INTERNATIONAL ENERGY AGENCY
Implementing Agreement on PROCESS INTEGRATION

Annex V - Energy Systems Integration between Society and Industry including Cogeneration Systems and Power Plants

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IEA definition of Process Integration

Systematic and General Methods for Designing Integrated Production Systems, ranging from Individual Processes to Total Sites, with special emphasis on the Efficient Use of Energy and reducing Environmental Effects.

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Annex Ⅴ : Energy Systems Integration between Society and Industry including Cogeneration and Power Plants

Objectives:

- Produce a survey of available computer programs.
- Develop generic methodologies for optimal use of industrial waste heat in industry and society.
- Identify important technical, economic and environmental parameters for optimal use of industrial waste heat.
- Develop tools to analyse how to adapt cogeneration at industrial sites.
- Use and evaluate developed methodologies and tools in selected case studies.

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Annex Ⅴ : Energy Systems Integration between Society and Industry including Cogeneration and Power Plants

Scope:

- Identify optimal design of cogeneration units.
- Optimise the design of short/long term heat storage systems between cogeneration units and process industries.
- Develop methods for load managament between industry and community, including heat storage.
- Study the environmental consequences of different solutions.

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Annex V: Case studies

- Carriço, Portugal
  - cogeneration system and salt recrystallistation process
- Sudbury and Toronto, Ontario, Canada
  - district heating, cascading loads and buildings
- South Karelia, Finland
  - pulp and paper plant and district heating system

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Case study – Carriço, Portugal

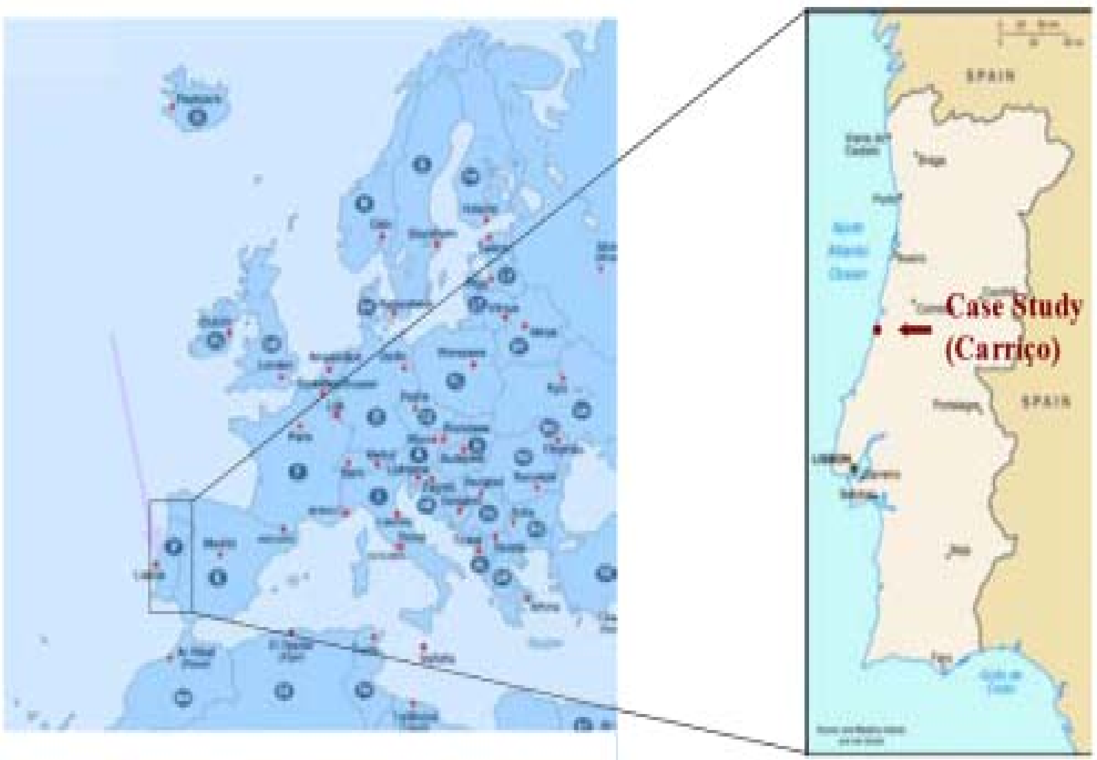
Objective

Identify the best operational conditions of a cogeneration system to optimise the integration with a salt cavern storage and a salt recrystallisation process

Case study – Carriço, Portugal

Brief description

- A natural gas salt cavern storage (Transgás)
- A gas turbine cogeneration system (Galp power)
- A salt recrystallisation process (Renoeste)



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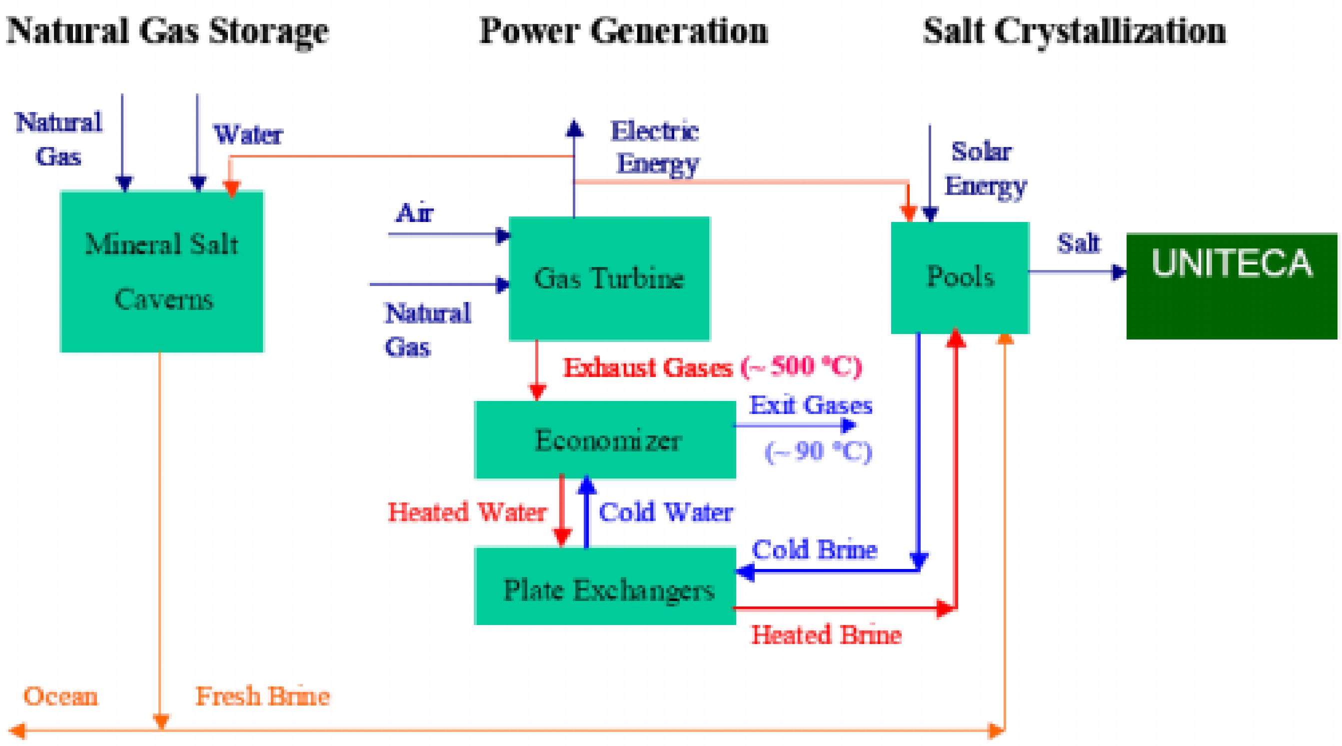
Case study – Carriço, Portugal

The integrated system



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Case study – Carriço, Portugal
Conclusions

- Air temperature has a strong influence on the system
  - an increase of 10ºC in T_{air} causes a reduction of almost 10% in the electric power
- The minimum number of pools necessary to start-up strongly depends on the atmospheric conditions considered (never less than 3)
- Possible to define an improved set of operational conditions to obtain a long-term profitable business

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Case study – Sudbury and Toronto, Ontario, Canada

Objective

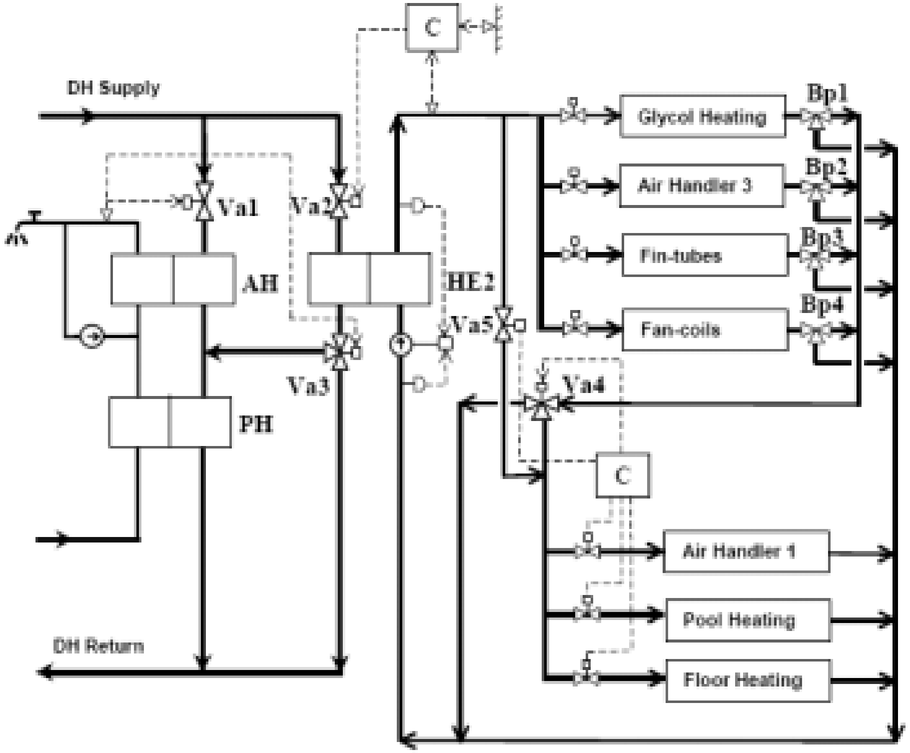
- Identify the most important technical, economic and environmental parameters influencing the optimal use of CHP-plants linked to a district heating system
- Keeping in mind: Effective district heating system has two primary distinguishing features:
  - Low operating temperatures (both supply and return)
  - High temperature difference (ΔT) between supply and return

Case study – Sudbury and Toronto, Ontario, Canada
Brief description

- Case 1
  - Location: Sudbury
  - Large multifunctional buildings
  - Combined cycle gas turbine
  - 5 DH substations and building heating system connection schemes
- Case 2
  - Location: Toronto
  - Small commercial building
  - Internal combustion engine
  - 2 DH substations and building heating system connection schemes

Case study – Sudbury and Toronto, Ontario, Canada

Example Connection scheme (Case 1)



- Large multifunctional building (school, swimming pool, rehabilitation centre, daycare)
- Two heating levels (cascading)
  - Level 2: Air handler 1, pool water heating, floor heating system (require lower temperature)

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Case study – Sudbury and Toronto, Ontario, Canada

Results

- Optimum design of building heating systems could lead to optimal use of waste heat.
- Important factors for yearly overall ?T improvement:
  - required temperature level of different thermal loads
  - magnitude of different loads
  - time-of-day usage patterns of different loads

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Case study – Sudbury and Toronto, Ontario, Canada

Conclusions

- Optimal design of building heating system is a very important factor regarding the performance of a CHP plant
- Cascading has its greatest effect when the loads are required for a major portion of the year

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Case study – South Karelia, Finland

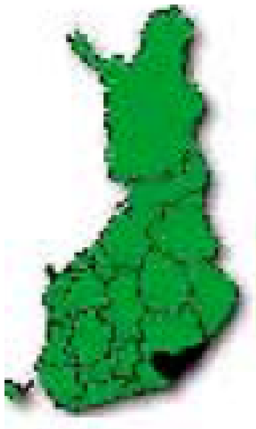
Objectives

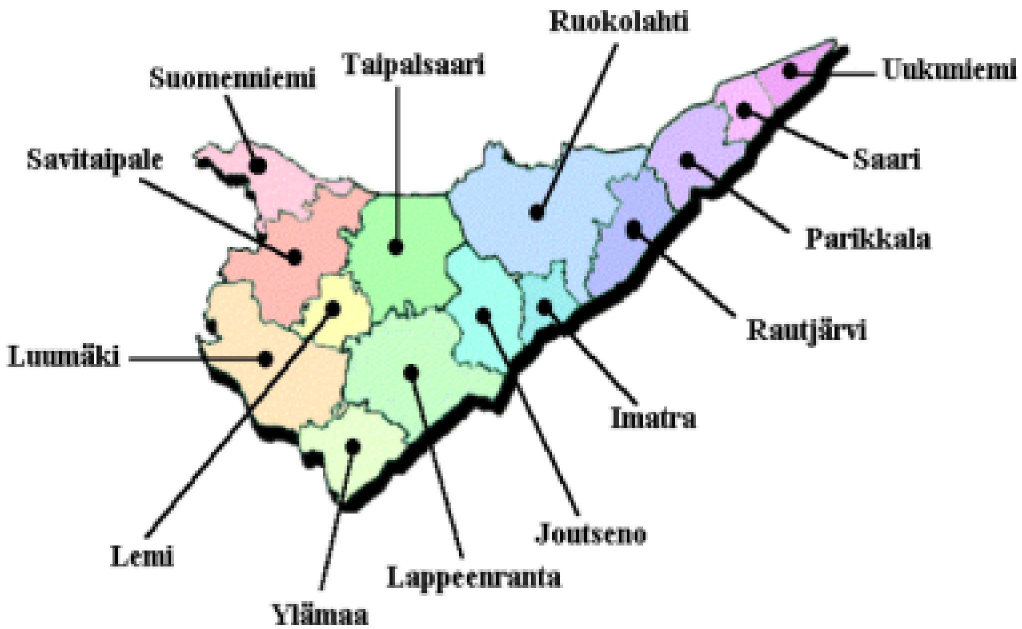
- Investigate investments regarding a new boiler and new turbines and connecting UPM-kymmene Kaukas industry integrate with the district heating system in the city of Lappeenranta, South Karelia, Finland

Case study – South Karelia, Finland

South Karelia

- Population: 137.000
- Total amount of jobs 53.630 (17.000 in industry)
- Forest industry major industy in the region





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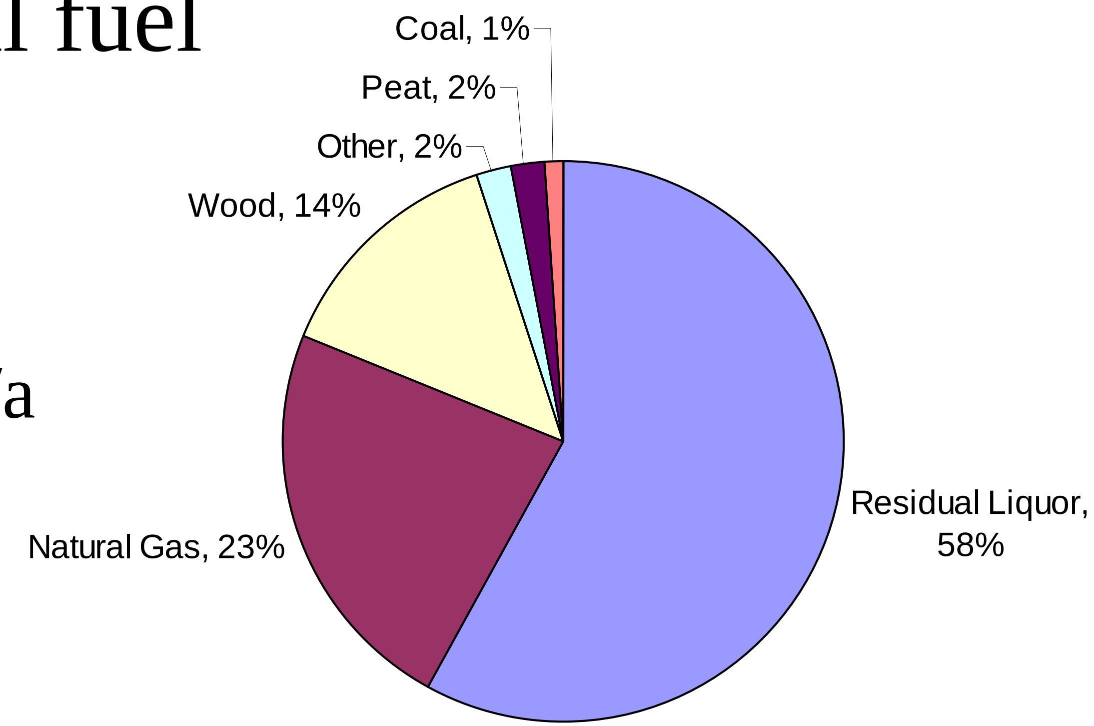
Case study – South Karelia, Finland

South Karelia

Industrial and municipal fuel consumption in 1999:

- Gross 17433 GWh/a
  - External fuel 4700 GWh/a
    - natural gas 80%



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Case study – South Karelia, Finland

City of Lappeenranta

- Population 60.000
  - 90% of the inhabitants live in the central urban area and about 10% in the rural parts
- Area 848 km^2
- Jobs 26 200
  - about 20% in industry

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Case study – South Karelia, Finland

Lappeenrannan Energia

- 85% of inhabitants live in houses connected to the district heating network
- Natural gas fired power plant Mertaniemi:
  - electricity capacity: 180 MW
  - district heating capacity: 150 MW
- Energy sales 2001
  - District heating 510 GWh/a
  - Electricity 485 GWh/a

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Case study – South Karelia, Finland

UPM-Kymmene Kaukas (1/2)

- pulp and paper mills
- saw mill
- plywood mill
- chemical factory
- power plant
- effluent treatment plant

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Case study – South Karelia, Finland
UPM-Kymmene Kaukas (2/2)

- pulp mill
  - annual production 625.000 tons
  - two seperate fiber lines (birch and pine)
  - steam demand
    - High pressure steam: 37.3 MW
    - Medium pressure steam: 20.3 MW
    - Low pressure steam: 164.2 MW
- power plant
  - Turbines connected to Kraft recovery boiler: 73 MW
  - Bark boilers: 31 MW

Case study – South Karelia, Finland

Developed methodologies

- 1 method for local fuel availability and costs
- 3 methods for finding optimal process flowsheet
  - 1 method for flexible heat exchanger network synthesis
  - 2 methods for general process synthesis

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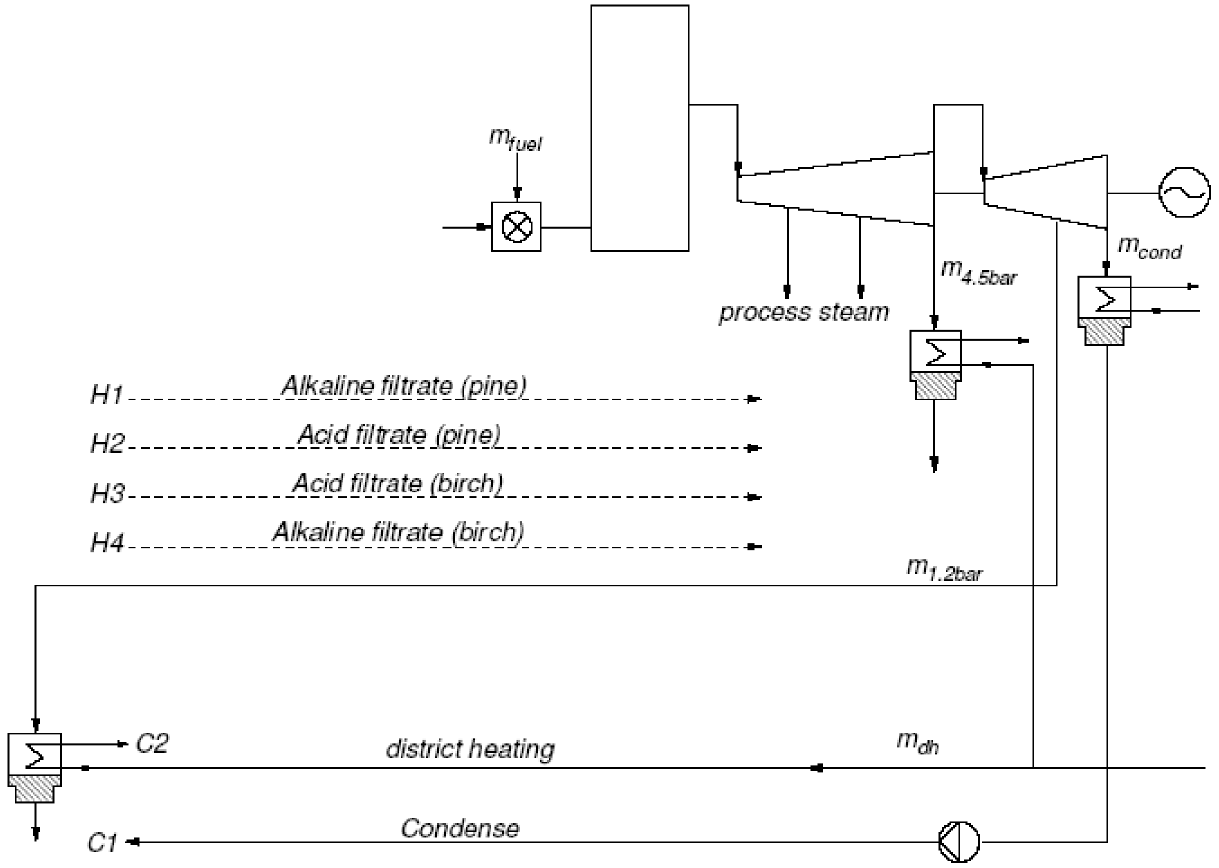
Case study – South Karelia, Finland

Superstructure of modified process



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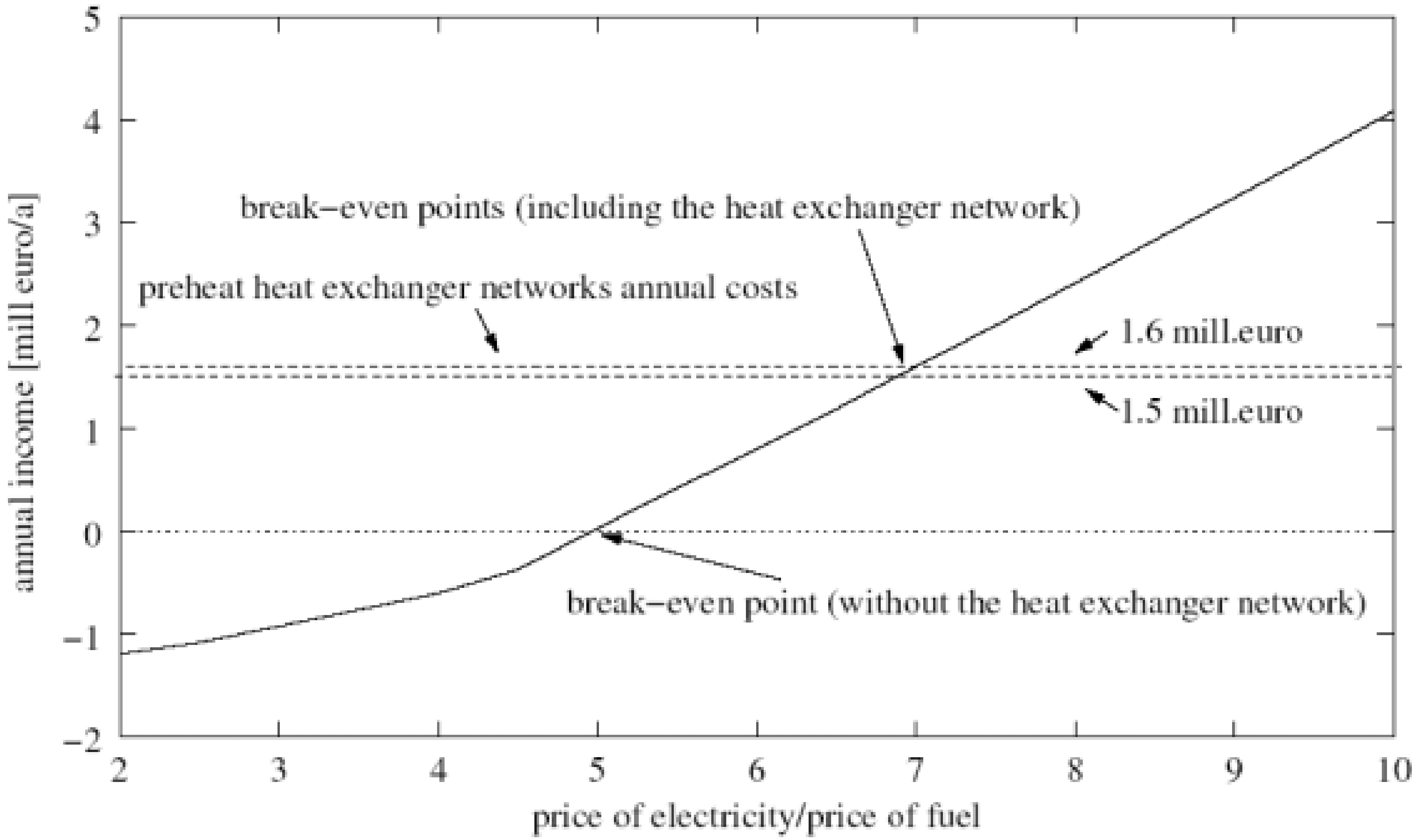
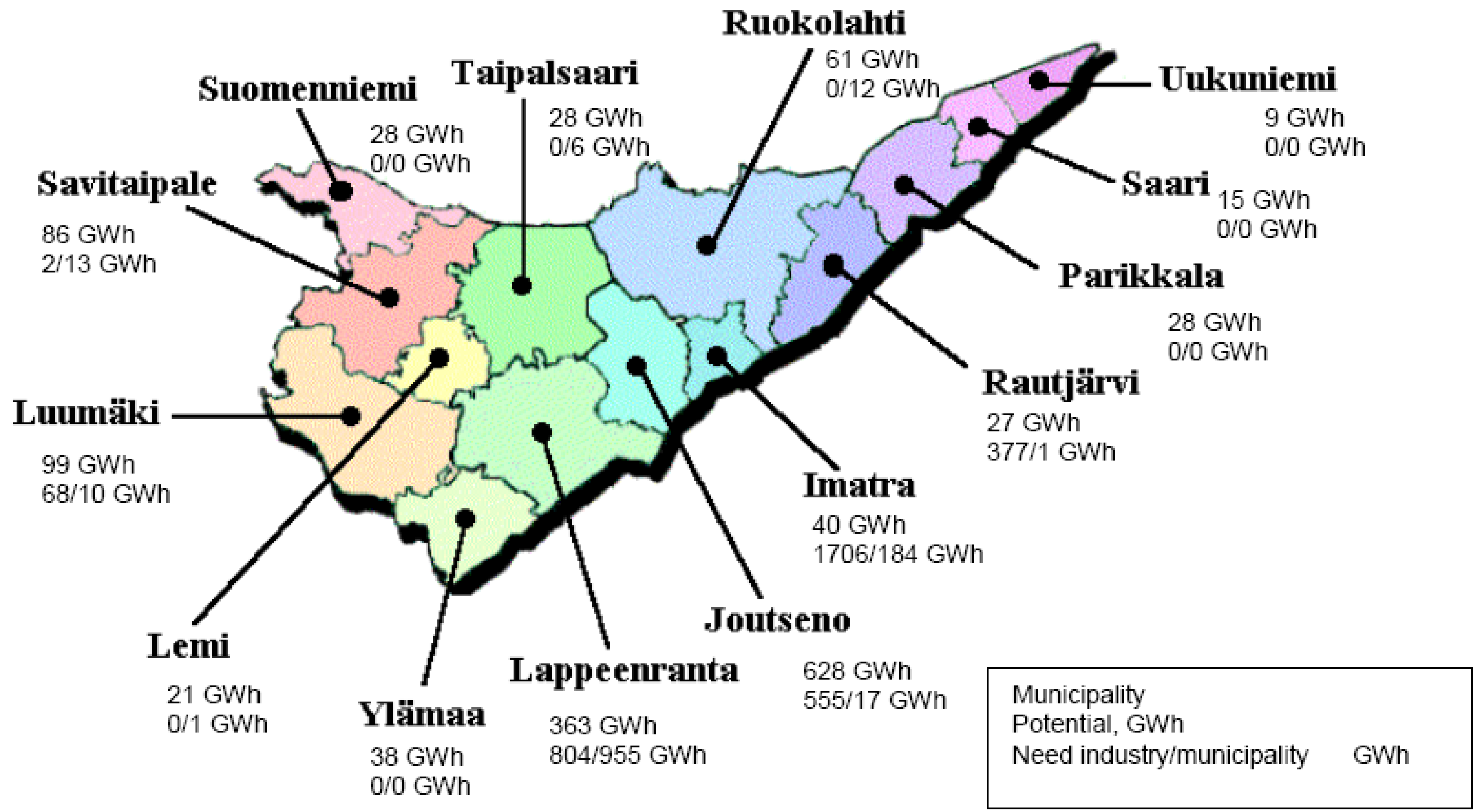
Case study – South Karelia, Finland

Results



Case study – South Karelia, Finland

Results



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Case study – South Karelia, Finland

Results

- Total external fuel need: 4.7 TWh/a
  - natural gas 80 %
- Total fuel demand for municipalities: 1.2 TWh/a
- Area's by-product fuel potential 1.2-1.5 TWh/a

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Case study – South Karelia, Finland

Conclusions

- Potential availability of forest by-product fuel:
  - 1.2 to 1.5 TWh/a (14100 to 17200 truck loads)
- Municipal production costs:
  - bark : 6.65 to 7.40 €/MWh (~900 to 1000 yen/MWh)
  - forest residual: 7.92 to 9.72 €/MWh (~1070 to 1310 yen/MWh)
- Investigated turbine and district heating investments feasible if electricity prices are 7 to 8 times higher than fuel costs
- Major steam savings only possible if heat transfer between the production process sections is allowed

Further information

- IEA Process integration homepage
  - http://www.iea-pi.org/
- Energy Engineering and Environmental Protection homepage
  - http://eny.hut.fi/