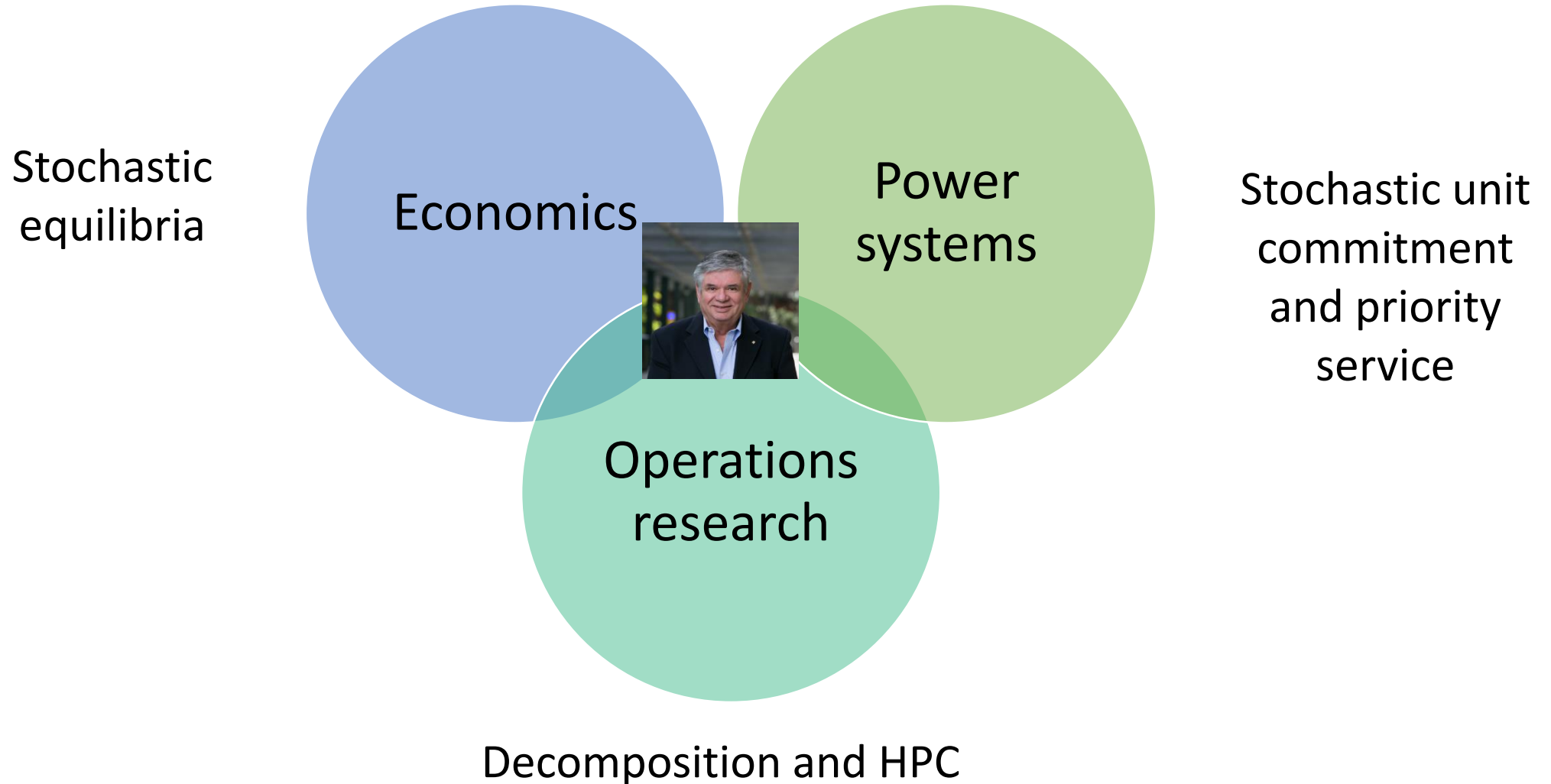# A Random Walk Down Hearst Avenue

Energy and Market Engineering Symposium
in Honor of Shmuel Oren

Anthony Papavasiliou, Université catholique de Louvain

Uncertainty and the Oren Triangle

Stochastic equilibria

Stochastic unit commitment and priority service

Economics

Power systems

Operations research

Decomposition and HPC

Decision-Making under Uncertainty

*"I treat my students like I treat my children."*

- Shmuel Oren

Intro to Decision Trees: Decision Nodes

- Decision trees are the basic building blocks of *sequential decision making under uncertainty*
- **Decision nodes** represent stages at which an agent needs to decide on an action
- The action influences the agents' future states
- Decision nodes are indicated with boxes
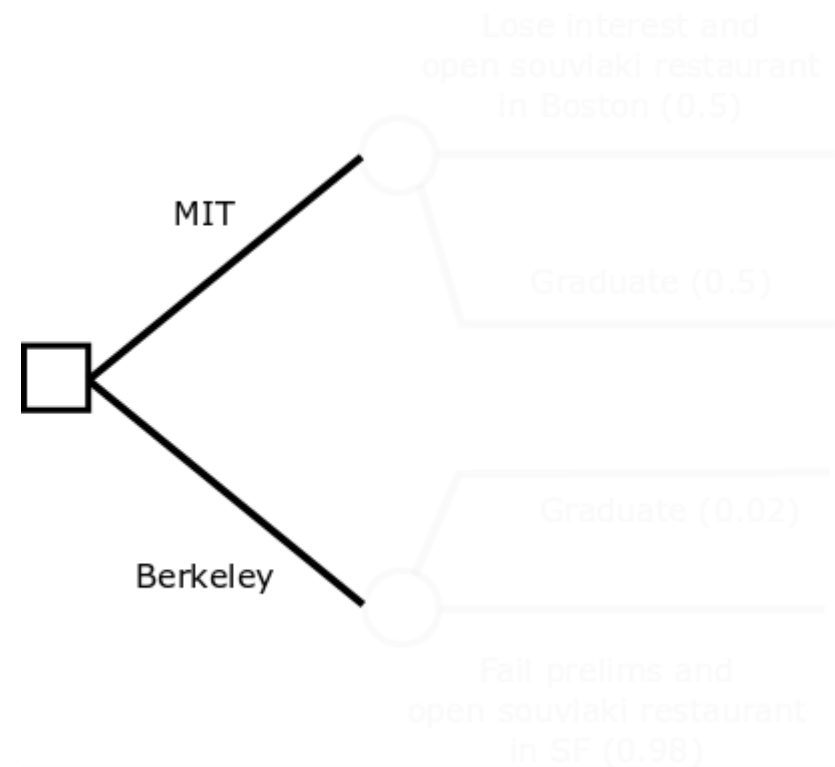
Intro to Decision Trees: Outcome Nodes

- **Outcome nodes** represent stages at which nature reveals uncertainty

- The uncertainty may depend on the past decisions

- Decision nodes are indicated with circles

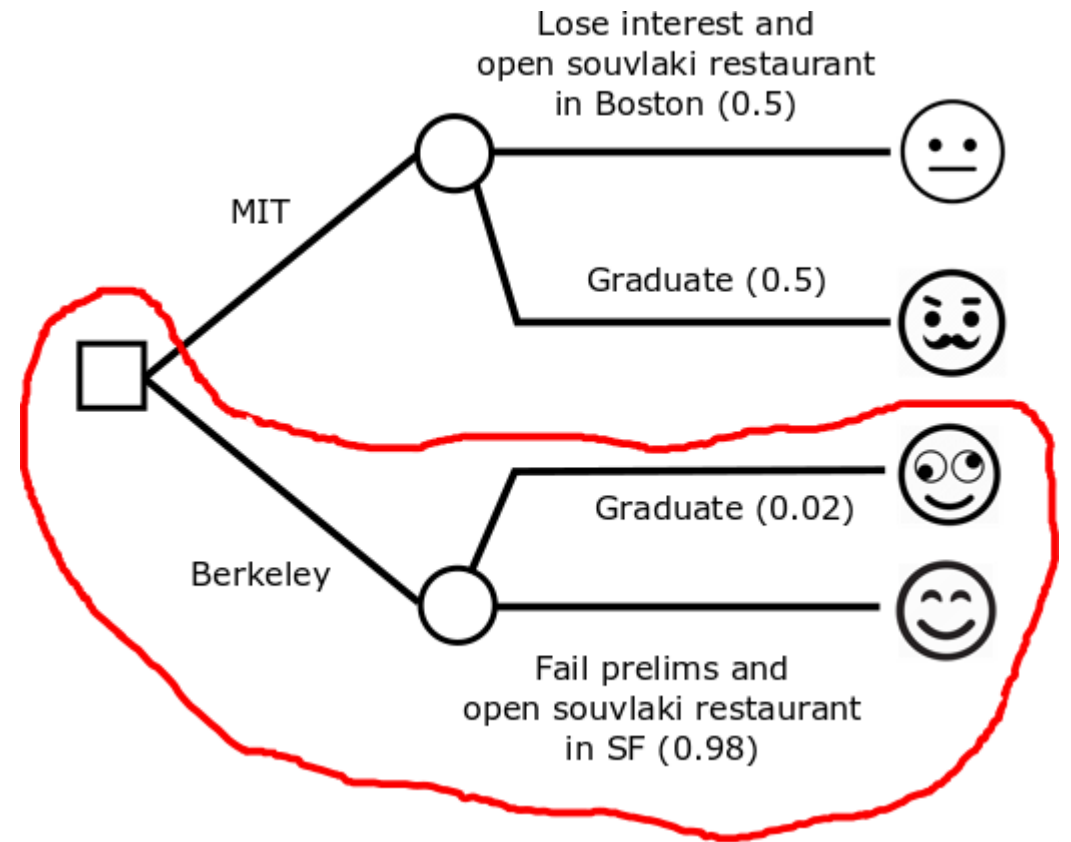- Each outcome has an associated probability
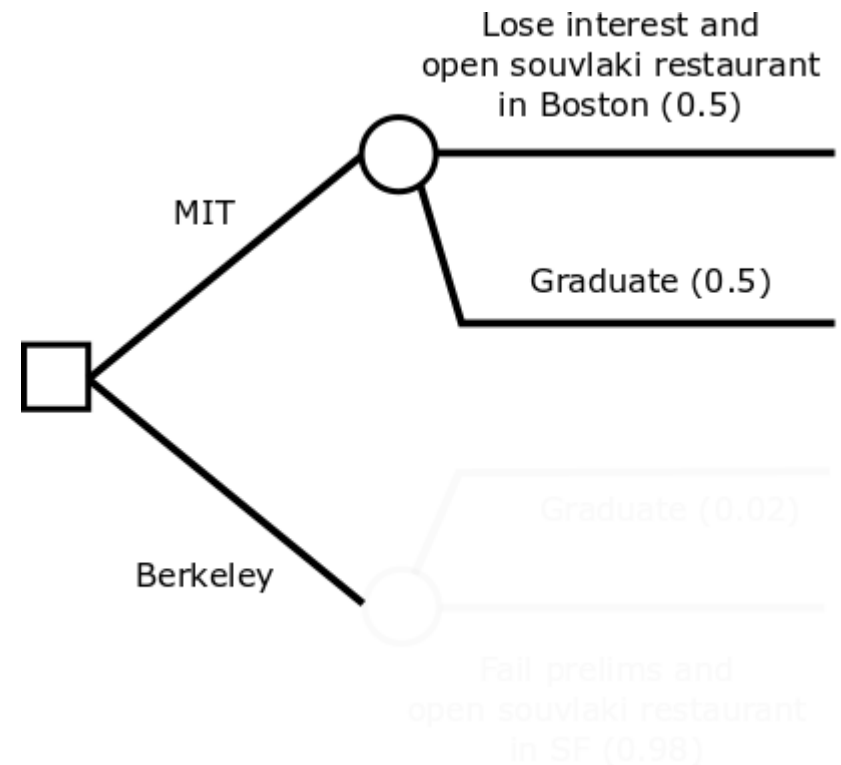
Intro to Decision Trees: Payoffs

- **Payoffs** represent rewards that an agent collects as a function of past decisions and uncertainty realizations
- Payoffs are typically represented with continuous data such as
  - numerical values, or
  - emojis
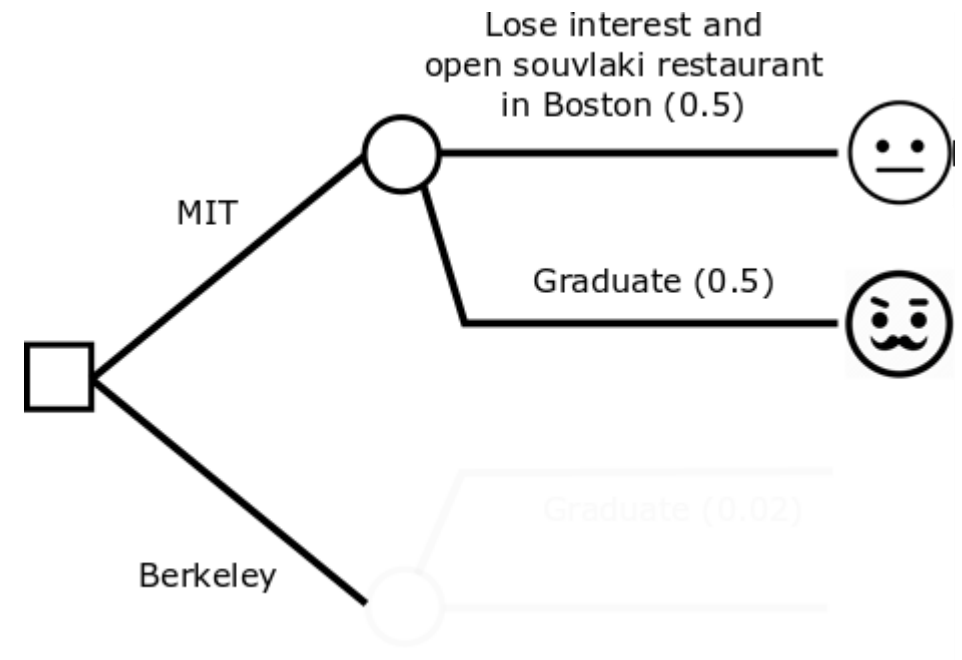
Intro to Decision Trees: Optimal Decisions

- **Optimal decisions** are determined by back-tracking our options and computing their expected payoff

- We select the decision with the greatest expected payoff

- The optimal choice between MIT and Berkeley is clearly and always Berkeley. Go Bears.

Lose interest and open souvlaki restaurant in Boston (0.5)

MIT

Graduate (0.5)

Berkeley

Graduate (0.02)

Fail prelims and open souvlaki restaurant in SF (0.98)

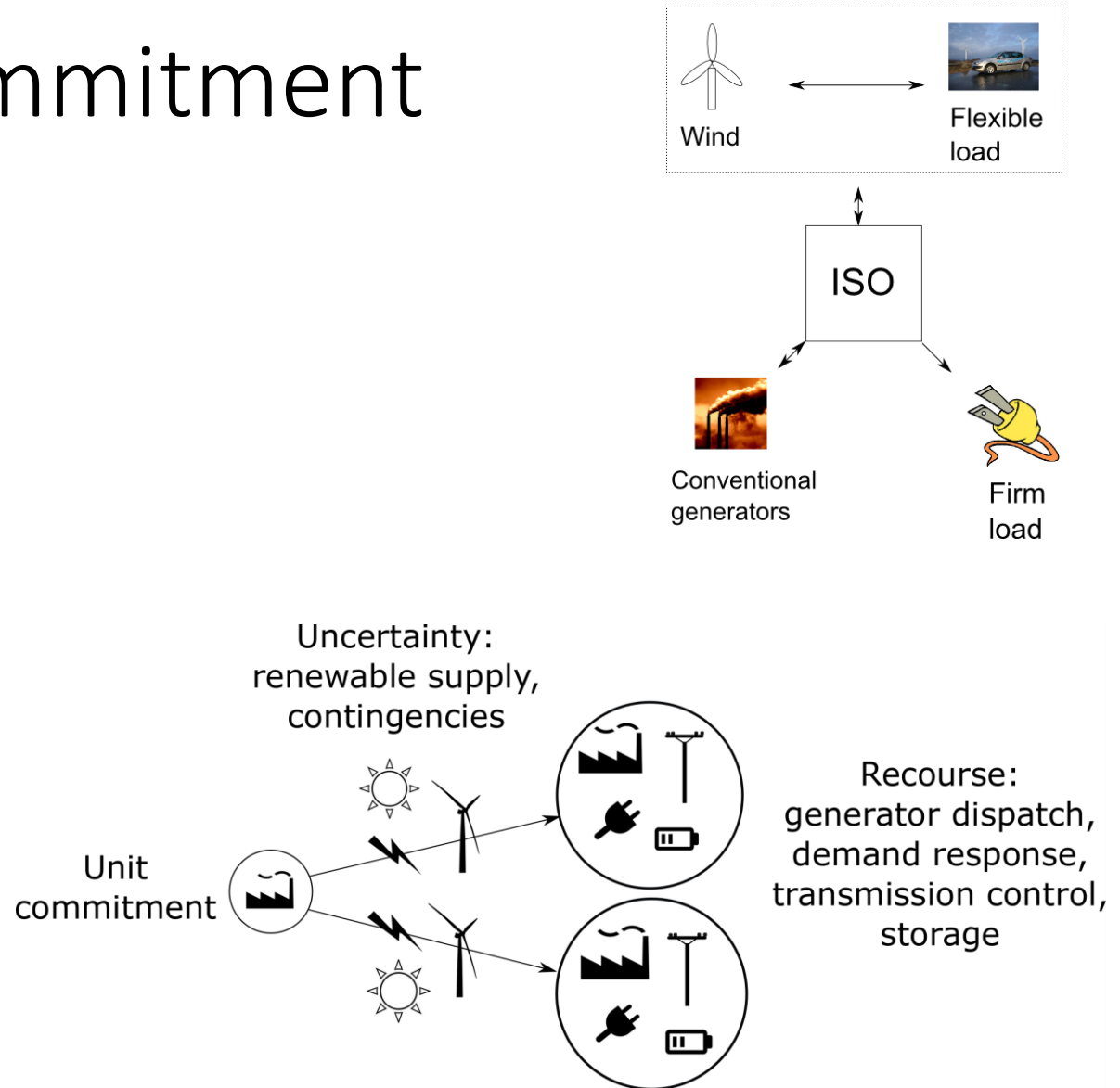# Follow the Love

Acknowledgments

Power Systems: Stochastic Unit Commitment and Priority Service

"Economists are good at finding problems and bad at proposing solutions."

- Shmuel Oren

Stochastic Unit Commitment

- Original motivation:
  quantify benefits of
  demand response in
  reducing *reserve
  requirements*

- Eventually:
  operational tool for
  day-ahead *residual
  unit commitment*

Wind

Flexible load

ISO

Conventional generators

Firm load

Uncertainty: renewable supply, contingencies

Unit commitment

Recourse: generator dispatch, demand response, transmission control, storage
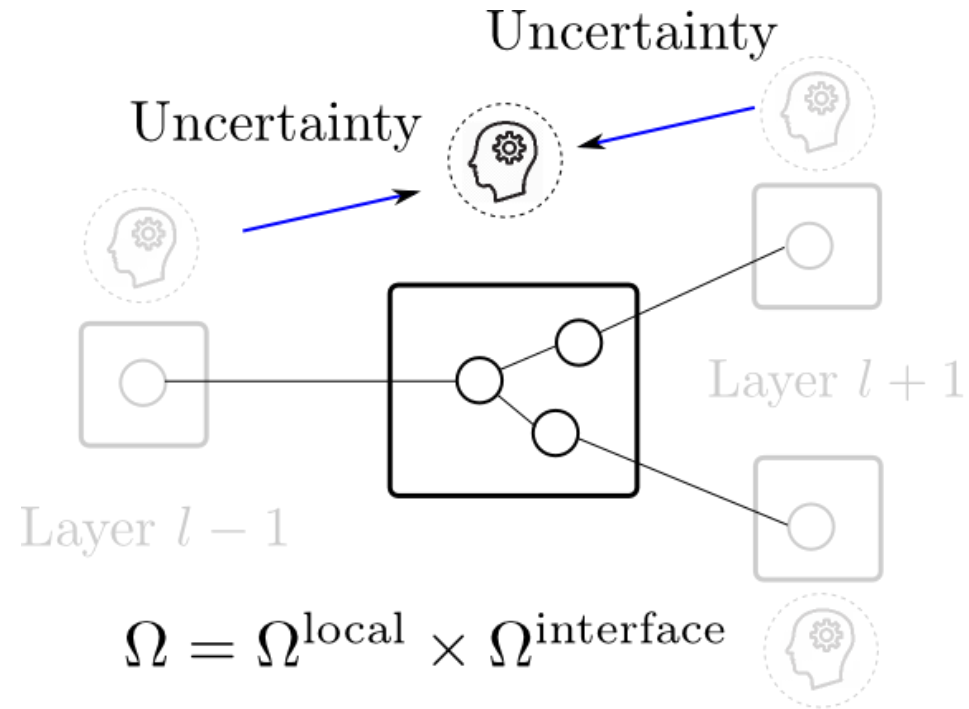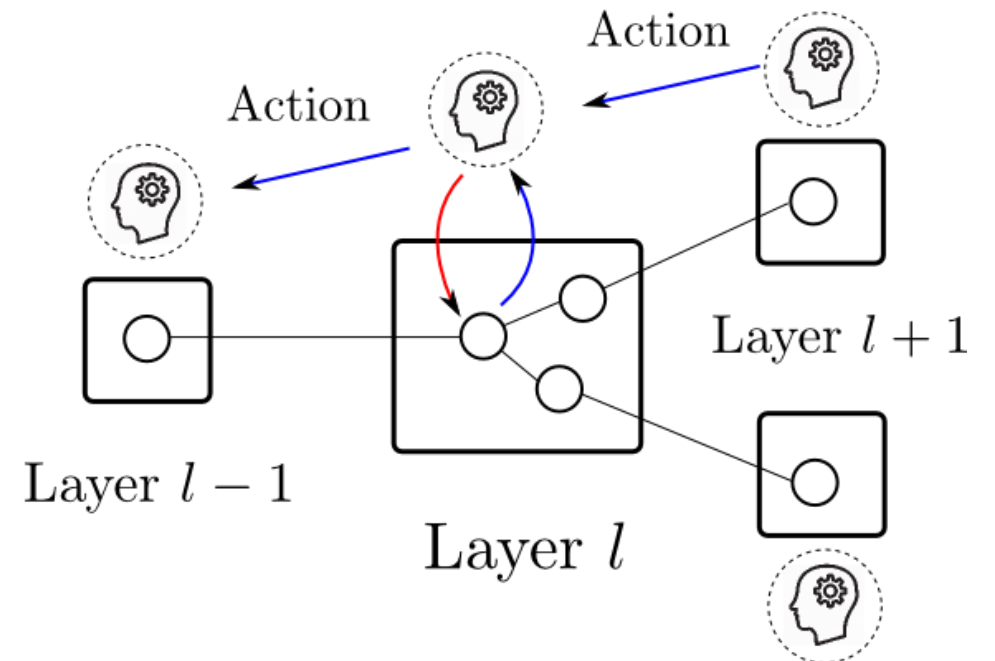
Insights

- Deterministic unit commitment underestimates the cost of fast unit activations

- Stochastic UC pays off *especially* in the presence of **transmission constraints**

Reserve Minimum Run Levels for 2020 Study, Spring Weekdays
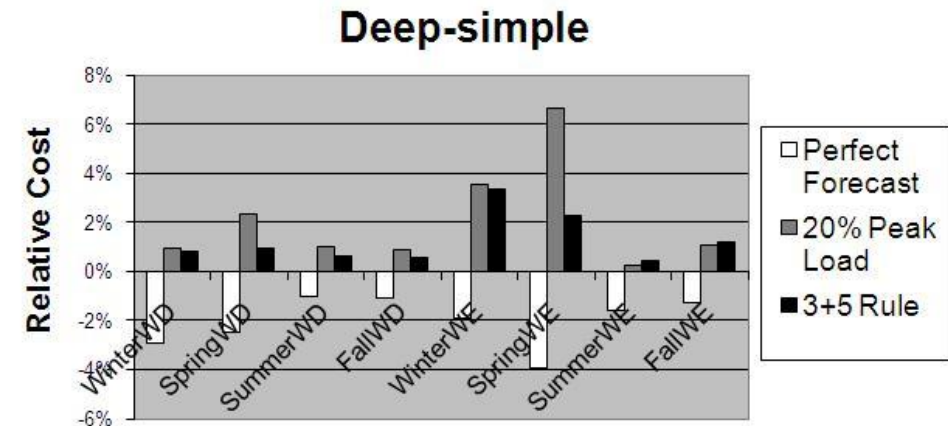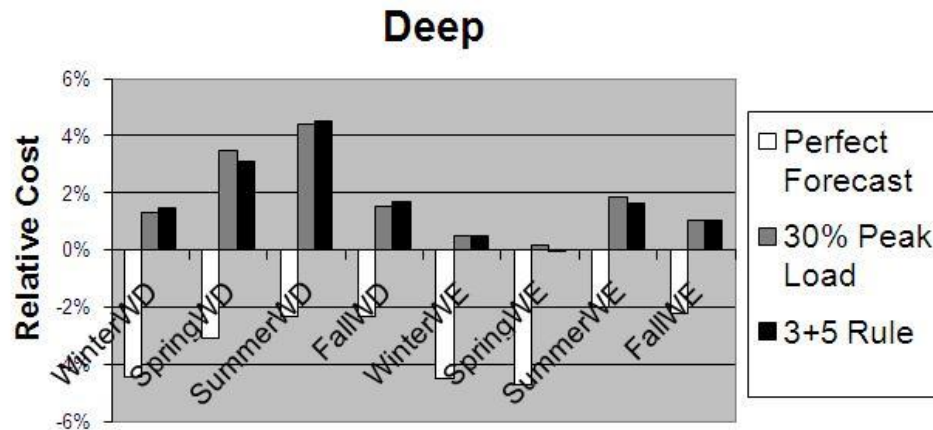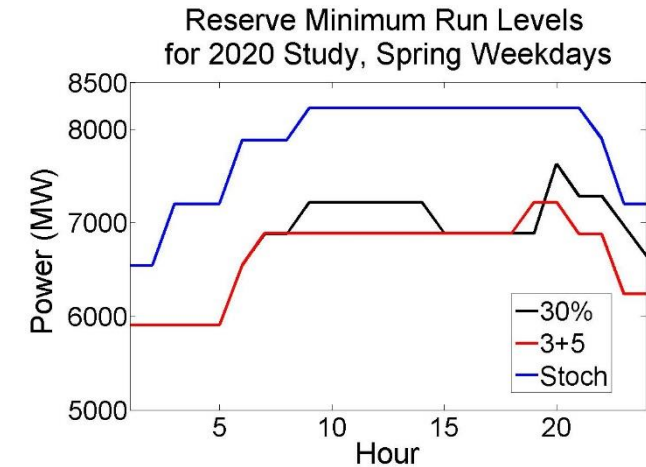
Hierarchical Organization of Future Systems

$$\Omega = \Omega^{\text{local}} \times \Omega^{\text{interface}}$$

Day-ahead planning: distributed

Real-time dispatch: hierarchical

Priority Service Pricing

- The *residential sector* is a key part of the solution
- Oren-Chao-Wilson priority service pricing problem can be cast as a Stackelberg equilibrium and *integrated* with **unit commitment models**
- Individual households can be controlled by *energy routers* trained by **reinforcement learning**
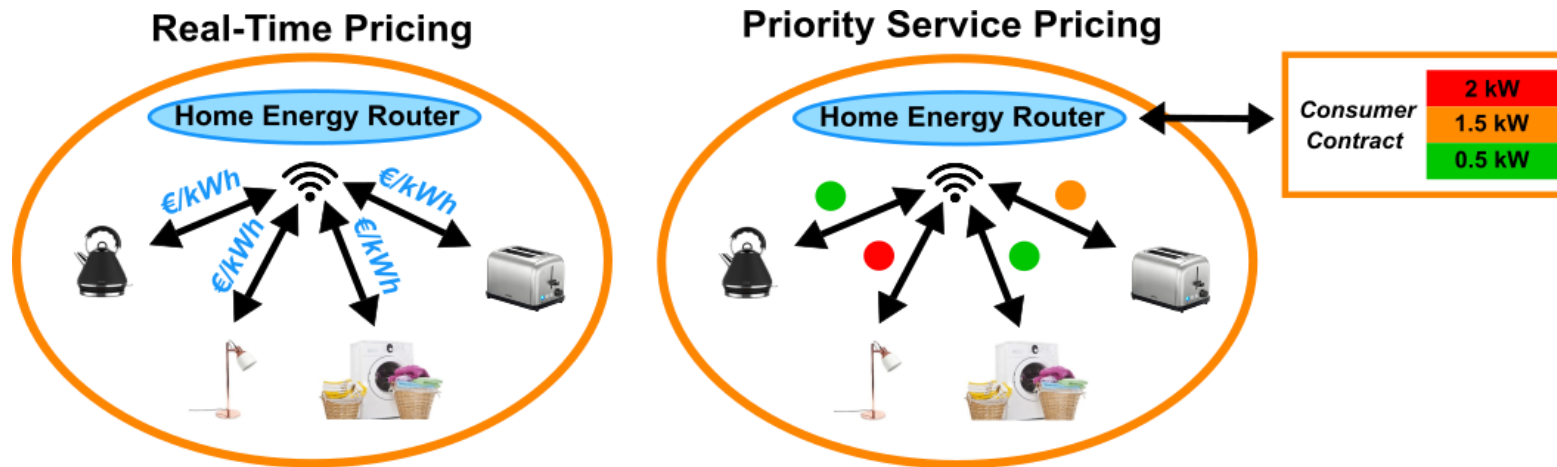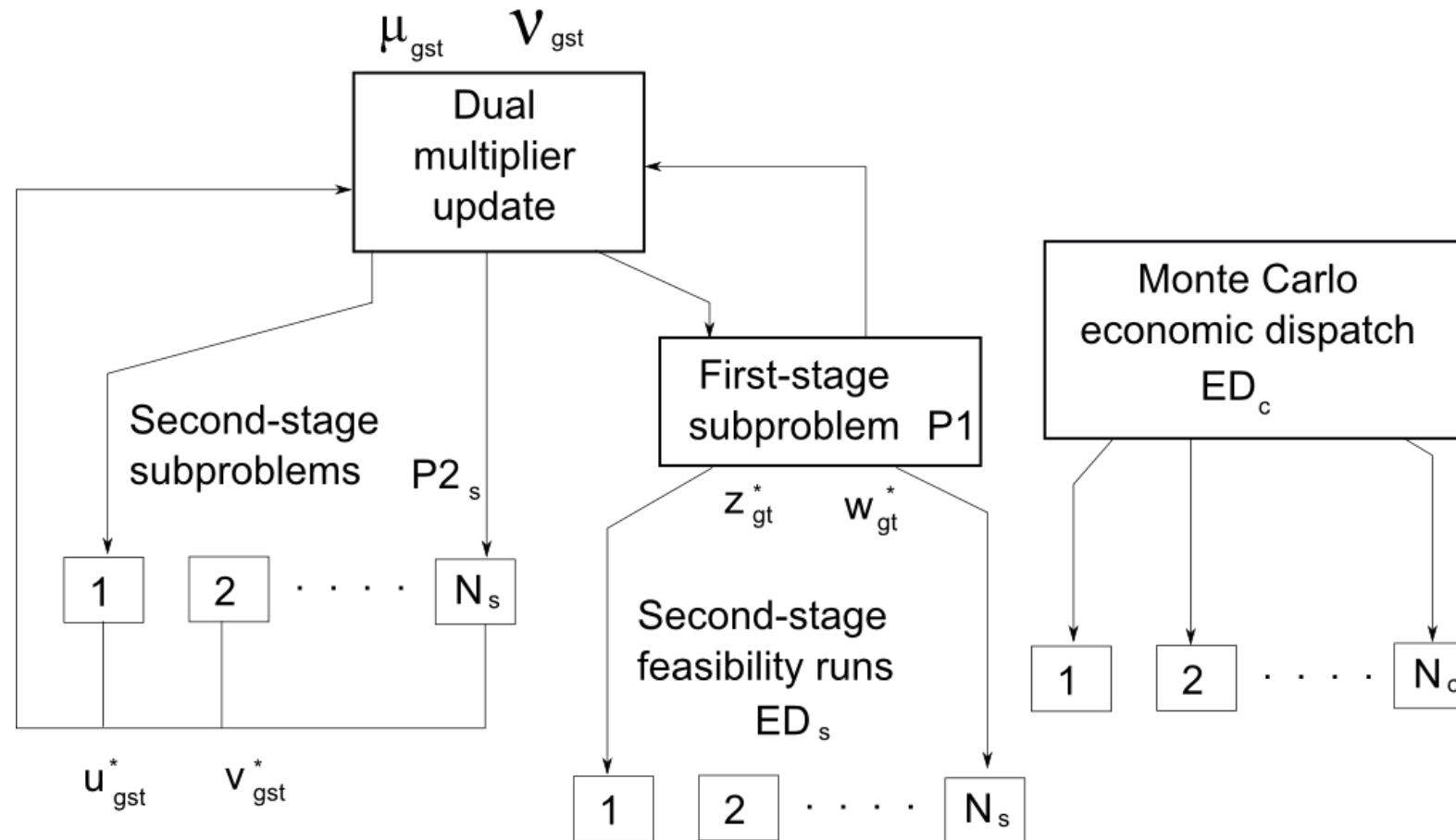
Operations Research: Decomposition and HPC

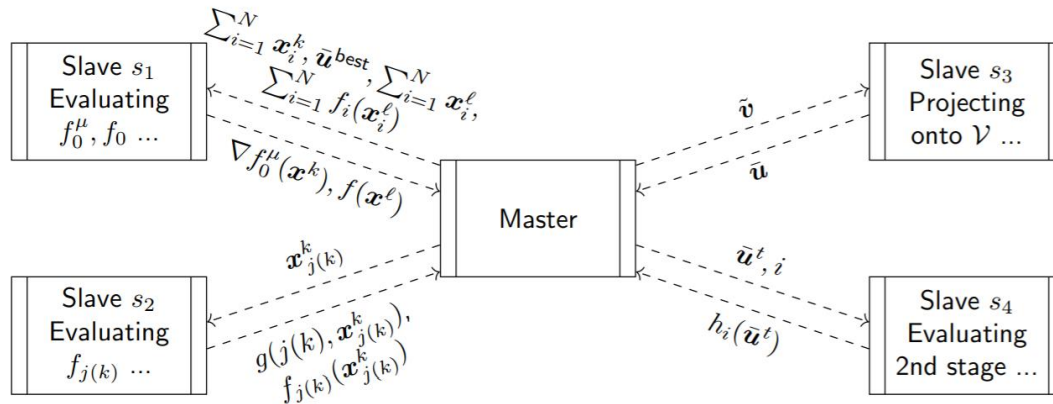*"You look like you haven't slept in a week."*

- Shmuel Oren

Decomposition

High Performance Computing

- Asynchronous dual decomposition can improve parallel computation performance tremendously

- Today, we can solve SUC with *O(100)* scenarios on **real** systems in *O(minutes)*

# Economics: Stochastic Equilibria

"We need to talk."

- Shmuel Oren

Scarcity Pricing

- The *missing money problem* has recently hit Belgium hard, winter 2014-2015 and winter 2018-2019 have been *very tight* for Belgium

- **Scarcity pricing** (a.k.a. **ORDC**) is a market design that mitigates the missing money problem by introducing a *real-time market for **reserve capacity*** that values reserve based on *LOLP* calculations

- Belgian system operator (ELIA) recently published *parallel runs* on the impact of scarcity pricing in the Belgian market for 2017

- The Belgian regulatory authority (CREG) has commissioned a study on the **design** of a scarcity pricing mechanism

Stochastic Equilibria
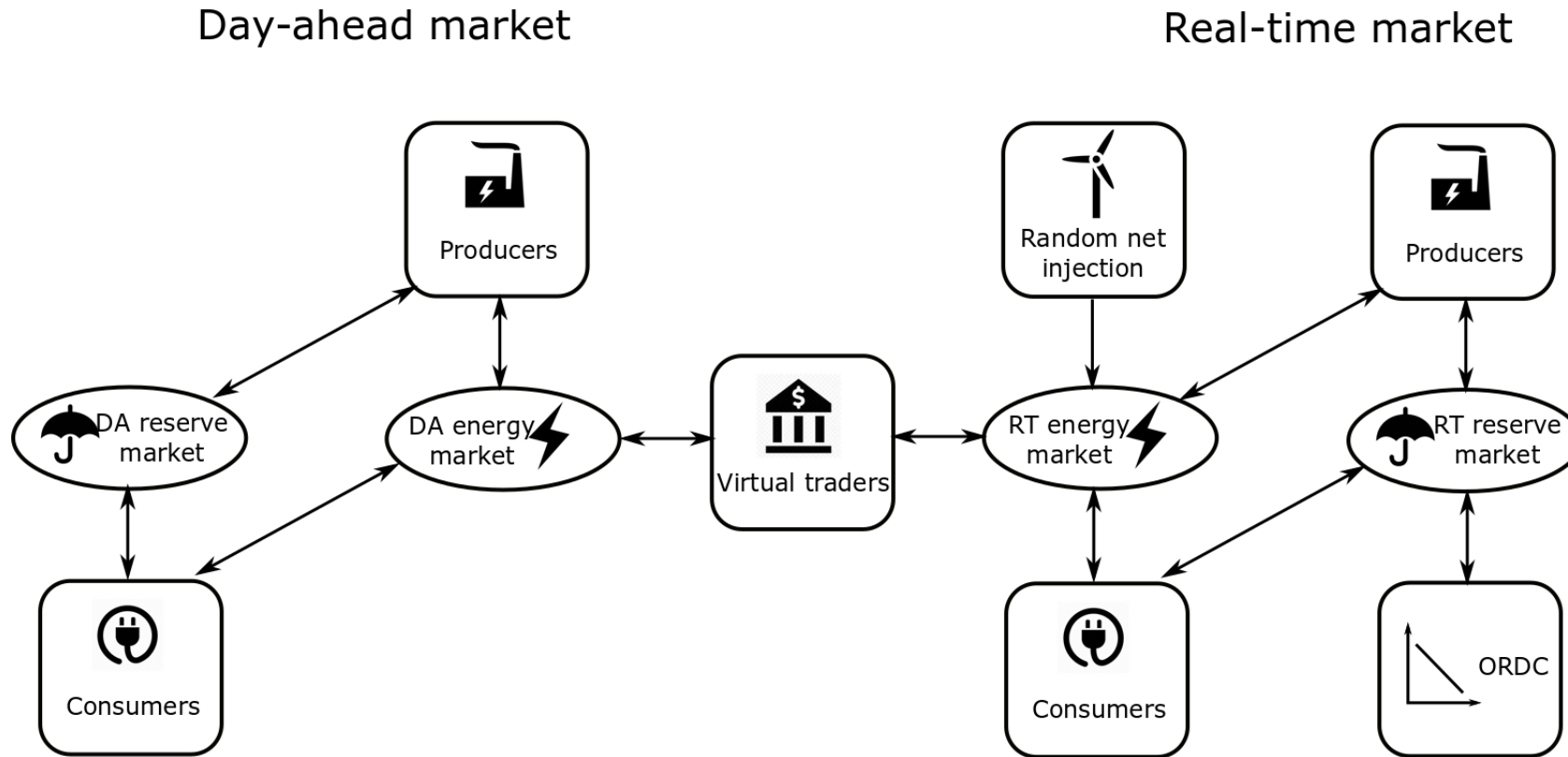
Insights

- The model can be used in order to capture the **back-propagation** of reserve capacity prices to forward markets

- Recommendation to Belgian regulatory authority
  - Set real-time market for reserve capacity in place
  - Virtual trading and day-ahead co-optimization of energy and reserves less important

Thank You Shmuel for the Incredible Ride!