WP7 – Decision-Making and Support Systems

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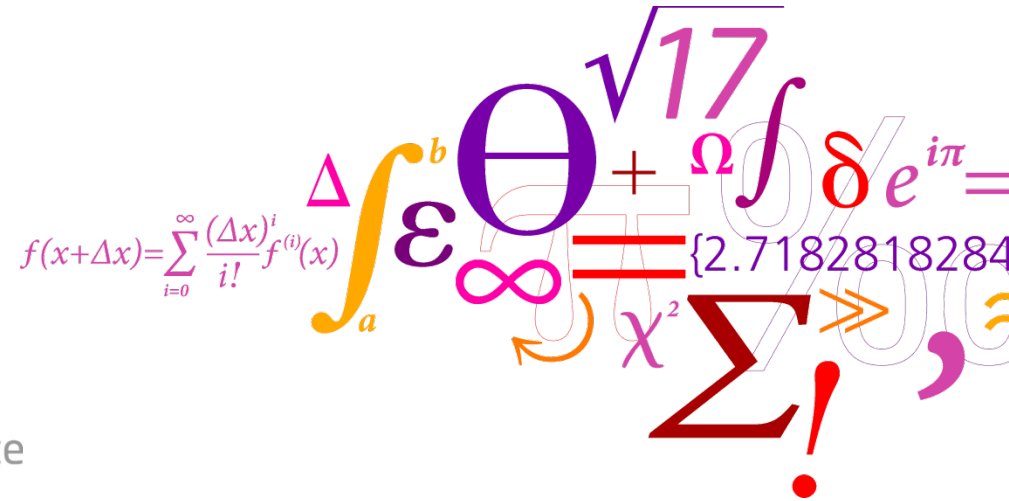
CITIES kick-off meeting

Kgs. Lyngby

28 January 2014



DTU Compute
Institut for Matematik og Computer Science

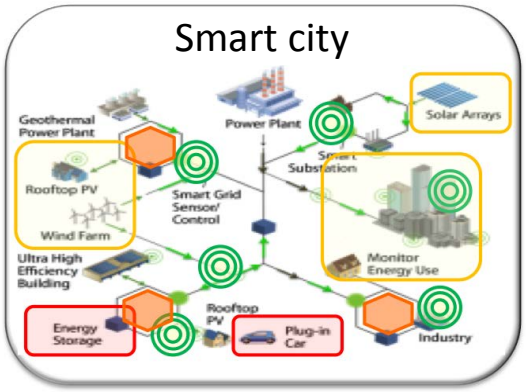
Background

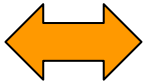
Aim: Decision-making models for the optimal market participation of energy companies in smart cities and identification of business cases and strategic investments

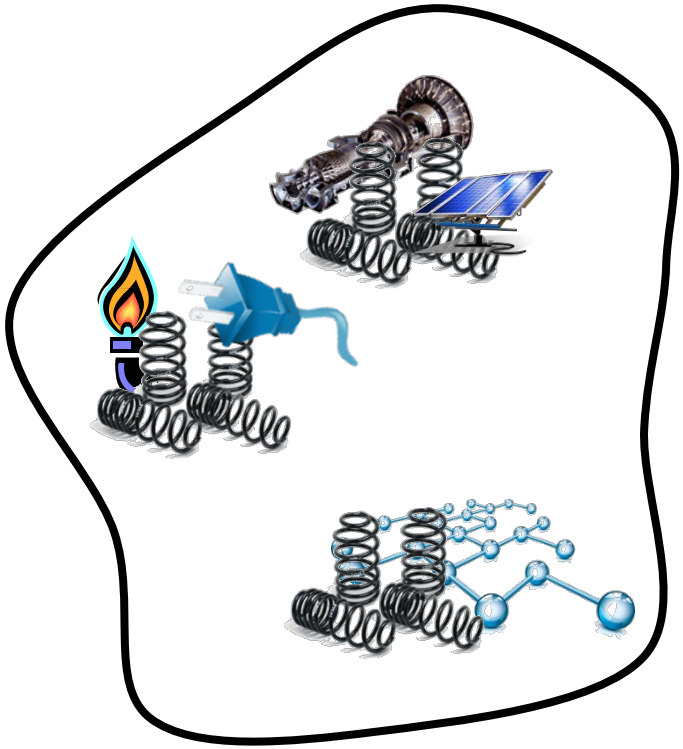
Starting point: Methods and tools will be built on the outputs of WPs 1-5, i.e.,

- WPs 1-3 provide models for the operation of city components: *we understand how these components behave*
- WP 4 provides (novel) market framework and organization: *we know the functioning of the market and its "rules"*
- WP 5 provides tools to predict and control PTSC and demand: *they do what we want them to do (approximately)*

Problem description







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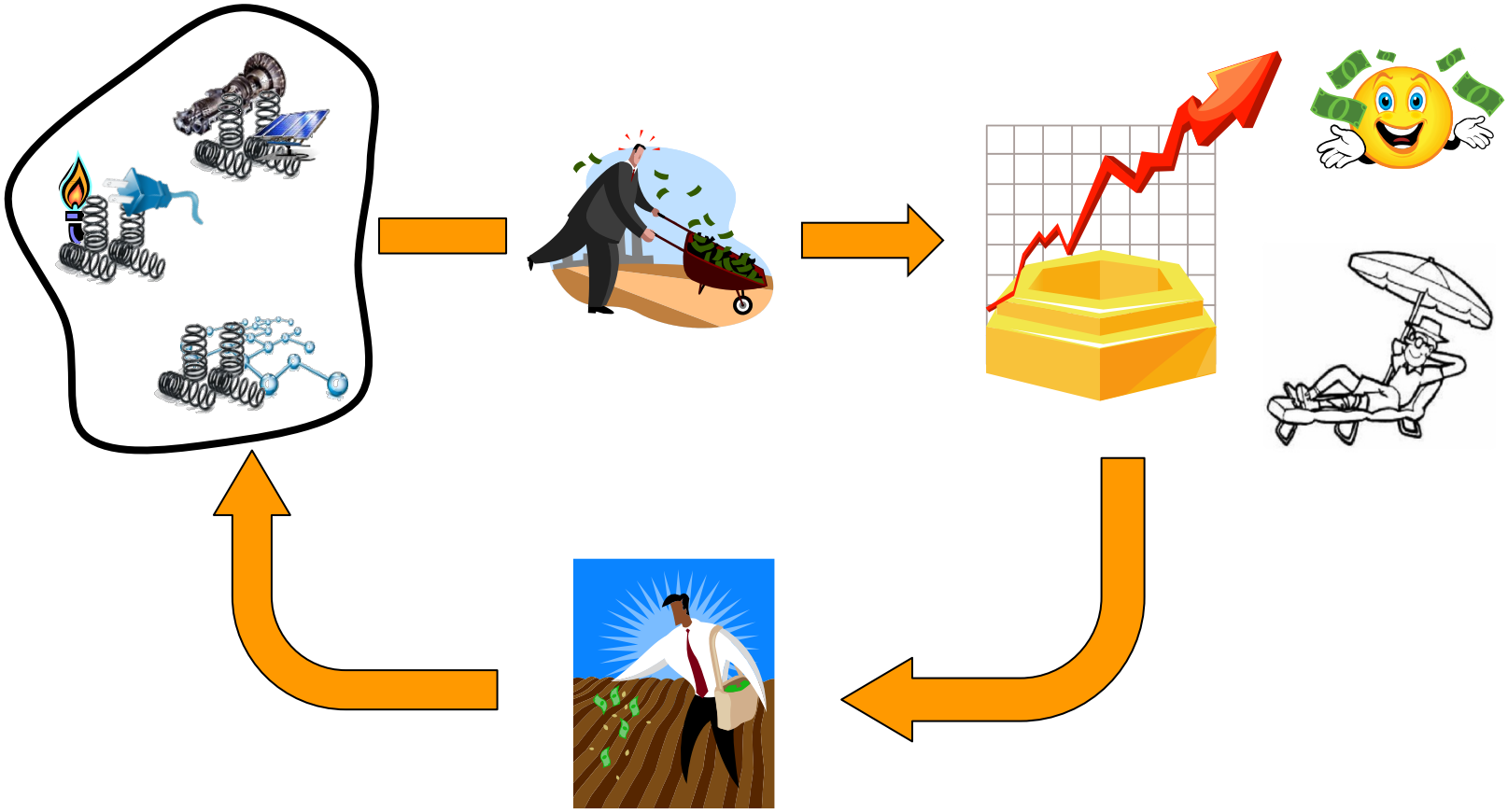

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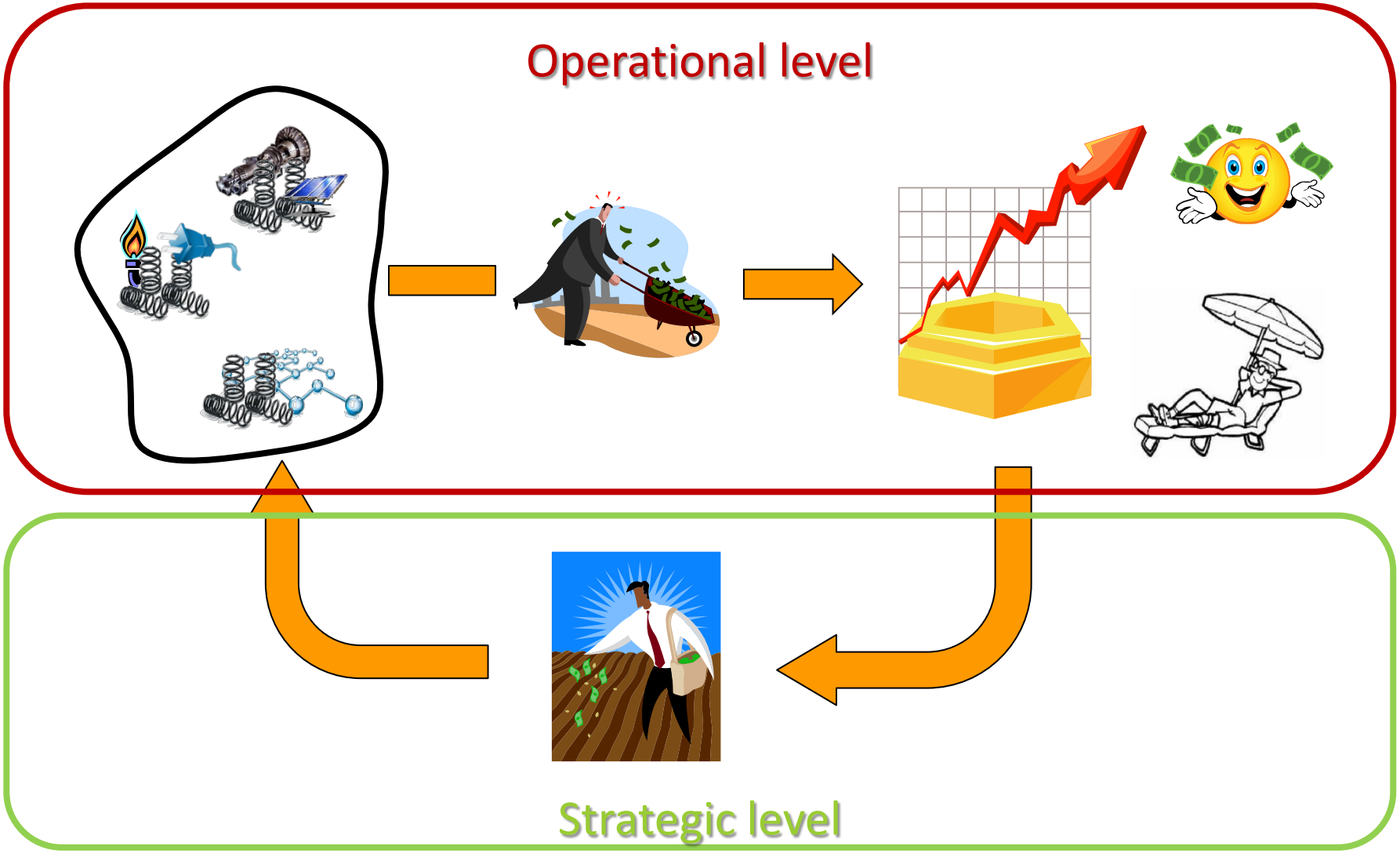
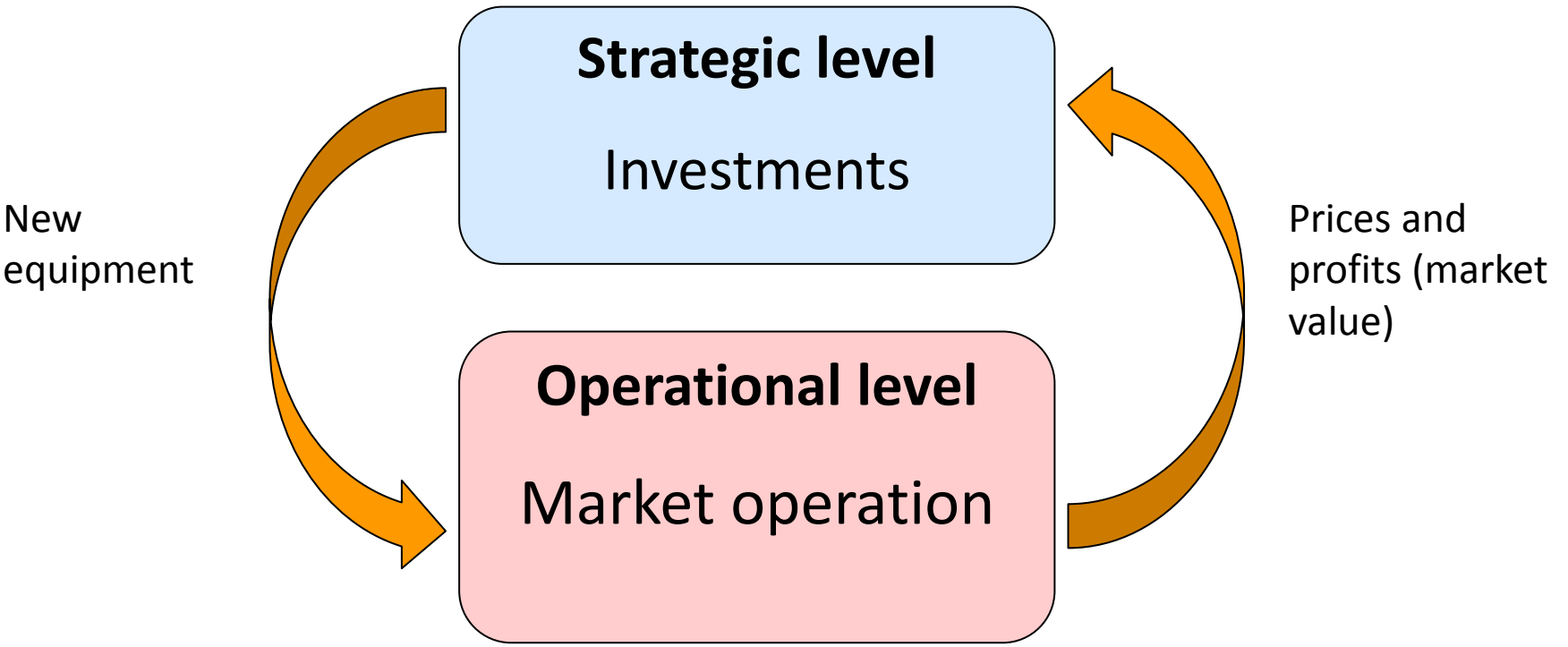
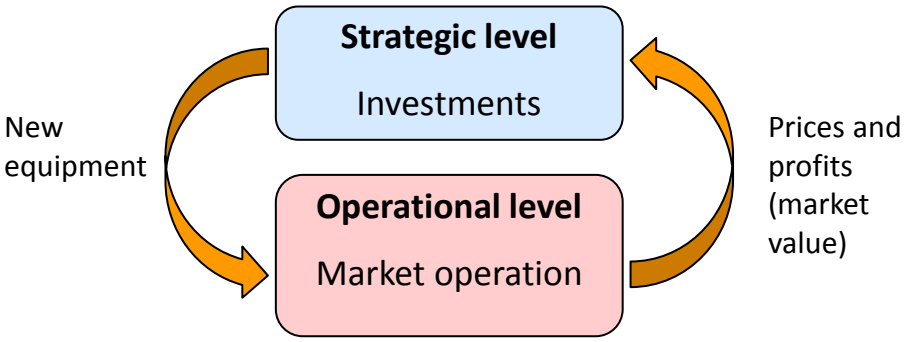


Hierarchical problem



Hierarchical problem
(State of the art)



A (substantial) number of references modeling the hierarchical relationship between investment and market operation decisions. However:

- Essentially focused on power (no integration of energy systems)
- Simplistic representation of the operational level

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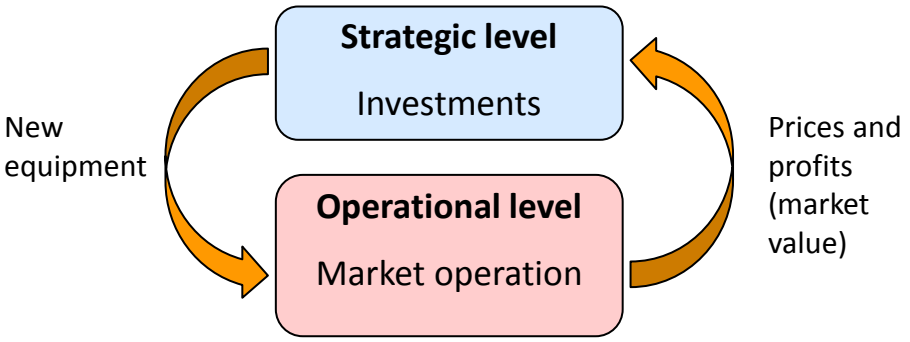
(State of the art)



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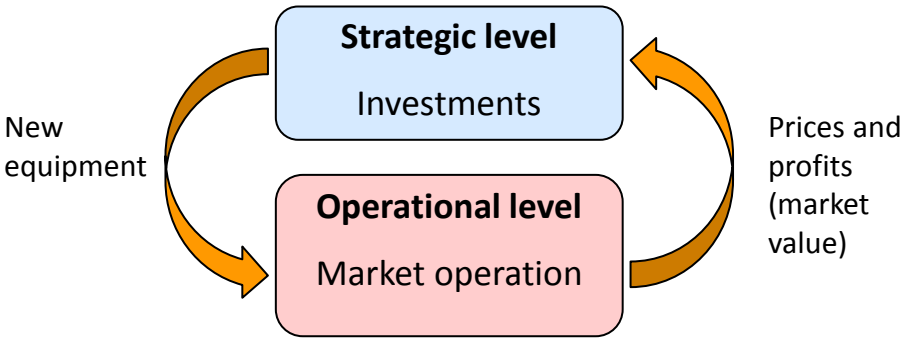
1. A. Ehrenmann and Y. Smeers (2011). **Generation Capacity Expansion in a Risky Environment: A Stochastic Equilibrium Analysis**. *Operations Research*, Vol. 59, no. 6, pp. 1332–1346

   They model the impact of investors' **risk aversion** on **power** capacity investments

2. S. Pineda and J. M. Morales. **Modeling the Impact of Imbalance Costs on Generating Expansion of Stochastic Units**. https://sites.google.com/site/jnmmgo/research

   They model the impact of **forecast errors** from renewables on **power** capacity investments by considering a **two-stage market**

Hierarchical problem
(State of the art)



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3. **Balmorel** (Hans Ravn, project manager), http://www.eabalmorel.dk/

   \+ Probably, the most advanced investment model in terms of integrating various energy systems and services (power + district heating + EVs)

   – It is not a pure hierarchical model (?) : investment and operational decisions are assumed to be made at the same time → OK to represent the view of a *central planner*

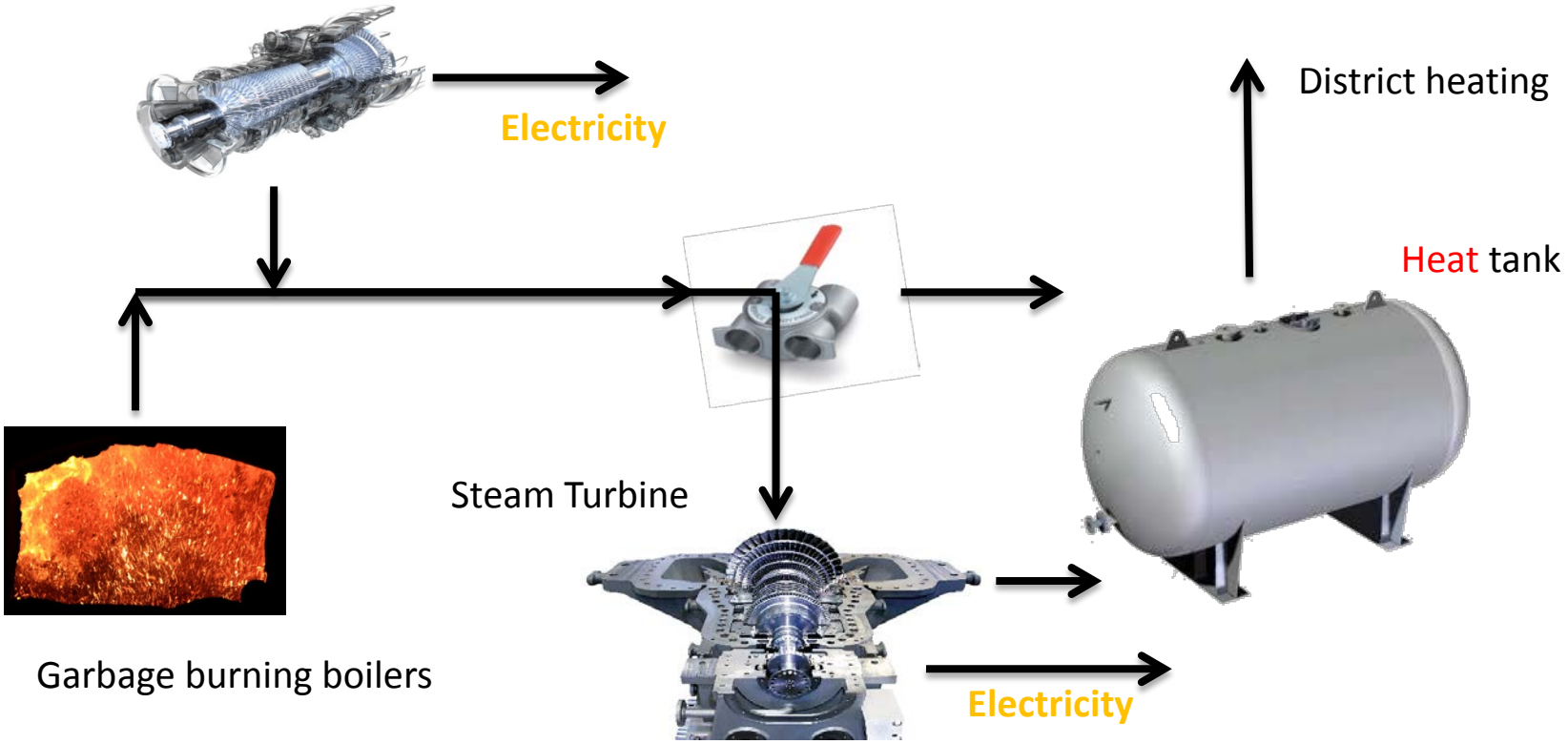
   – Degree of accuracy of the aggregated operational level (?)

We have already started…

- A paradigm of energy system integration in Denmark: A **combined heat and power plant** (CHP)
- In collaboration with DONG Energy

CHP plant at Cornell University

We have already started…



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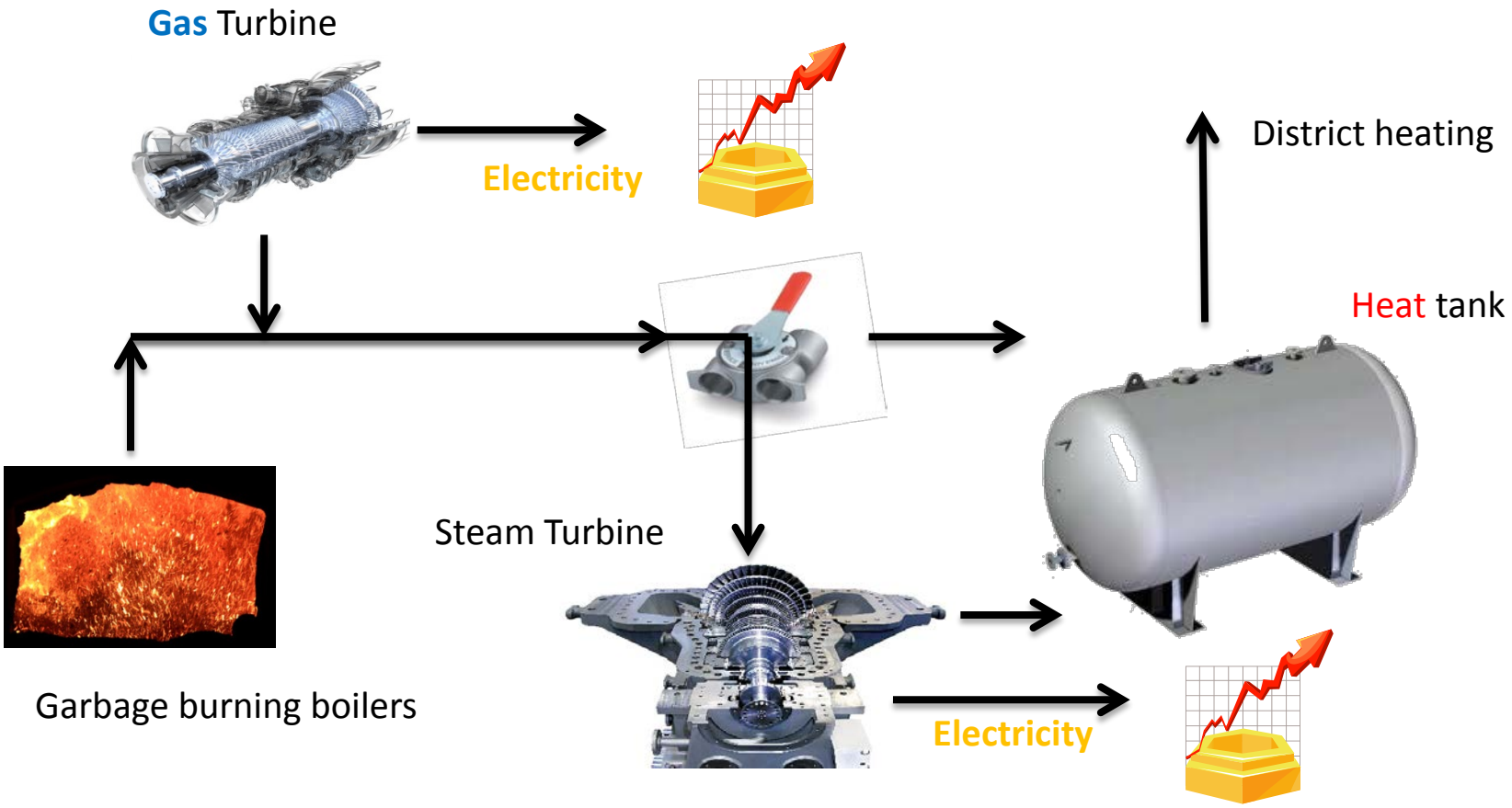
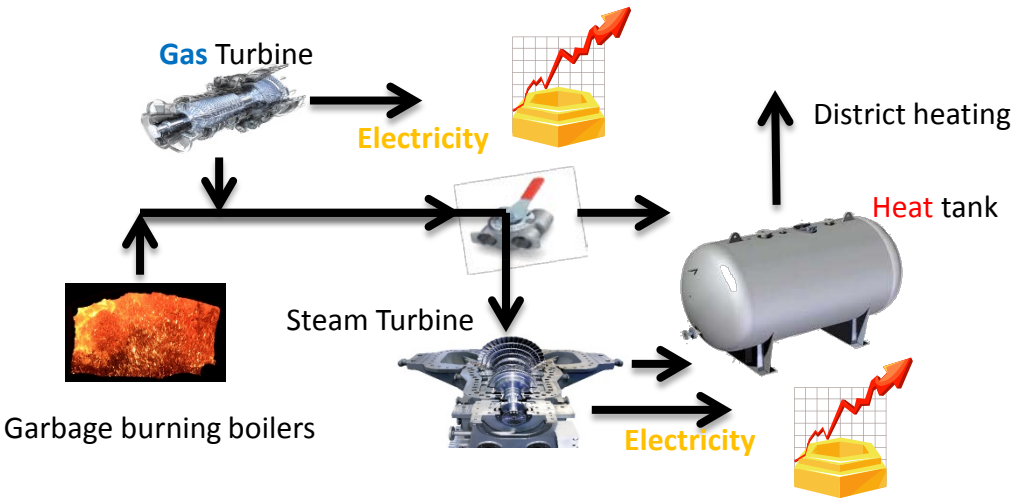


We have already started…

The demand for heating must be satisfied at all costs ⇒ **Robust optimization approach**



Robust optimization approach

Here-and-now decisions

(in advance)

Start-ups/shutdowns (v)

Power and heat production schedule (x)

Uncertainty δ

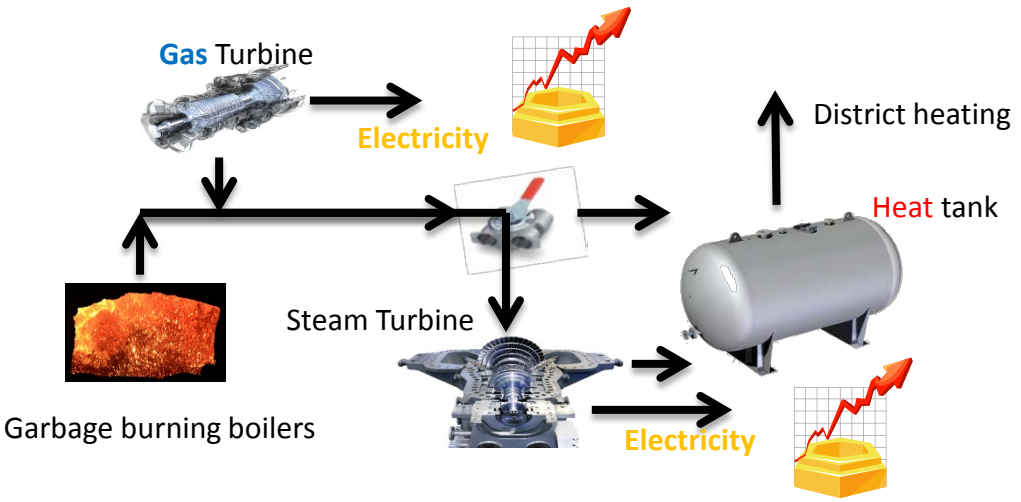
Recourse decisions

(real-time)

Adjustments in heat and power production (y)

Heat demand

Electricity price



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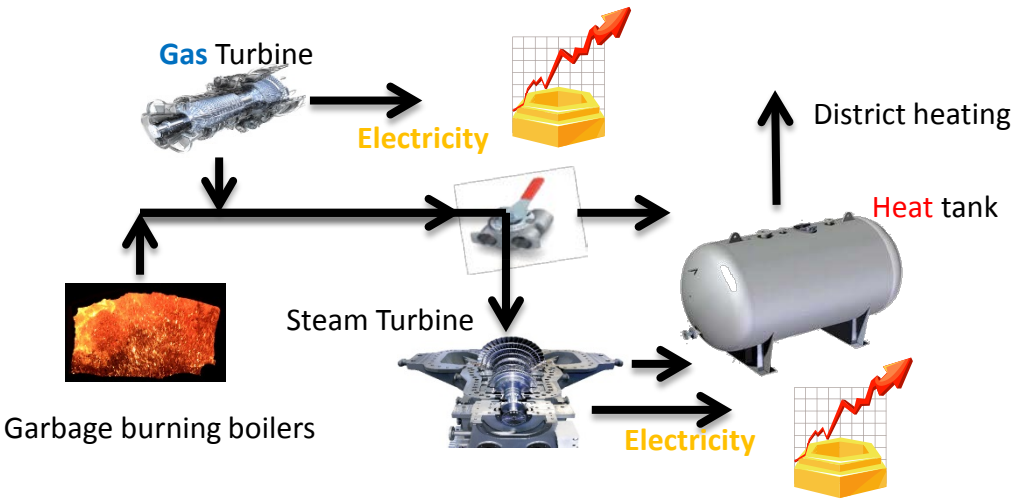


Heat demand

Electricity price

LINEAR DECISION RULES
(Affine control policies)

$$y = x + K\delta$$

Robust optimization approach

$$Expected\ profit = \rho = \sum_{t,k} \left[\widehat{\lambda}_t \widehat{p}_{kt} + \sum_{\tau} K^{p}_{kt\tau} \sigma_{t\tau}(\lambda, \delta) - c^{\mathrm{p}}_k \widehat{p}_{kt} - c^{\mathrm{q}}_k \widehat{q}_{kt} \right.$$
$$\left. - c^{0}_k v_k - c^{\mathrm{SU}}_k v^{\mathrm{SU}}_{kt} - c^{\mathrm{SD}}_k v^{\mathrm{SD}}_{kt} \right]$$

The integration of various *interdependent* energy services and commodities, together with the operational *flexibility* of the CHP, provides added value to the CHP asset

Covariance matrix of electricity price and heat demand

LINEAR DECISION RULES
(Affine control policies)

$$y = x + K\delta$$

Operation of CHP
(State of the art)

The technical literature is rich in references on the operation of a CHP (many coming from Nordic authors):

- Relationship with electricity markets to be better studied
- Approach to uncertainty is often simplistic

1. R. Aringhieri and F. Malucelli (2003). **Optimal operations management and network planning of a district heating system with a combined heat and power plant.** *Annals of Operations Research, Vol. 120, no. 1–4, pp. 173–199*

   Operation of CHP systems with **fixed market price** and **deterministic heat load**

2. B. Rolfsman (2004). **Combined heat-and-power plants and district heating in a deregulated electricity market.** *Applied Energy, Vol. 78, pp. 37–52*

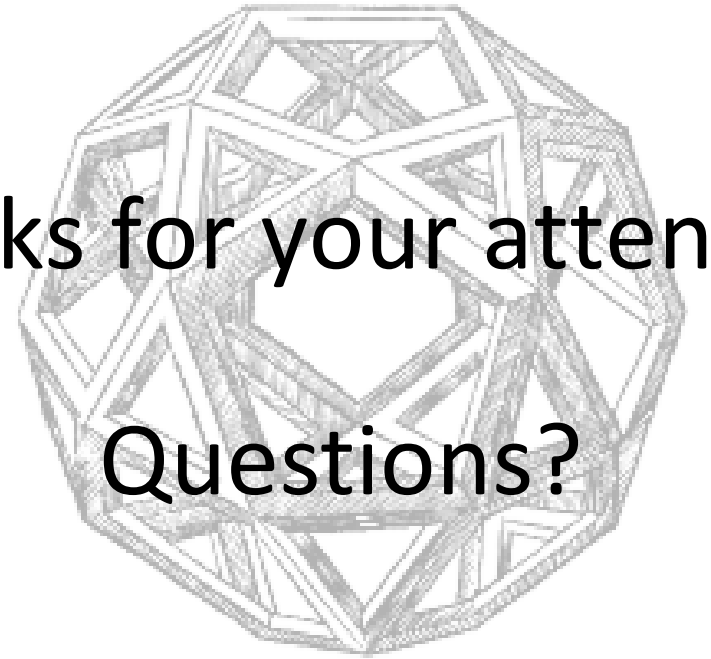
   Profitability analysis of CHP systems with **deterministic heat load** and **simple price forecasts**

3. F. De Ridder and B. Claessens (2013). **A trading strategy for industrial CHPs on multiple power markets.** *International Transactions on Electrical Energy Systems* (in print)

   Multi-market framework but **no correlation** between uncertain variables

Final Remarks

- To derive offering curves
- Extend the robust CHP operation model to consider uncertain gas prices and several trading floors and financial instruments (derivatives, day-ahead, adjustment, etc.)
- To evaluate the economic performance of a flexible CHP on real-life case studies (with DONG Energy).
- To explore portfolios of CHPs + renewables



Thanks for your attention!

Questions?