

Symposium Gas and Electricity Networks
19-23 May 2002, Brasilia

Energy Distribution Systems with Multiple Energy Carriers

Bjørn H. Bakken, PhD

Michael M. Belsnes, MSc

Jarand Roynstrand, MSc

SINTEF Energy Research

N-7465 Trondheim

Norway

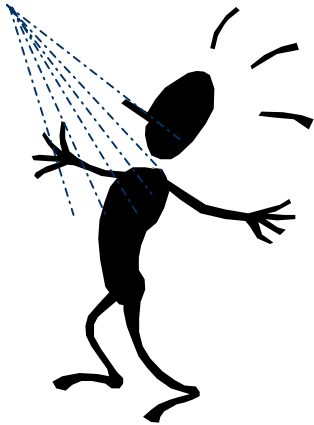
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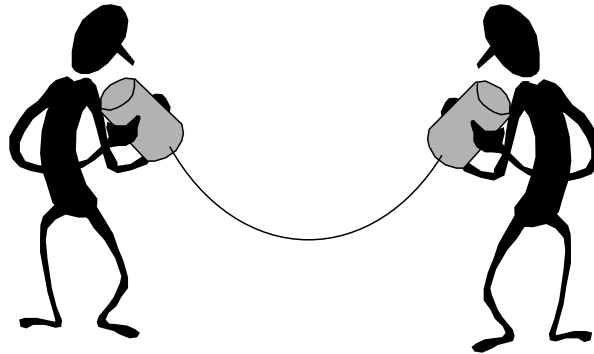
Background

- **New technologies for energy conversion, storage and transport are emerging**
 - ▶▶▶ better possibilities to design sustainable energy systems for the future
 - ▶▶▶ more complex energy systems to design, operate and maintain
- **An overall system perspective is necessary**
- **More flexible and comprehensive planning tools are needed**
- **New tool under development with detailed technology models combined in a generic linear network**

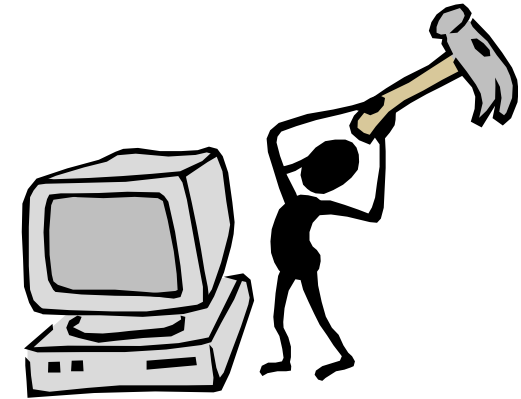
Customer needs are related to **use** and **comfort**, not specific forms of energy...



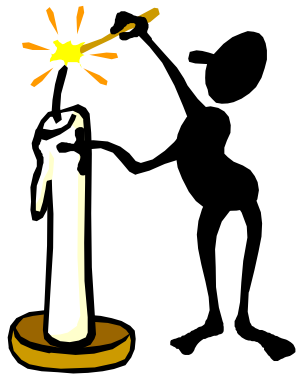
Hot water ...



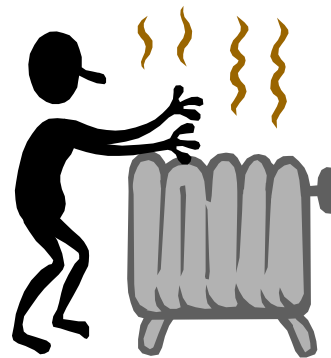
Communication ...



Data ...



Lighting ...

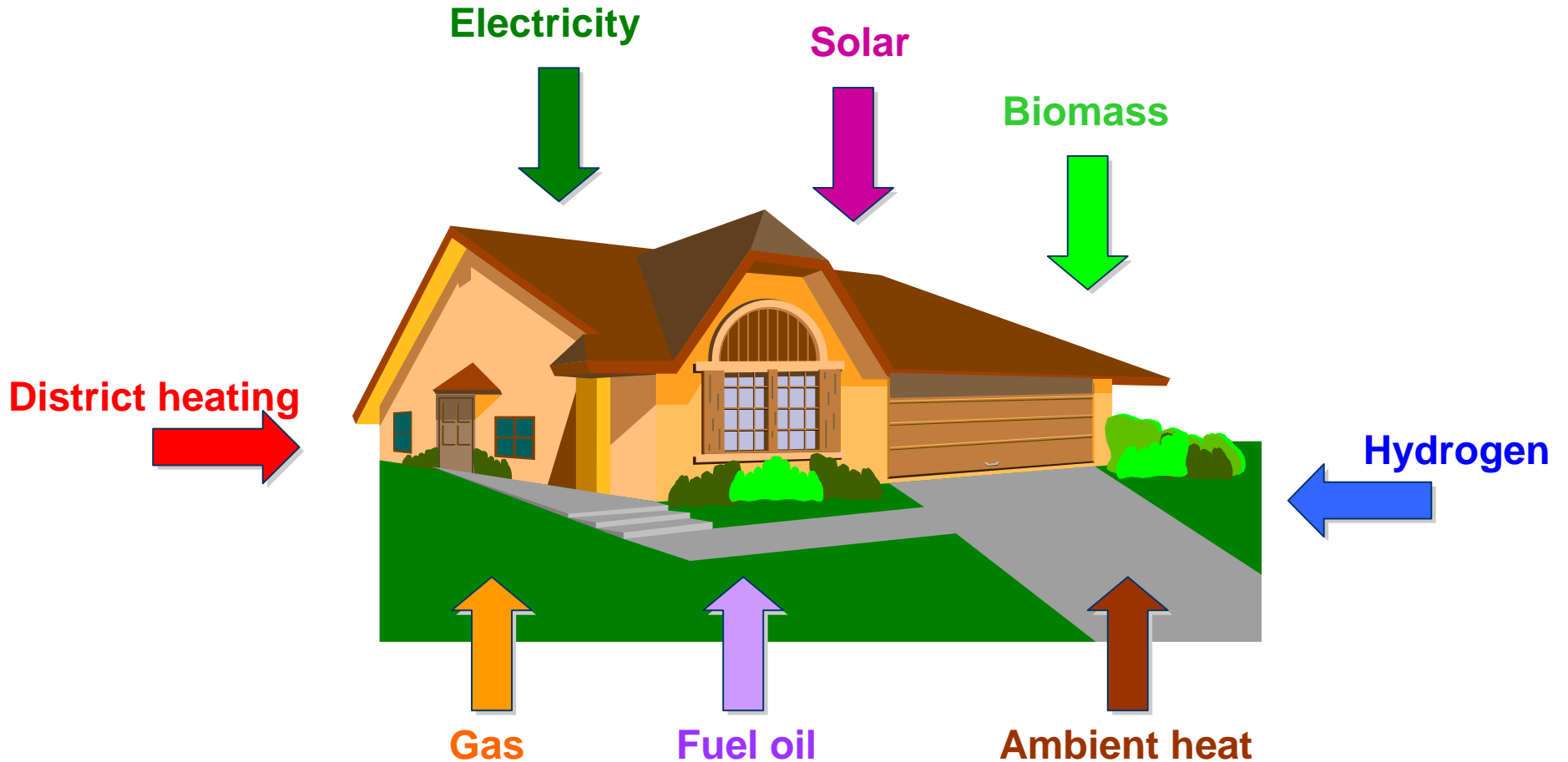


Heating ...

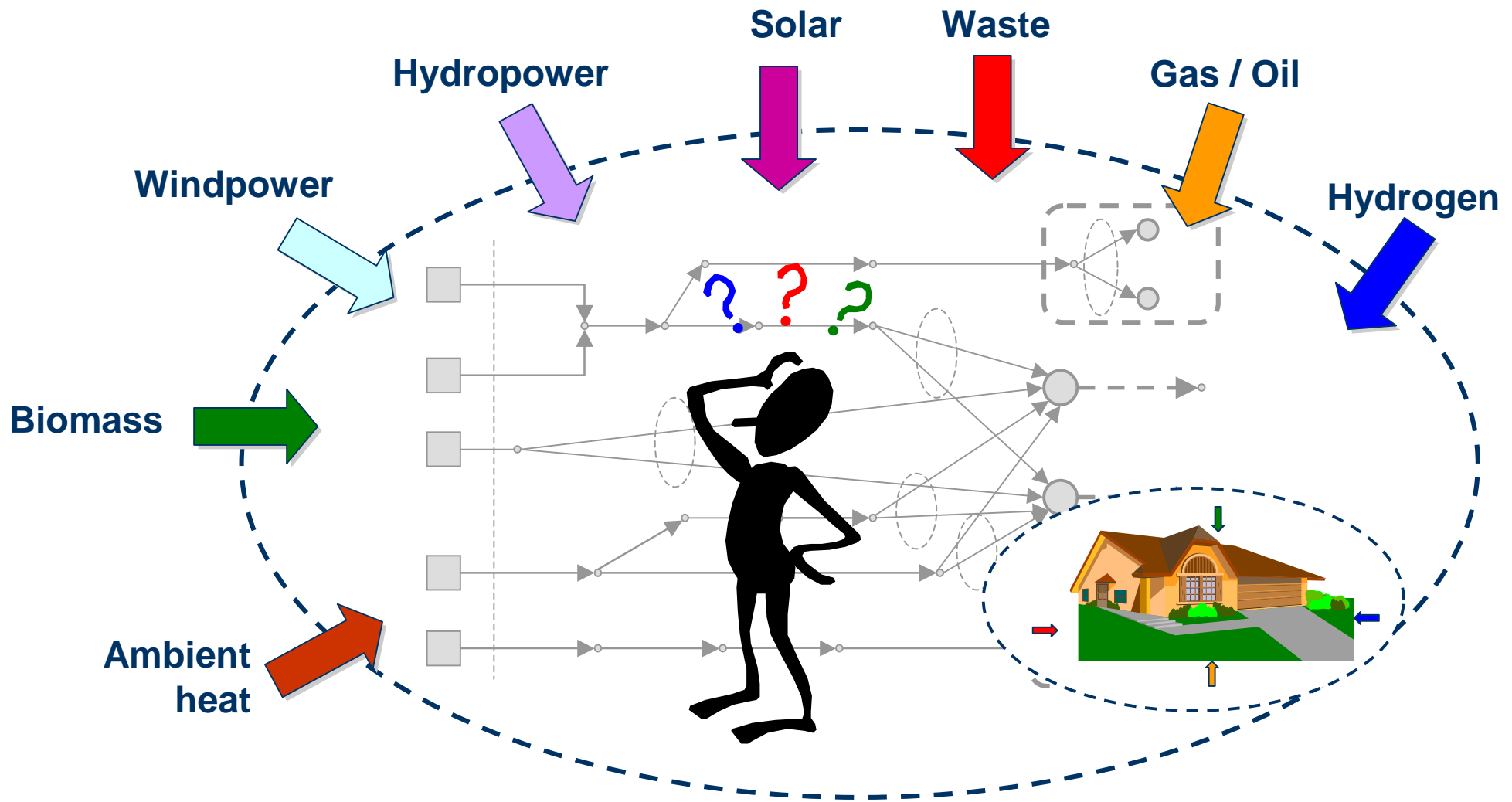


Cooking ...

Possible energy sources to end-users



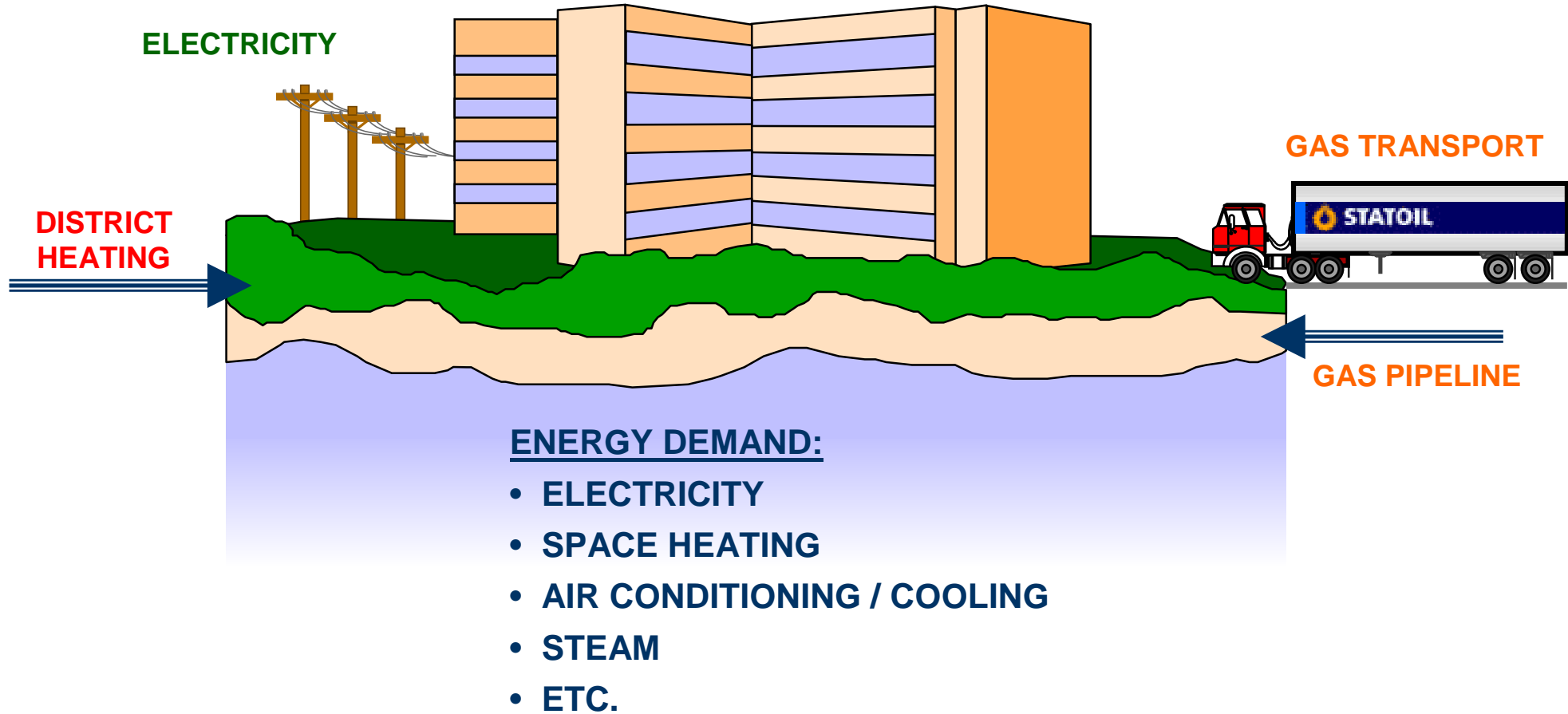
Possible local energy resources



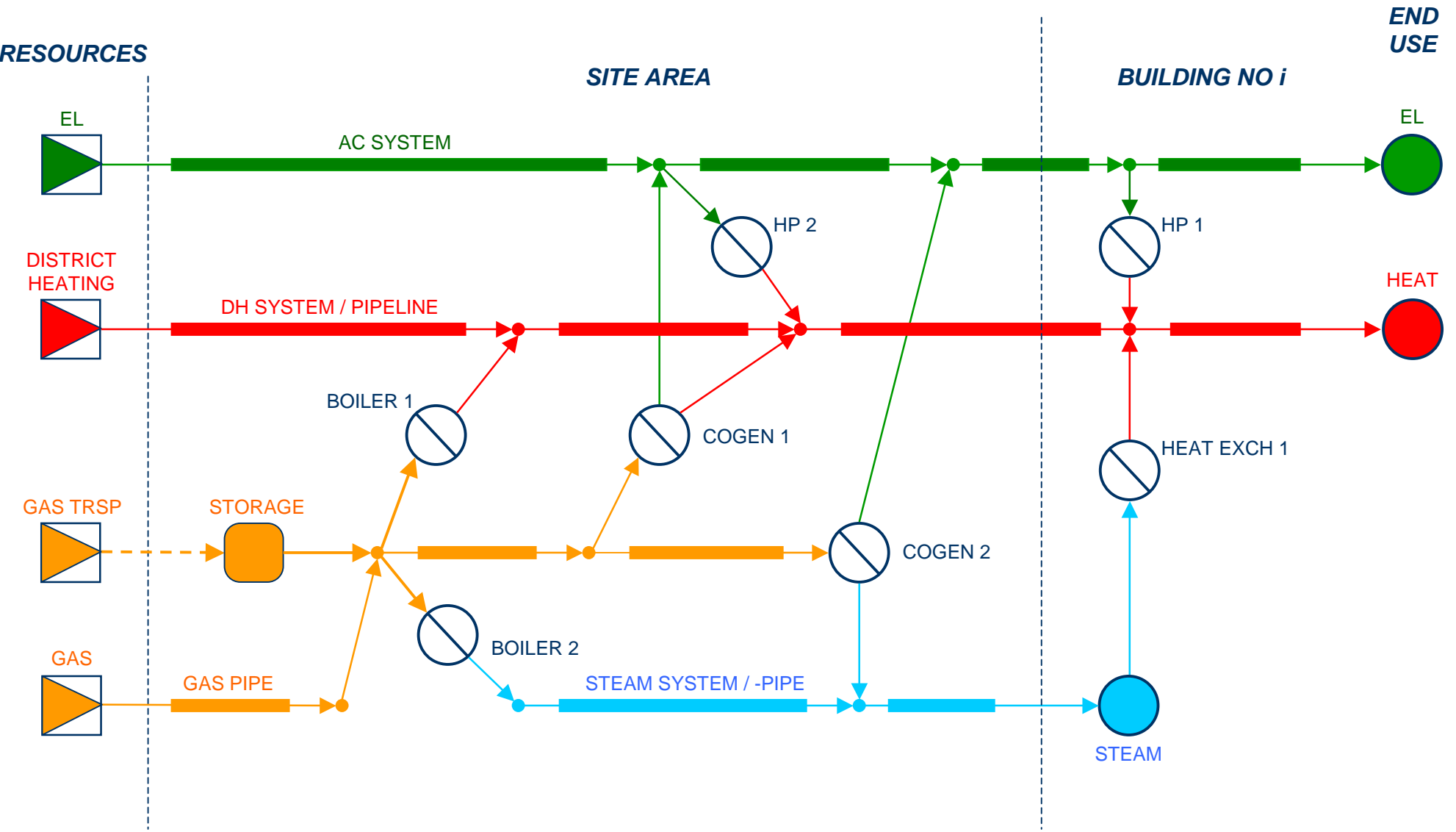
Methodology

- ▶ **OBJECTIVE: develop a flexible tool for analysis of complex energy systems with multiple energy carriers**
- ✓ generate system model with standard modules for **transport channels**, **energy conversion** processes and **storage** capacity
- ✓ detailed models of different energy technologies and energy carriers
- ✓ connection to superior system model through simple and uniform set of variables
- ✓ superior system analysis in a general network model
- ✓ multi-criteria optimization

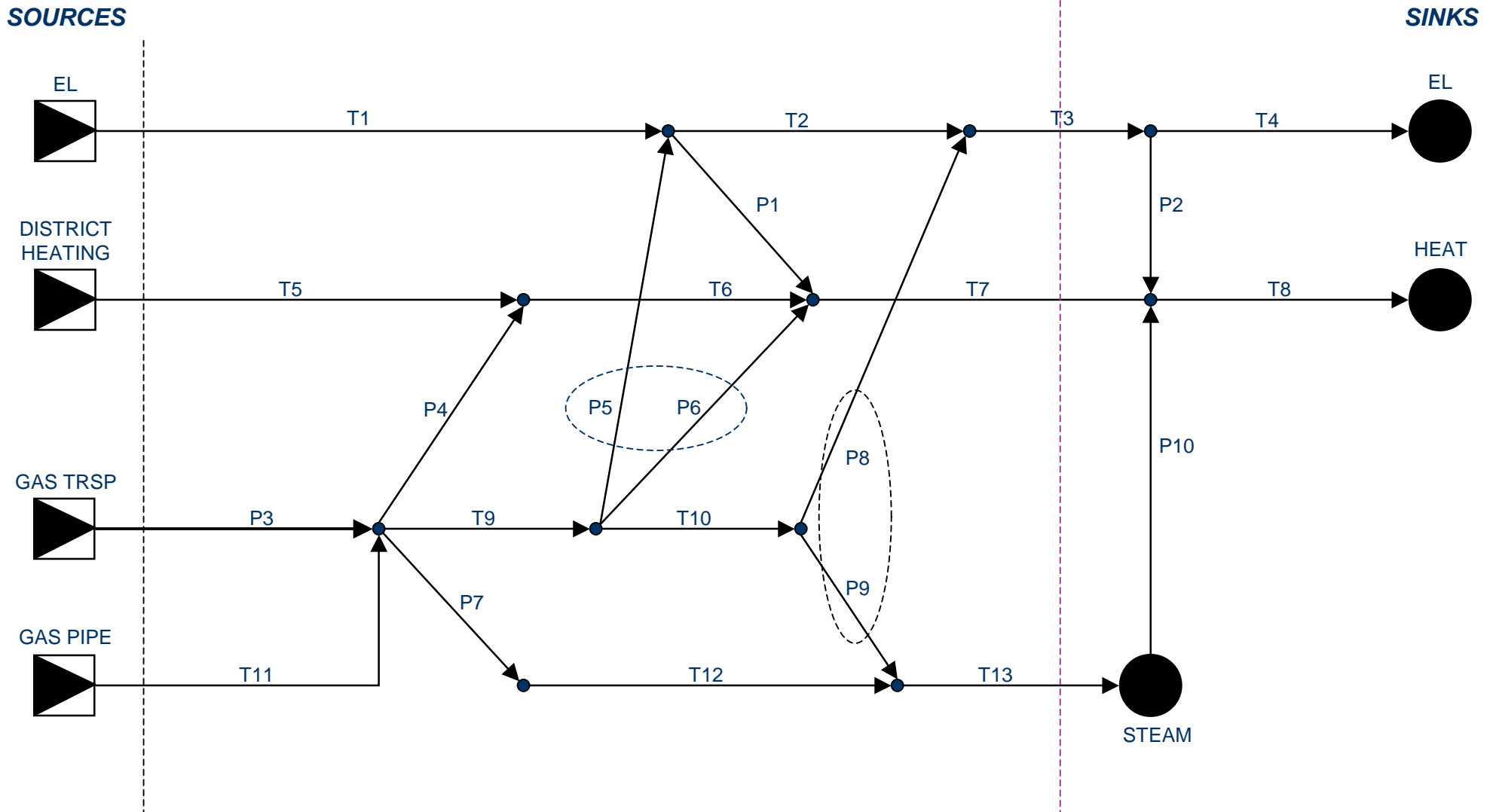
Sample: Energy supply to industrial site



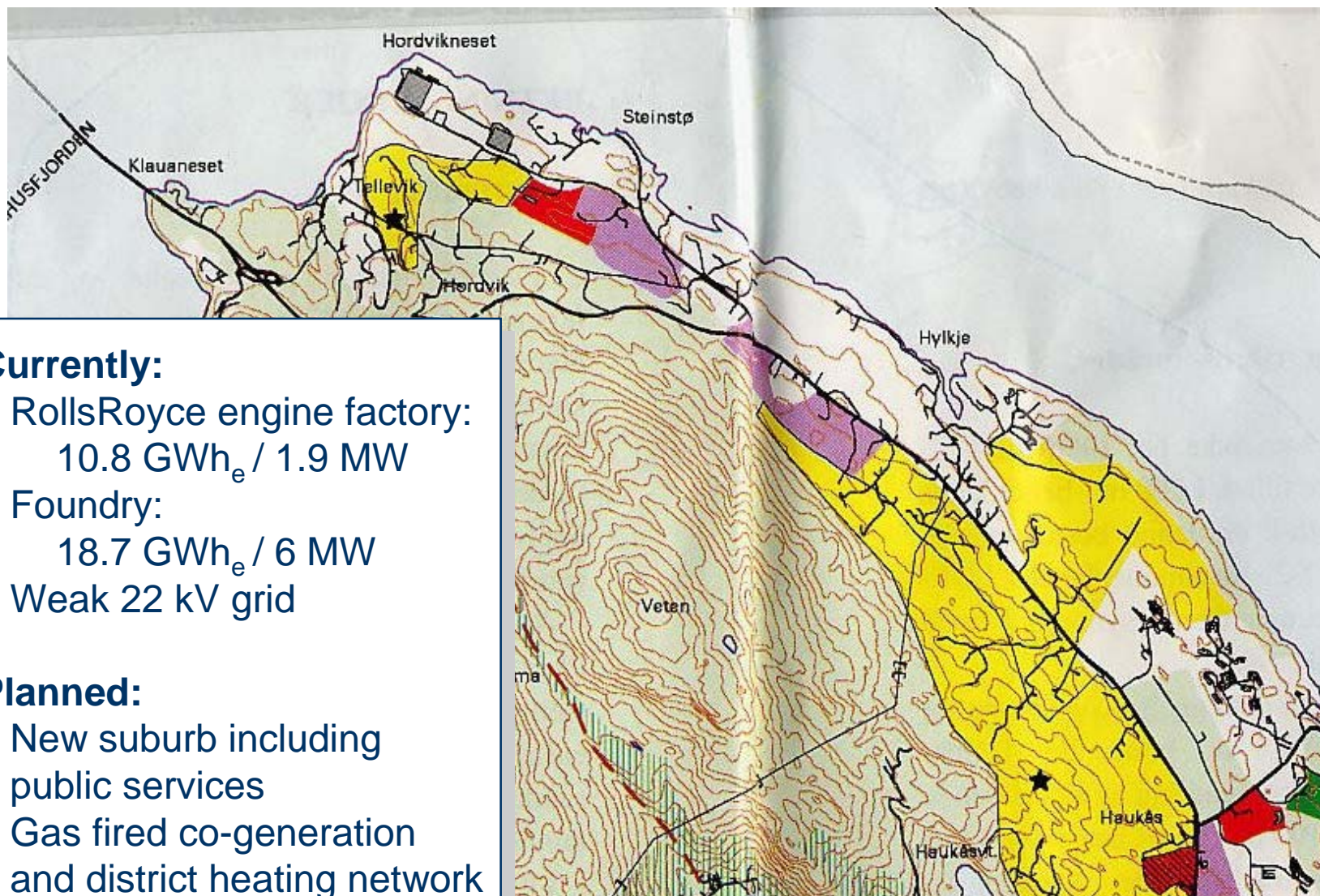
System model for industrial site



Network model for industrial site



Case: Hylkje suburb, Bergen



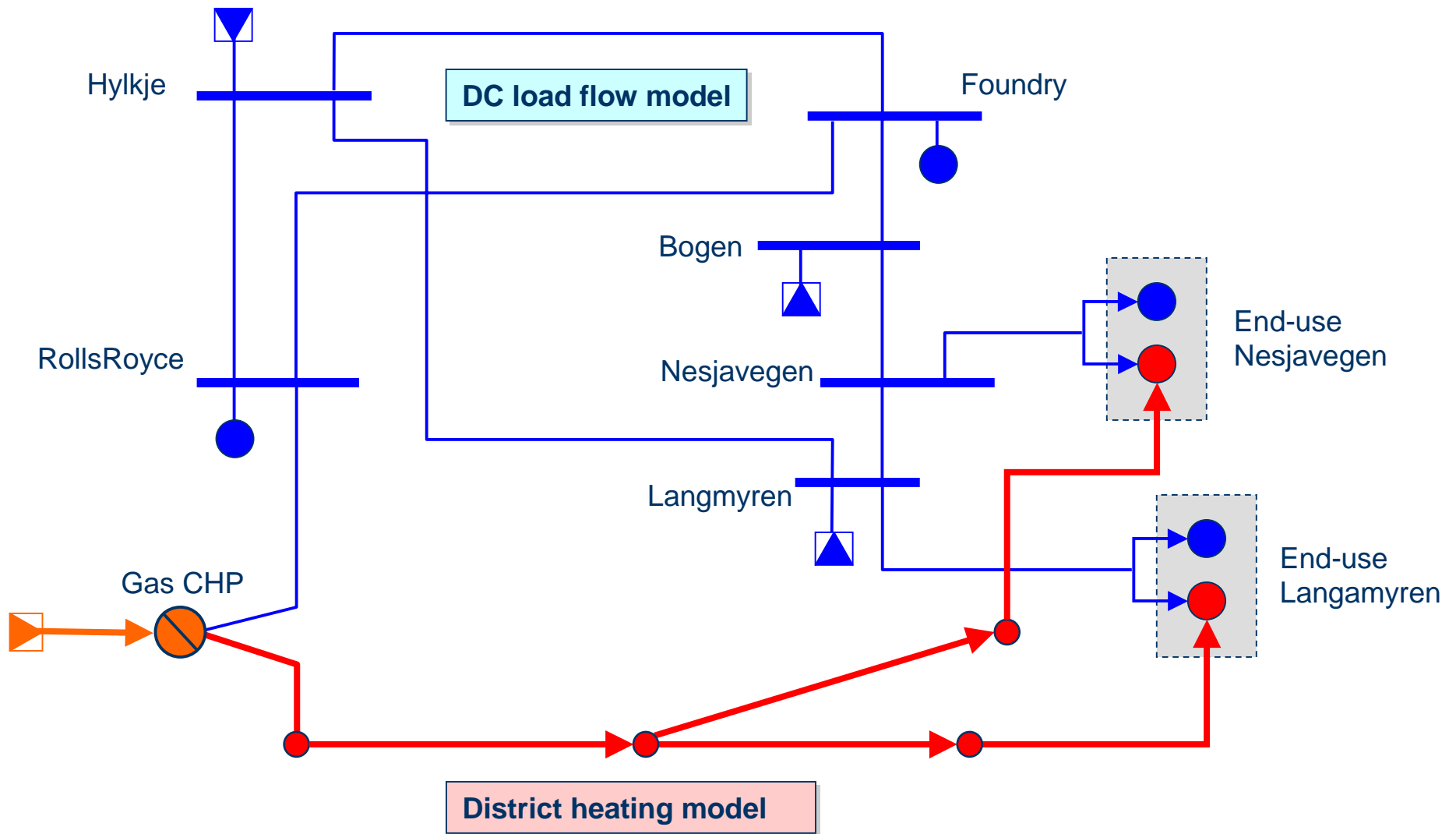
Currently:

- RollsRoyce engine factory:
10.8 GWh_e / 1.9 MW
- Foundry:
18.7 GWh_e / 6 MW
- Weak 22 kV grid

Planned:

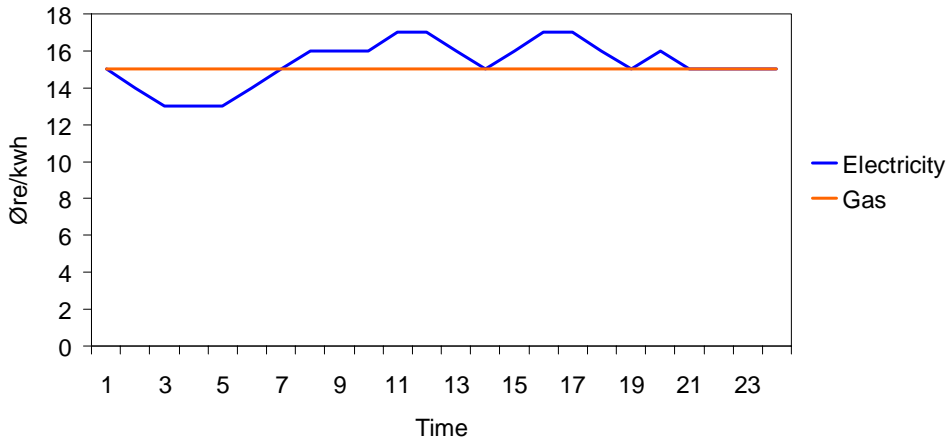
- New suburb including public services
- Gas fired co-generation and district heating network using surplus heat

Hylkje system model

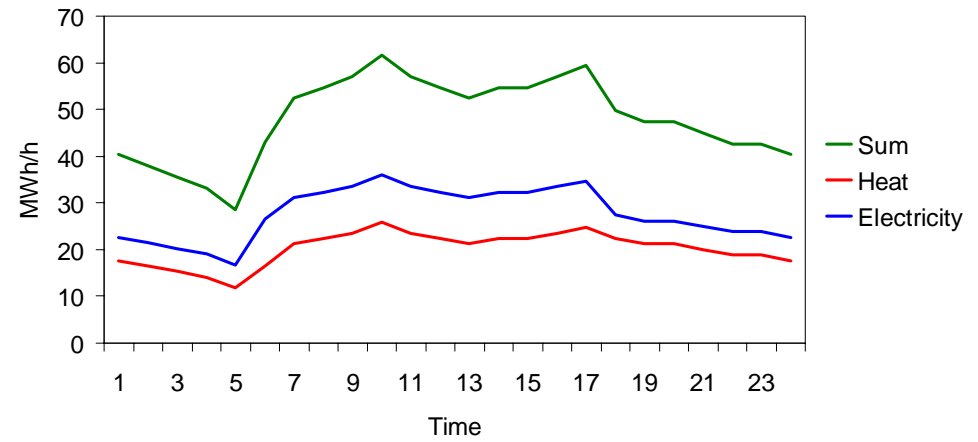


Hylkje sample results

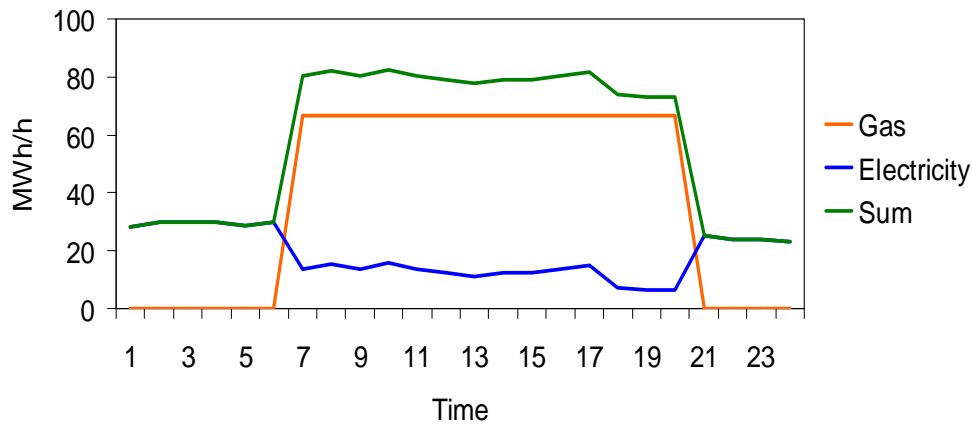
Energy price



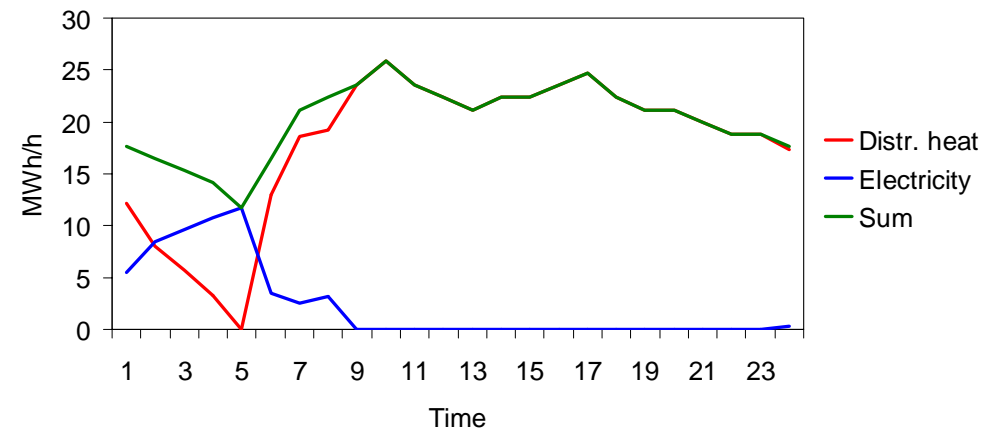
System Load



Energy purchase from sources



Energy for space heating



Summary

- Introduction of new technologies for energy conversion and transport creates more complex energy systems to design and operate
- More flexible and comprehensive tools are needed to handle multiple technologies
- New tool under development with standard modules for **transport channels**, **energy conversion** processes and **storage** capacity
- connection to superior system model through simple and uniform set of linear variables
- superior system analysis in a general network model
- multi-criteria optimization

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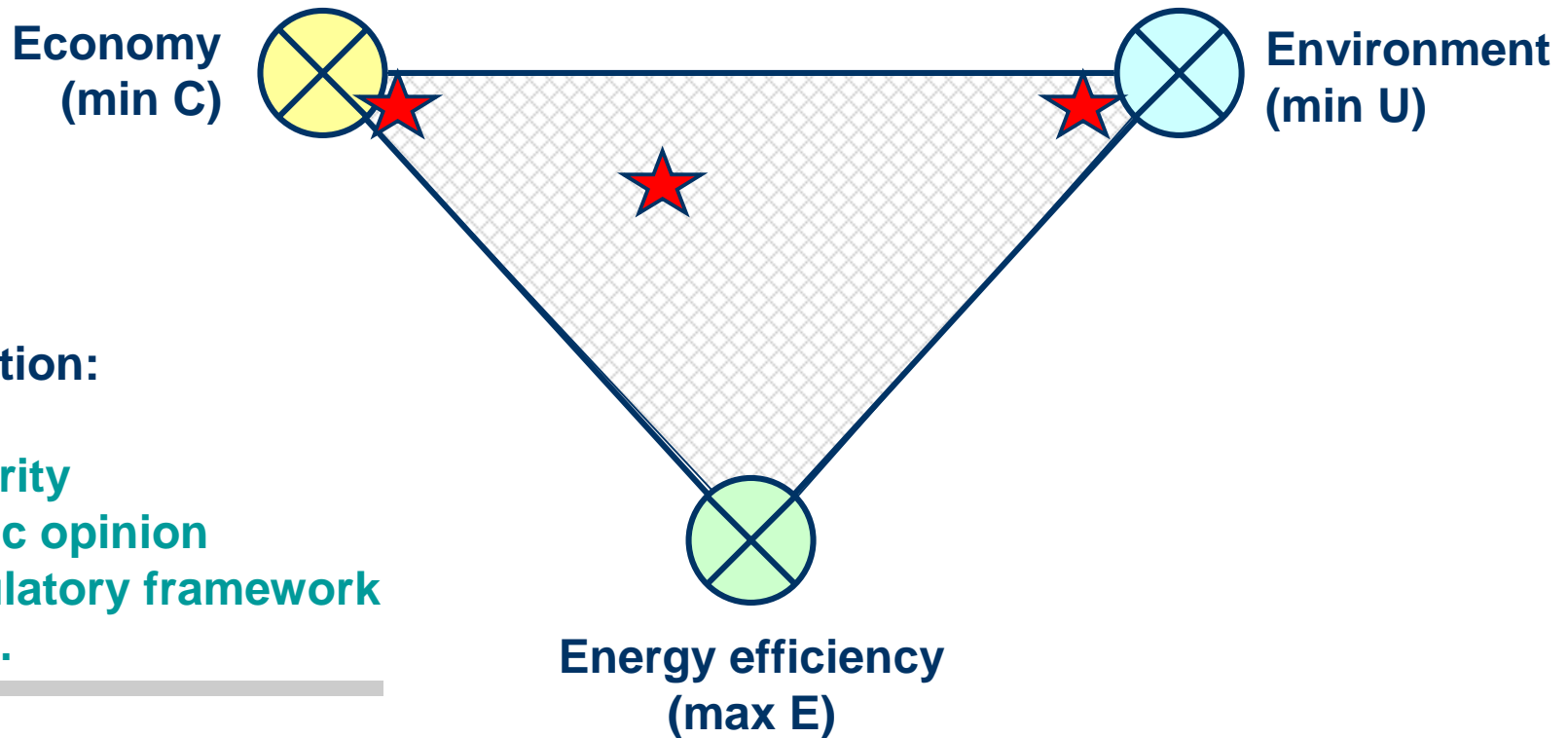
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Special Report Questions - 1

- Which are the dominating objectives and criteria in the planning process of the total energy distribution system?
- Who should make the weighing factors?
- Tool for **scenario studies** to evaluate different investment alternatives, price sensitivity, public taxes, environmental constraints etc
- Use of objectives and criteria depending on who is using the tool and which aspects they are considering
 - **Private investors:** Minimize costs subject to existing and future public demands like environmental taxes and/or constraints – How sensitive are the alternatives to different demands?
 - **Official staff:** Obtain public goals regarding environment and energy efficiency by using taxes and constraints – What means are best suited to reach the goals without destroying the economy of the projects?

Multi-criteria optimization



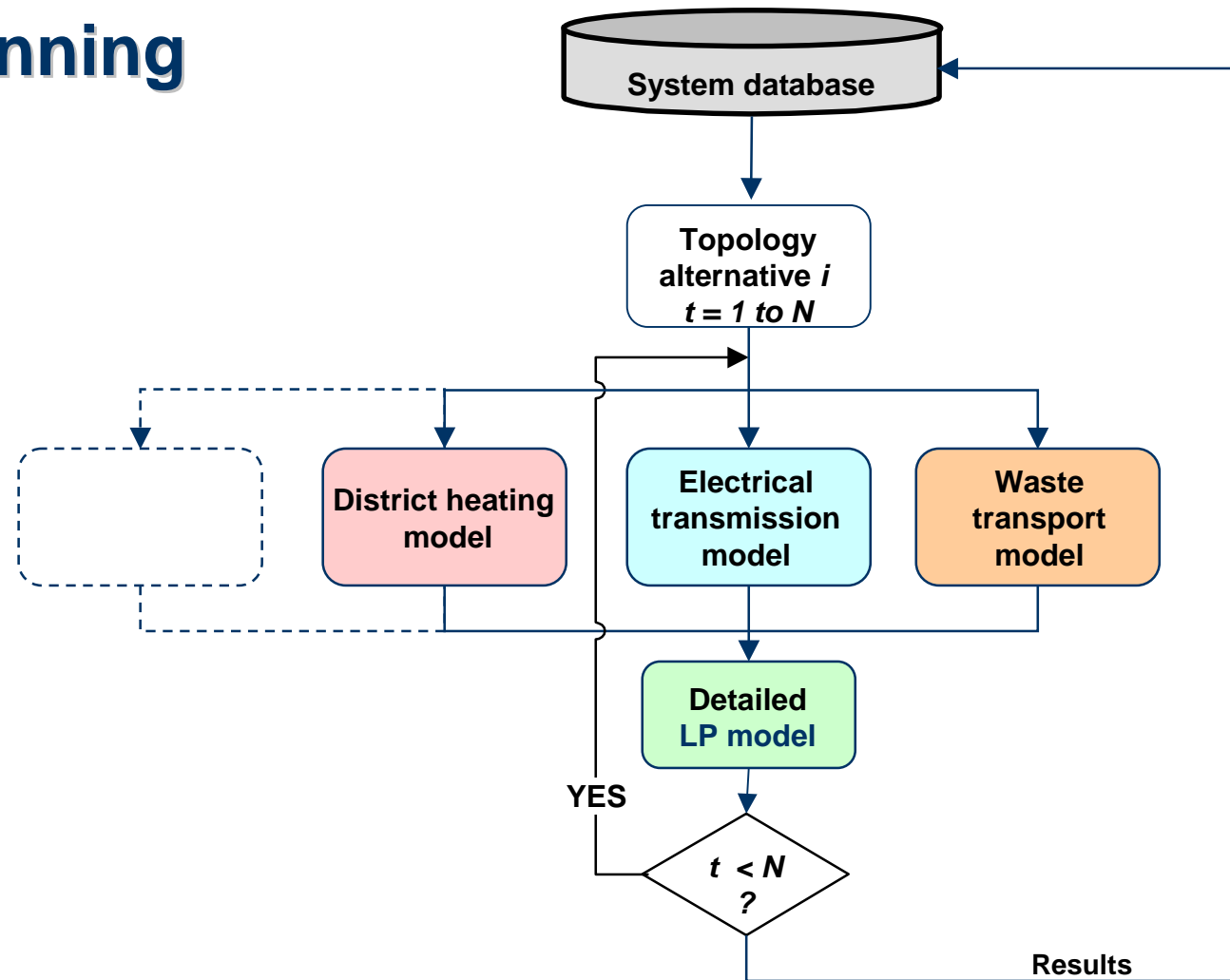
In addition:

- Risk
- Security
- Public opinion
- Regulatory framework
- etc ...

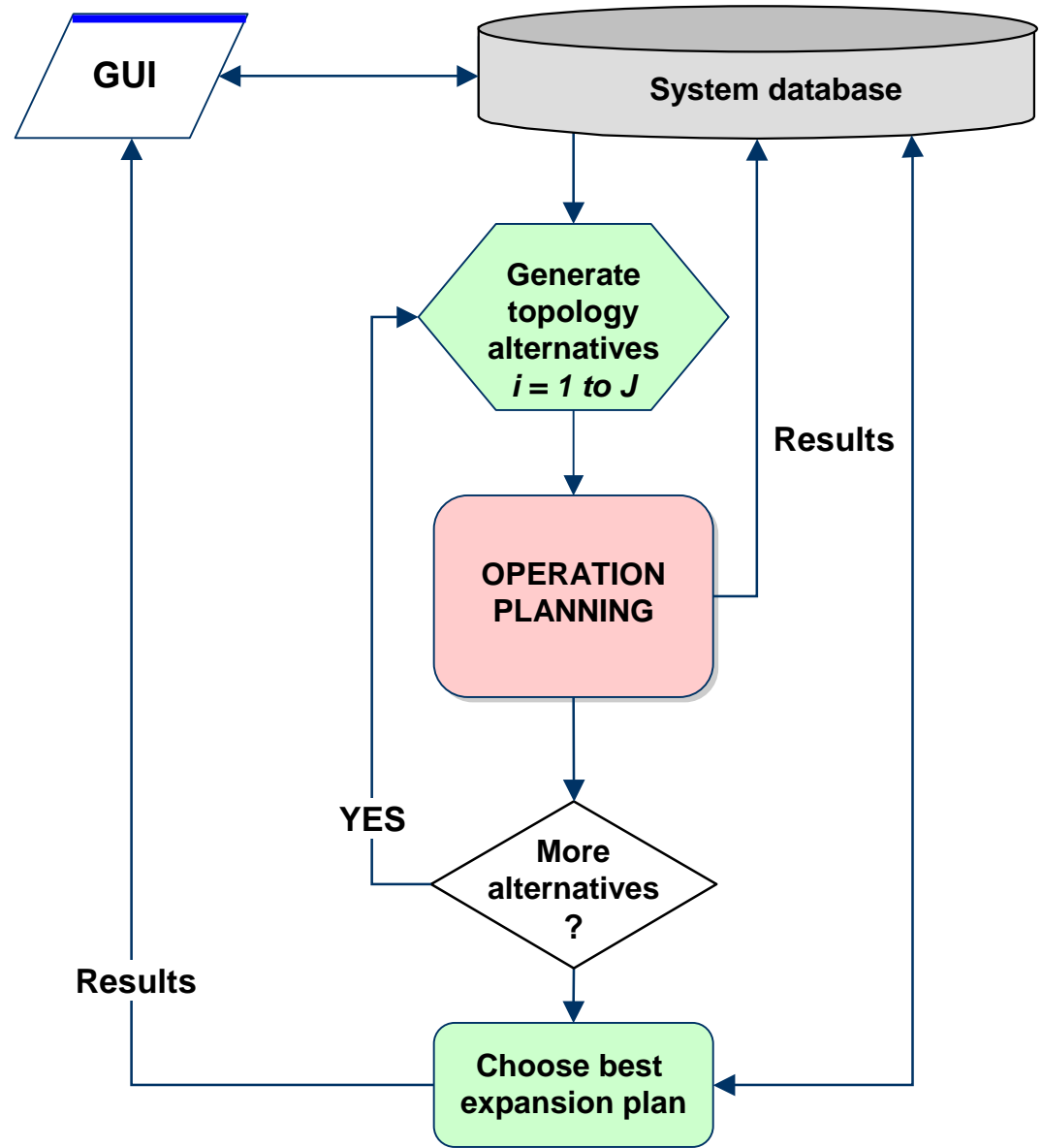
Special Report Questions - 2

- **Is a multi-criteria approach still valid under liberal market conditions?**
- ▶▶▶ **In general, an actor in an ideal liberal market might have a single criterion optimization (max Profit / min Cost), but he would still have to consider aspects like financial risk, security, environment, public opinion etc**
- ▶▶▶ **Note that even though market operations are liberalized, the system expansion planning is still highly regulated with numerous public demands, constraints and taxes**
- ▶▶▶ **Multi-criteria approach is a systematic approach to handle non-quantifiable and non-comparable objectives related to energy system planning like security, aesthetics, public opinion etc**
- ▶▶▶ **In addition, multi-criteria methods are suited for fuzzy techniques with “soft” constraints**

Optimization Operation planning level



=> Expansion planning level



Mathematical tools

- ✓ **Linear Programming with possible extension to MIP**
- ✓ **AMPL** as matrix generator, **CPLEX** for solver(s)
 - + **Mathematical equations rather than program code**
 - + **Easy to modify and expand during testing and development**
 - + **Easy to use in iterations**
 - **Difficult to implement GUI**
 - **Possible limitations in tool difficult to bypass**
 - **Difficult to combine several solvers in AMPL**
 - **Expensive!**
- ***Final implementation environment not decided***