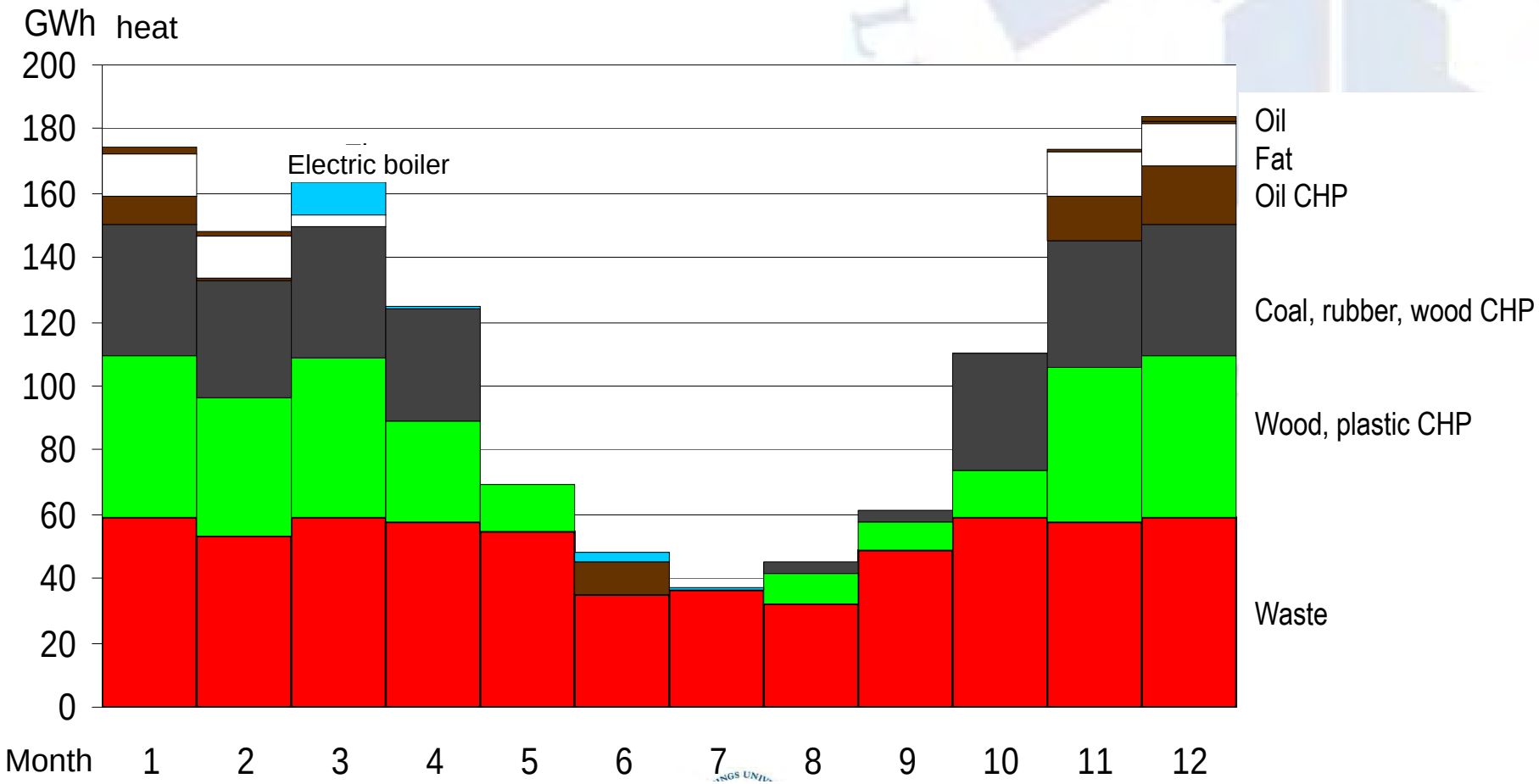
Common component types and energy flows for a local Swedish utility that supplies electricity and district heating



Issues for a local utility that can be analysed with MODEST

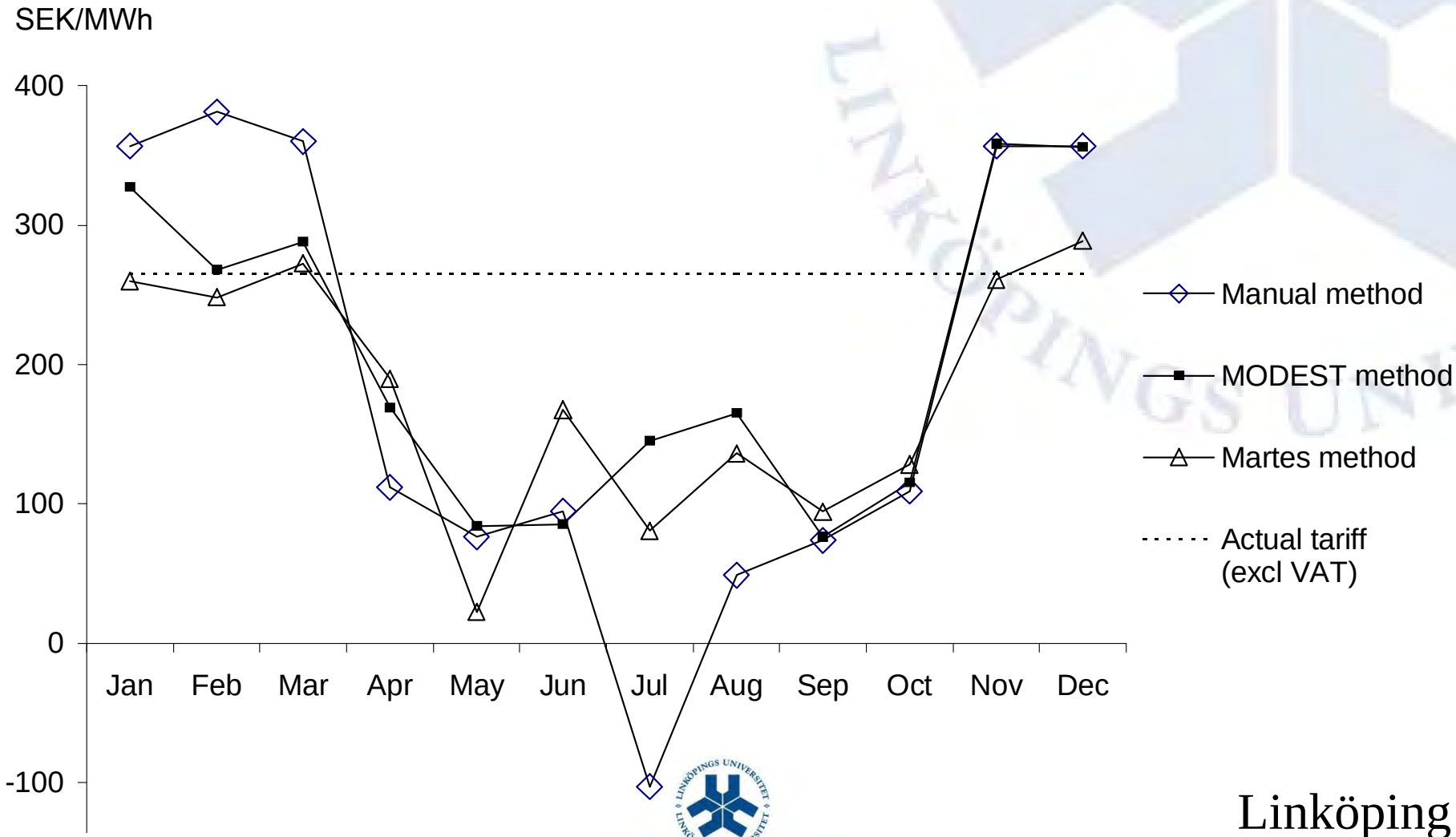
- Which kind and how large CHP plant should be built?
- What is the benefit of connecting separate district-heating networks?
- Which CO_2 emissions are caused by a solution?
- What is the marginal cost for heat and electricity supply at various occasions?
- Which impact has energy prices and policy instruments on investments and operations?

District heating production in Linköping



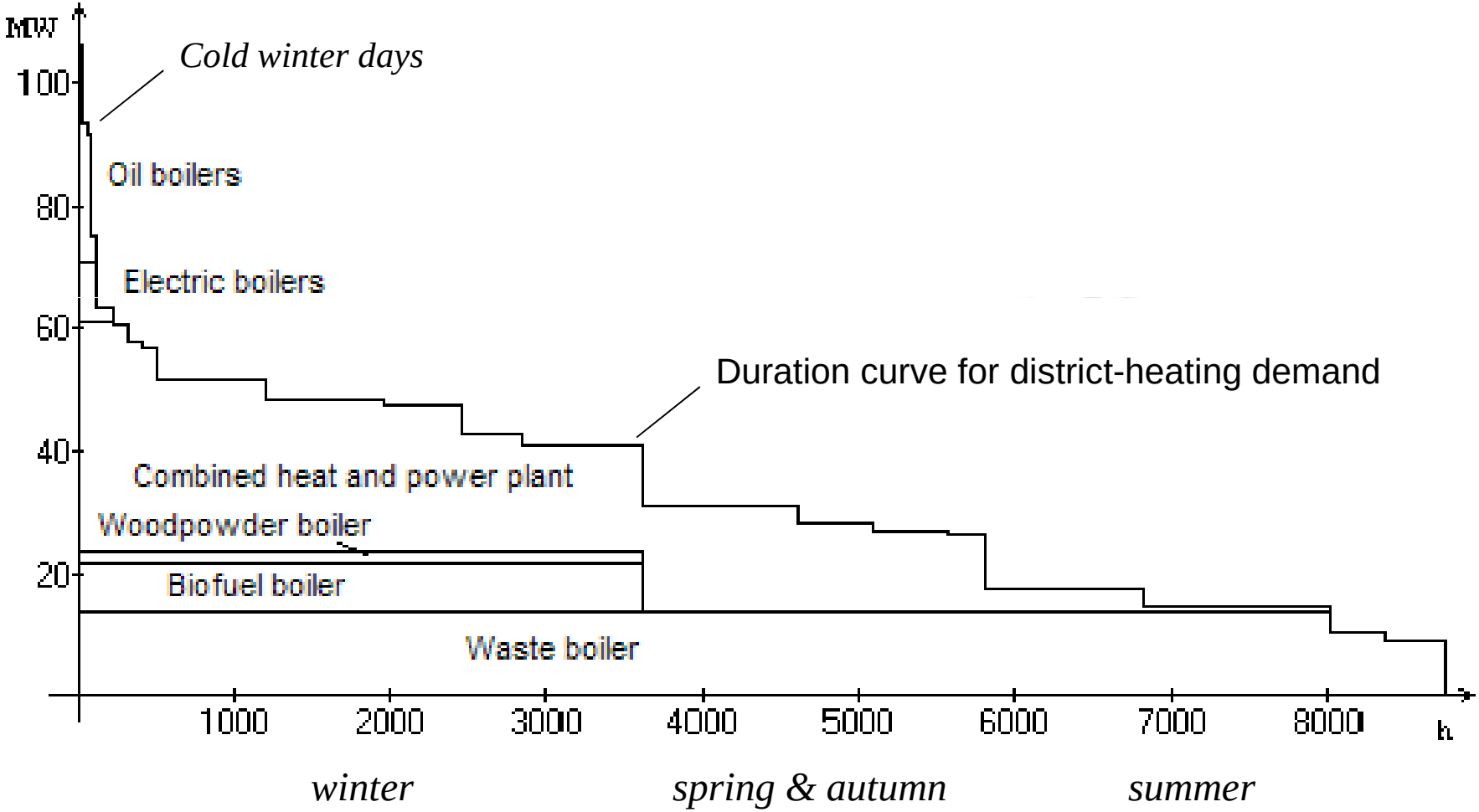
MODEST optimisation result

Marginal cost for district heating production



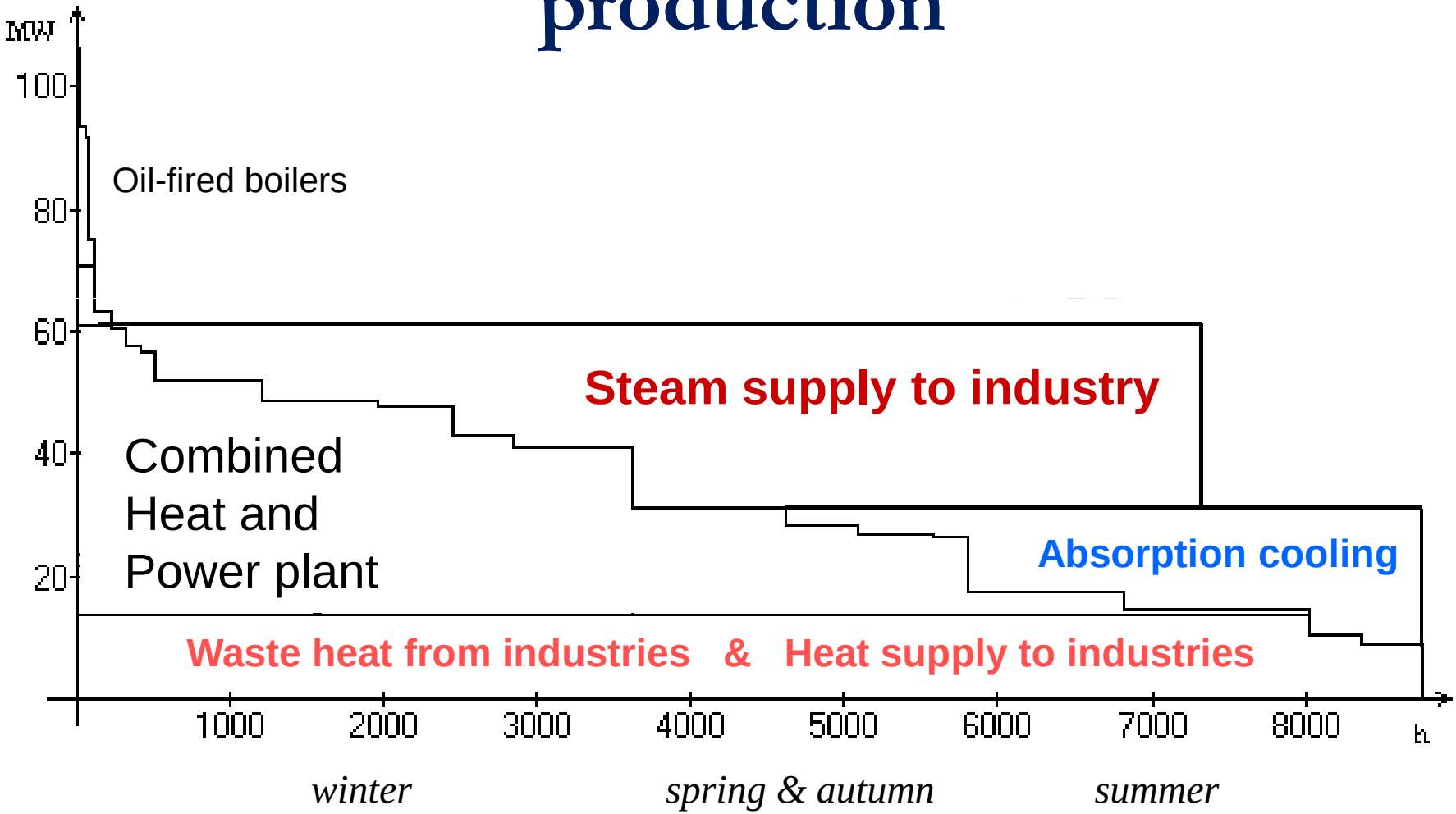
Linköping

Possible district-heating supply in a Swedish town during a year

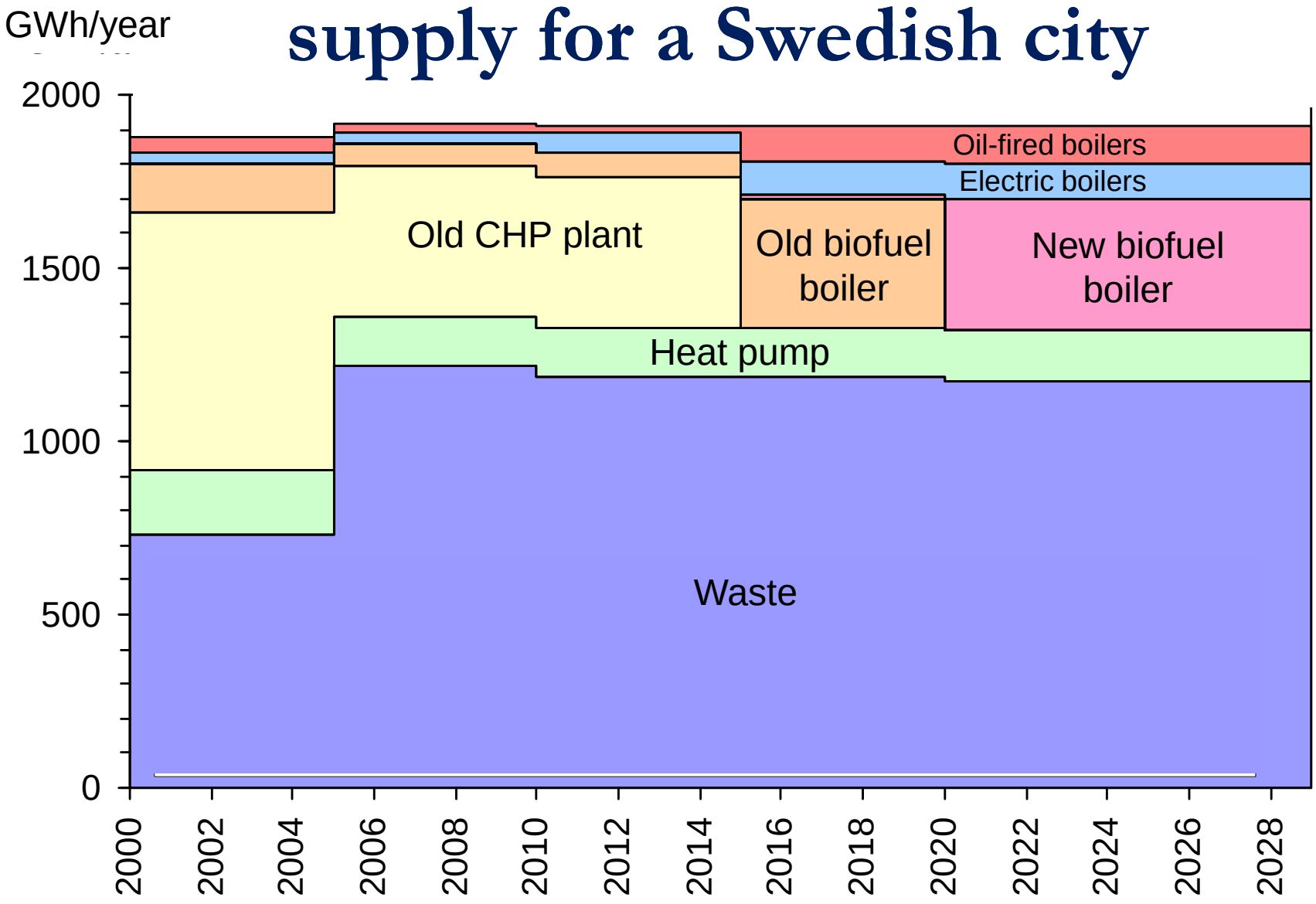


MODEST optimisation result

Possibilities to increase heat demand and utilisation time for CHP production



Long-term district-heating supply for a Swedish city



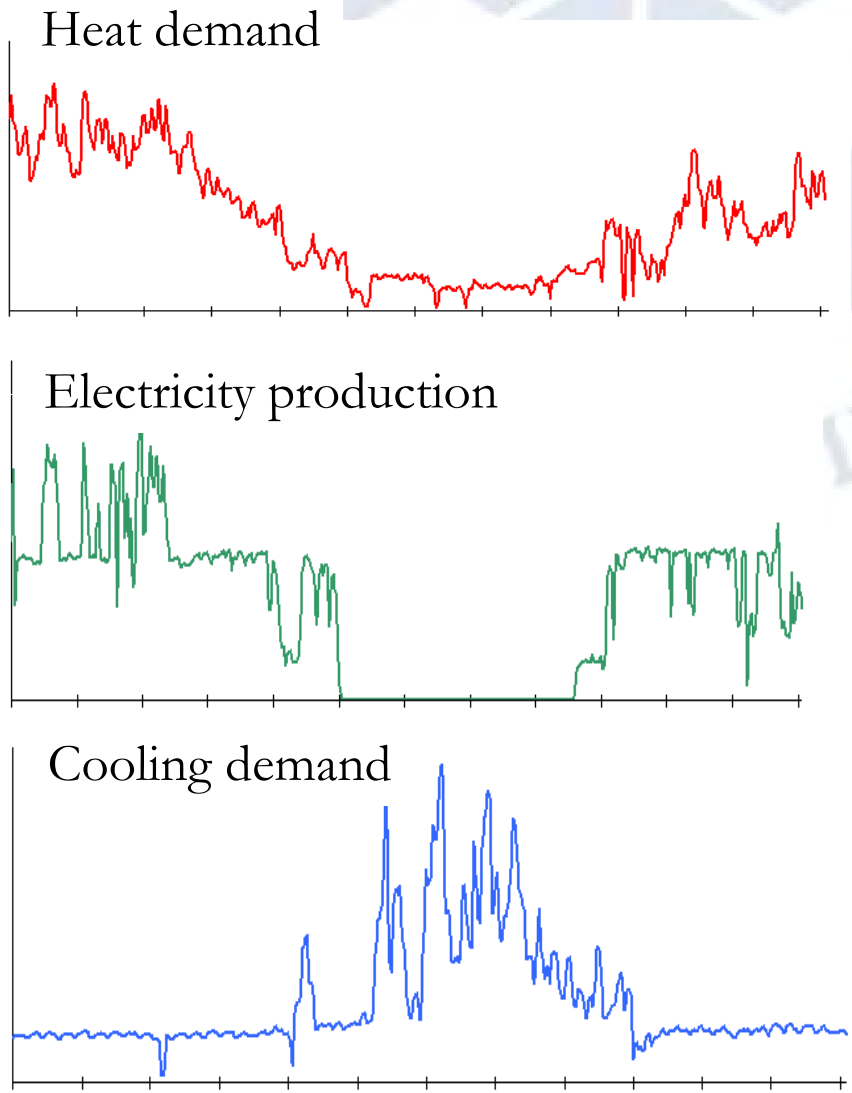
MODEST optimisation result

Absorption Cooling in CHP systems

Old technique with new opportunities

Windows of opportunity for AC in Sweden

- The need for cooling is growing
- Rising electricity prices
- Possibilities to further electricity production in CHP systems
- A surplus of heat in summer



Aim

The aim of this study is to analyse the economic and environmental impacts of introducing absorption chillers into a CHP system in a Swedish municipality.

Case study

- Local energy utility owned by one of the largest energy suppliers in Sweden

- The studied energy utility produces annually

  450 GWh of electricity

  1090 GWh of district heating

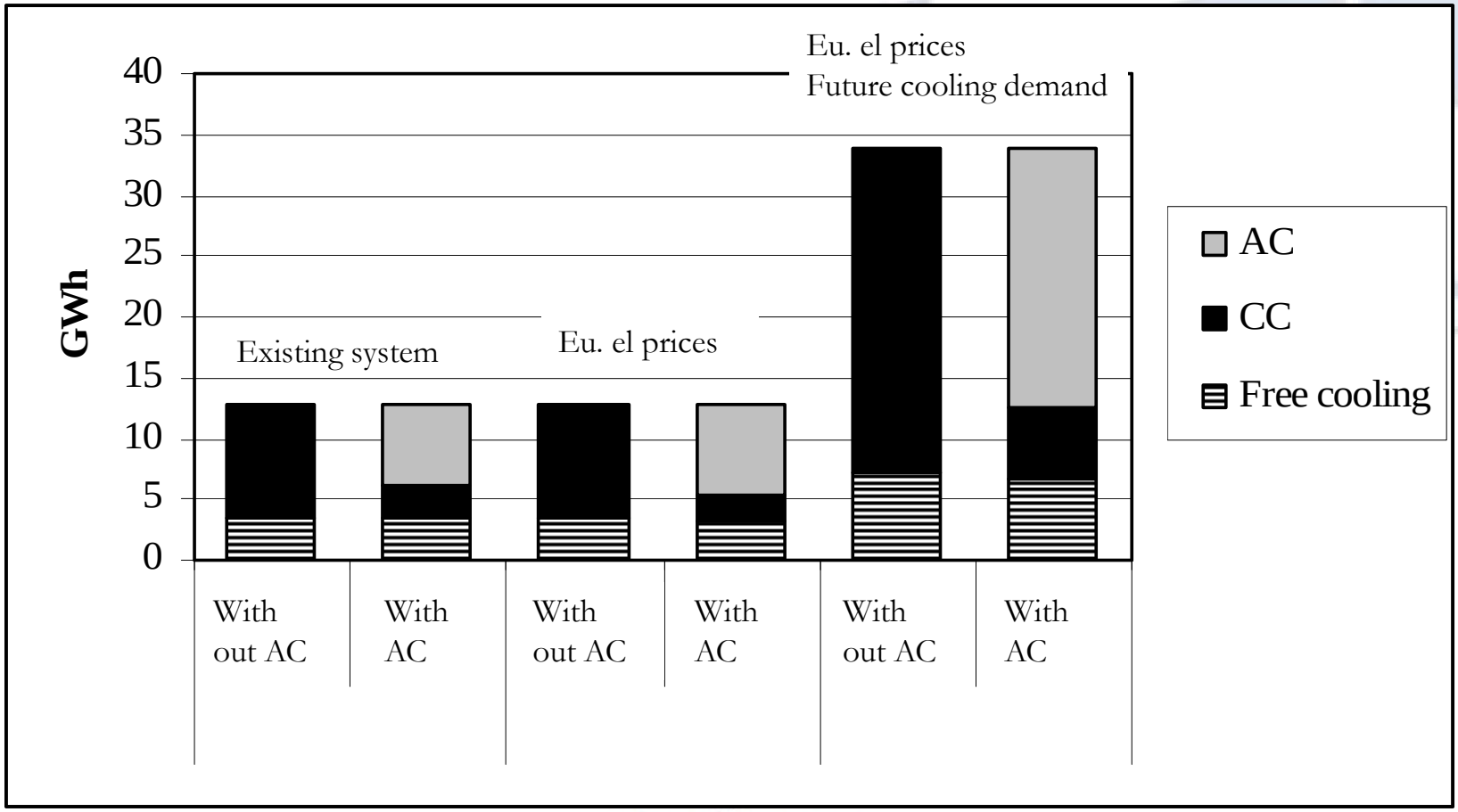
  13 GWh of district cooling

- Future investments plans

  New CHP plant for mix waste incineration

  New compression chillers (CC) or new absorptions chillers (AC)

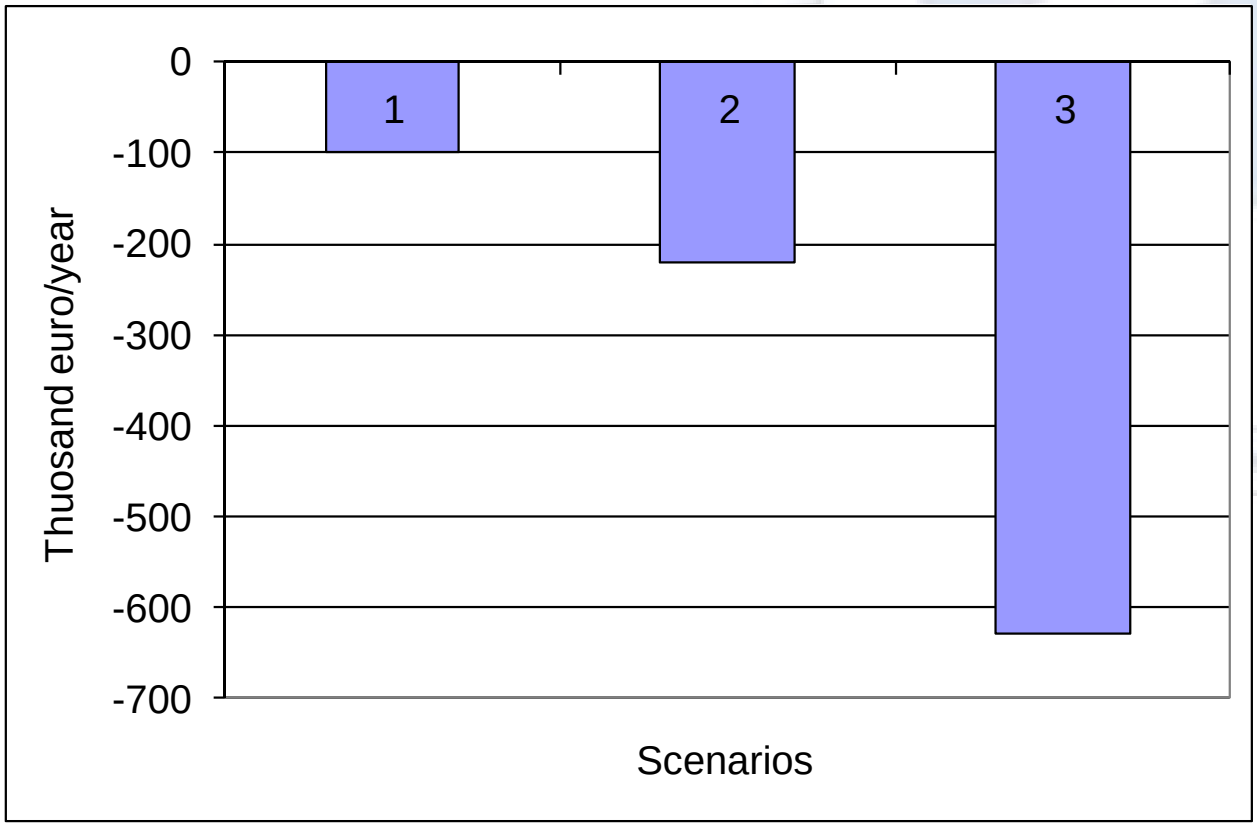
System-optimal production of cooling



Extra electricity generation when introducing AC

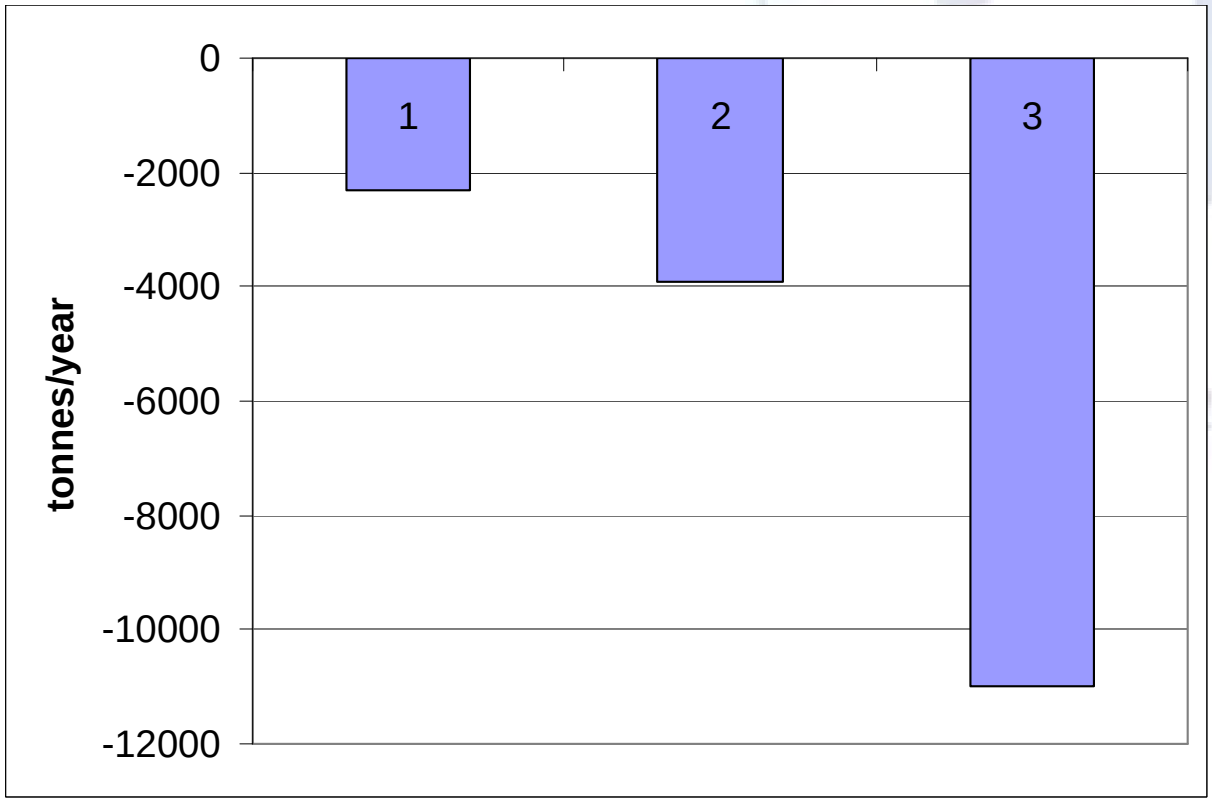
Scenario	Description	Electricity surplus [GWh/year]
1	Existing system	2.6
2	European electricity prices	4.7
3	European electricity prices and cooling demand	13.4

Effects on system cost when introducing AC



1 Existing energy system
2 European electricity prices
3 European electricity prices, higher cooling demand

Effects on global CO_2 emission when introducing AC



1 Existing energy system
2 European electricity prices
3 European electricity prices, higher cooling demand

Modelling of a Swedish Biogas System

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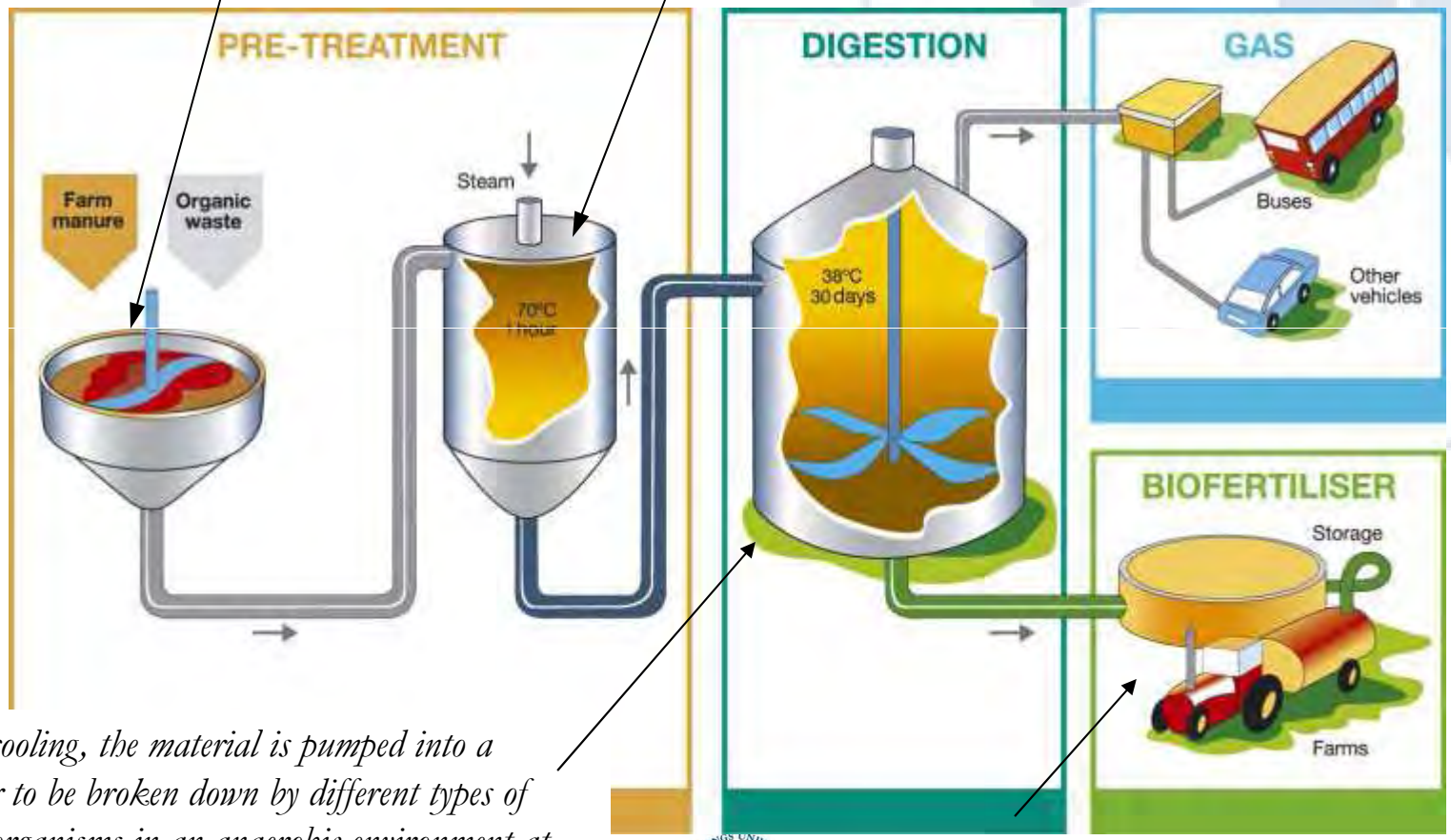
Objectives

- The objectives of this study are:
  - to present a model for a biogas system in order to achieve a cost-efficient system, and
  - to analyse the conditions for connecting a combined heat and power (CHP) plant to the biogas system.

Biogas System in Linköping, Sweden

The material is mixed into homogeneous slurry in a reception tank.

After which it is pasteurised for 1 hr at 70°C by heating, in order to kill bacteria

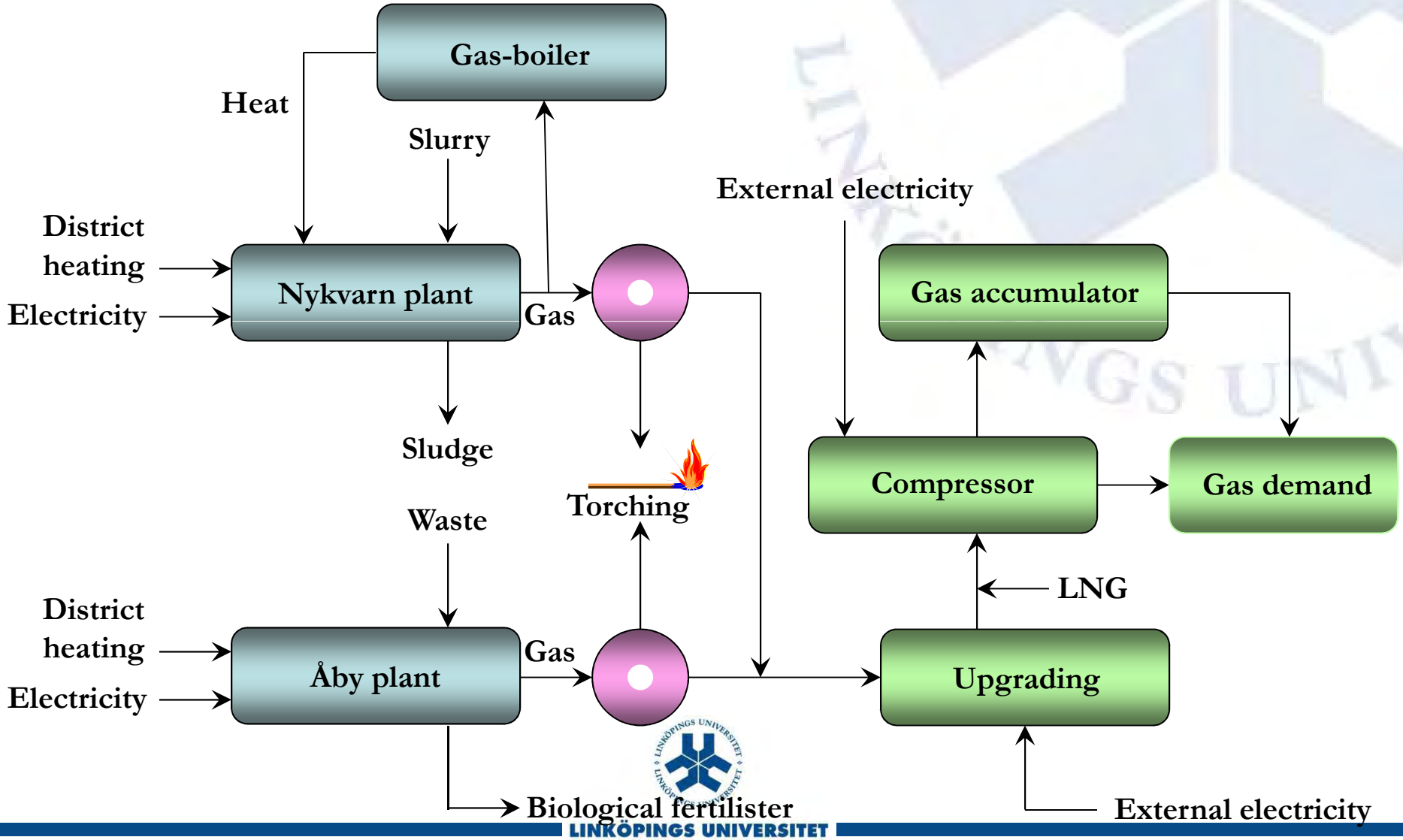


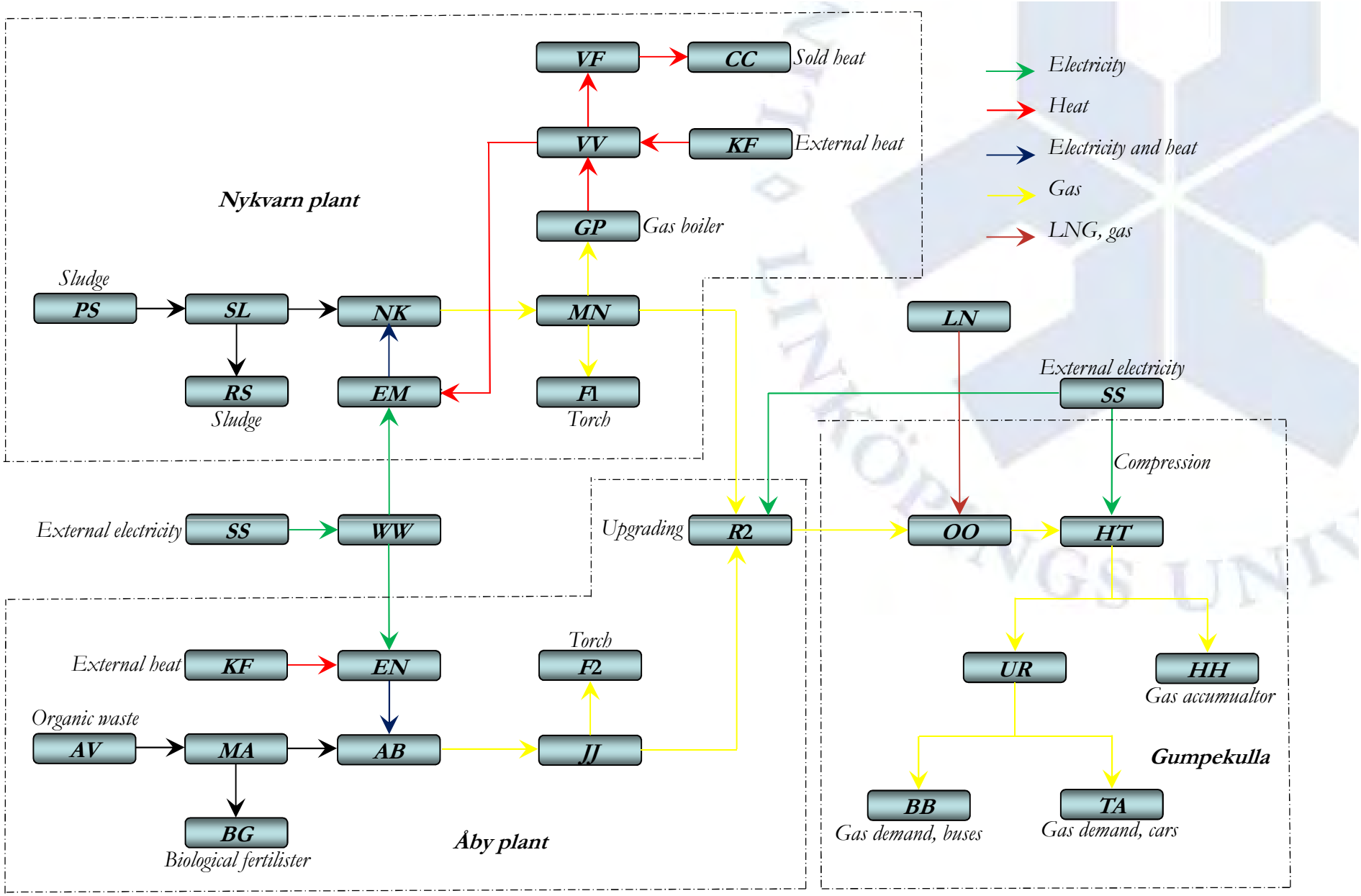
After cooling, the material is pumped into a digester to be broken down by different types of micro-organisms in an anaerobic environment at about 38 °C.

The material remaining after the digestion process is transported back to farmers and used as bio-fertiliser

Simplified view of biogas process at the biogas plant (Åby) in Linköping

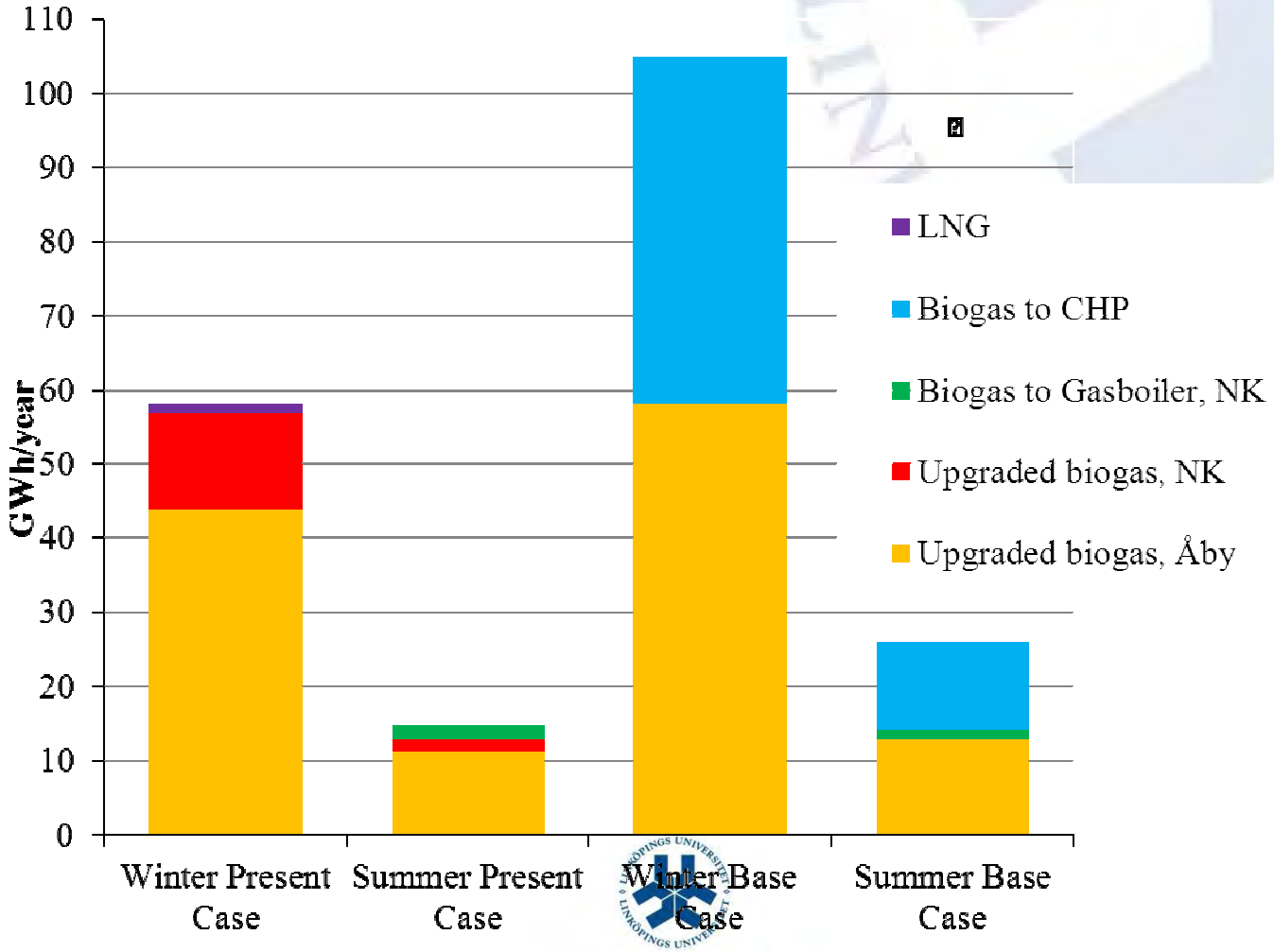
Simplified view of biogas production in Linköping

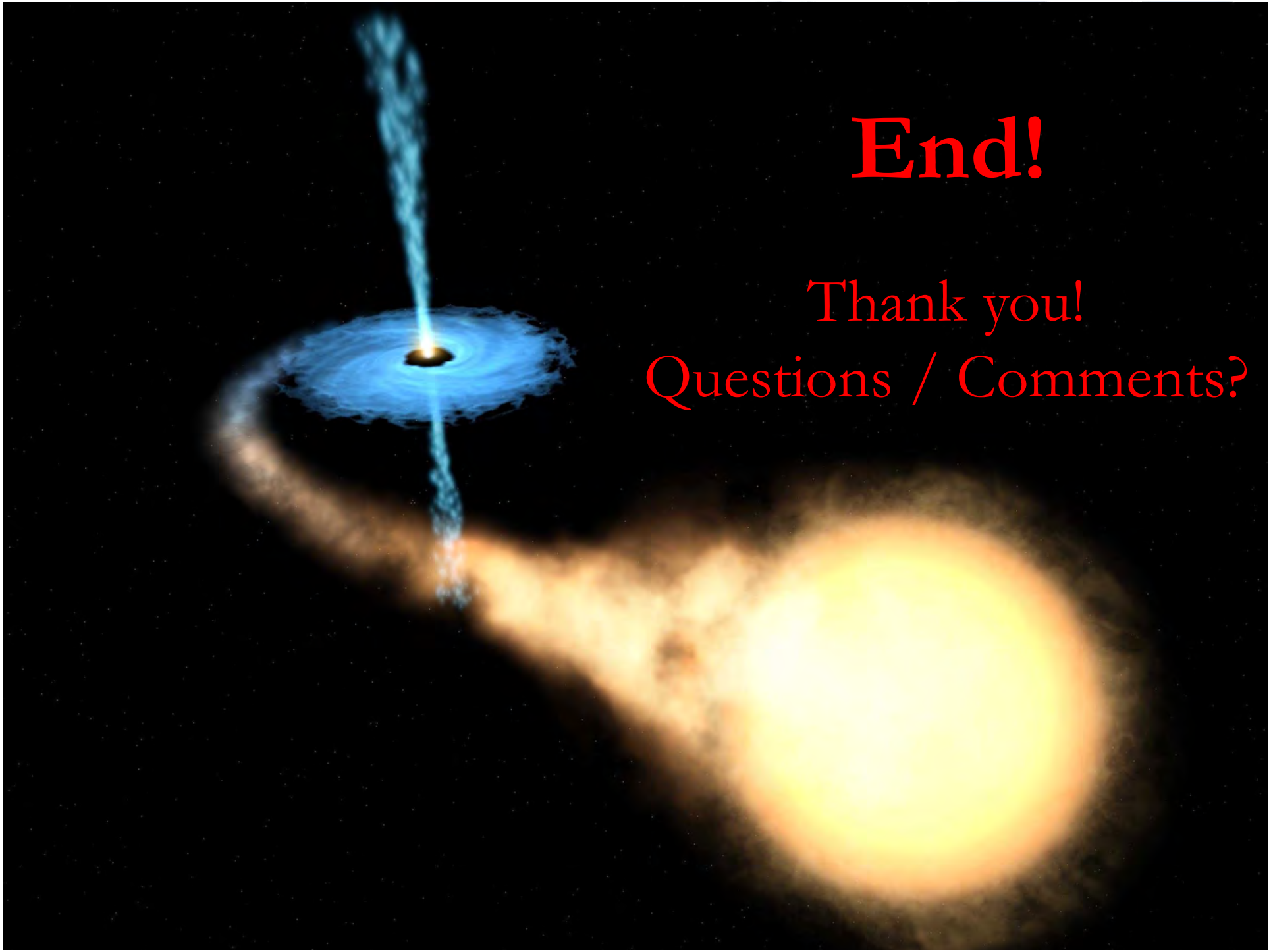




Components, as well as material, gas and other energy-carrier flows in the MODEST model of the biogas system in Linköping

Biogas production for Present and Base case in Linköping




End!
Thank you!
Questions / Comments?