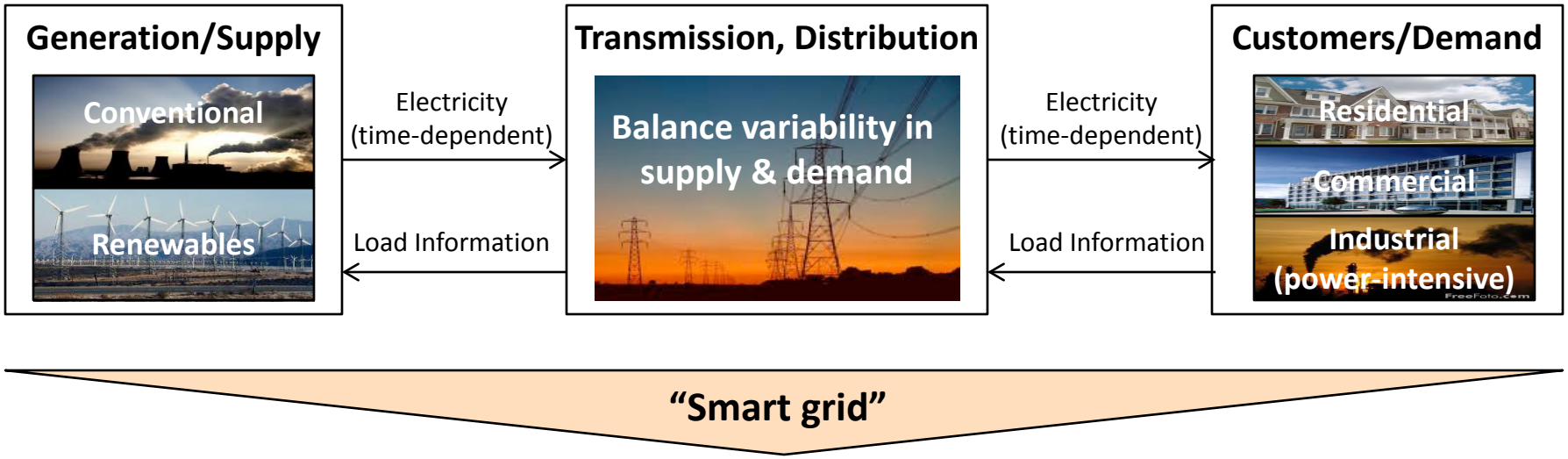
Multi-scale Demand-Side Management for Continuous Power-intensive Processes

Sumit Mitra
Advisor: Prof. Ignacio E. Grossmann
Department of Chemical Engineering,
Carnegie Mellon University, Pittsburgh, PA

Collaborators: Jose M. Pinto (Praxair), Nikhil Arora (Praxair)

Demand-Side Management (DSM) is a key ingredient to address variability in the future power system



Demand-Side Management (DSM)

"Systematic utility and government activities designed to **change the amount and/or timing of the customer's use of electricity** for the collective benefit of the society, the utility and its customers."*

Demand Response (DR)

→ Reduce demand on operational level

Energy Efficiency (EE)

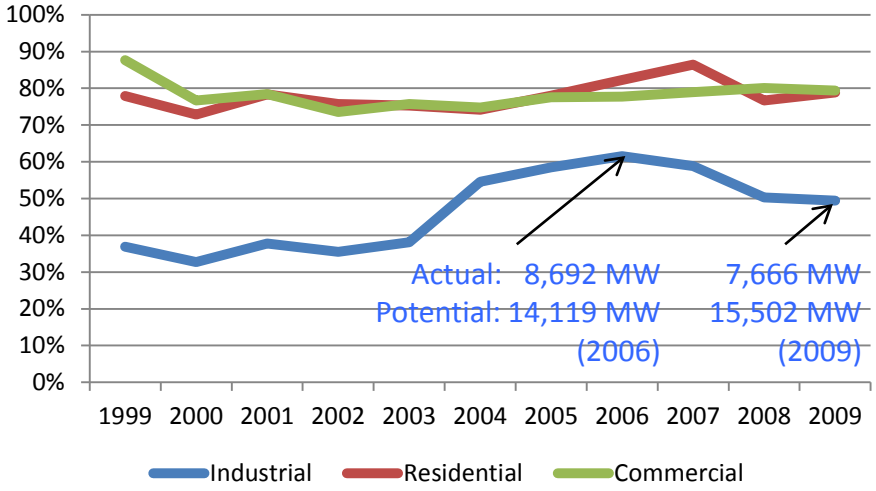
→ Permanently reduce power consumption

Source: [*] Charles River Associates, 2005 "Primer on Demand-Side Management, with an emphasis on price responsive programs", CRA No. D06090, Technical report, The World Bank.

Potential for industrial Demand-Side Management is not fully realized in the U.S.

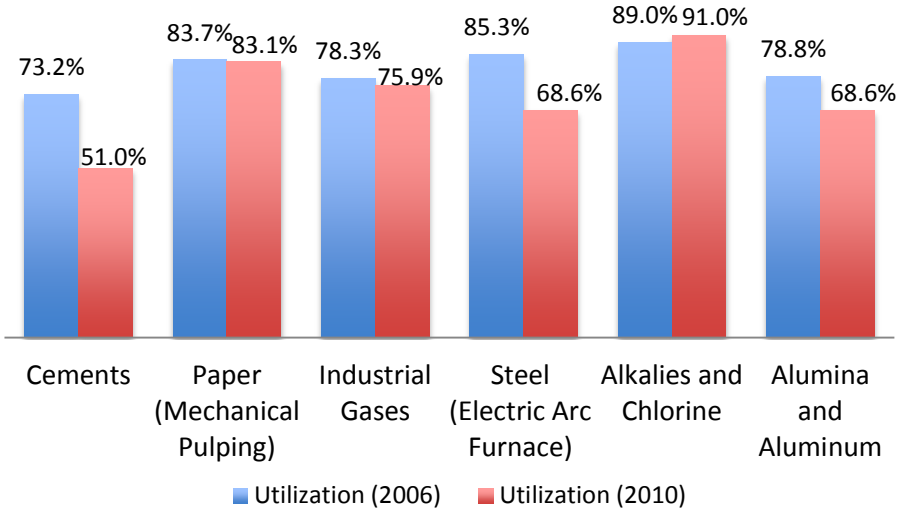
Industrial DSM decreased despite lower capacity utilization in the aftermath of the recession.

Ratio Actual/Potential Peak Load Reductions



Source: EIA, Electric Power Annual 2009, April 2011, Demand Side Management, Annual Effects by Program Category

Capacity utilization of selected sectors* with DSM potential: pre/post-recession



Source: Federal Reserve, Industrial Production and Capacity Utilization, March 2011; American Metal Market, 2007; CAPD analysis

[*] Selected sectors according to: Paulus, M.; Borggrefe, F. The potential of demand-side management in energy-intensive industries for electricity markets in Germany. Applied Energy, 88:432–441, 2011.

DSM is part of a complex multi-scale design and operations problem for power-intensive processes.

Process flexibility and product inventory facilitates performing DSM at air separation plants.

Operational layer

Variability and uncertainty in prices

- Timing and production quantities **(DR)***
- **Inventory management**
- Operability and safety concerns

- Satisfy demand
- Product distribution

Process Flexibility

Strategic (design) layer

Sourcing of electricity

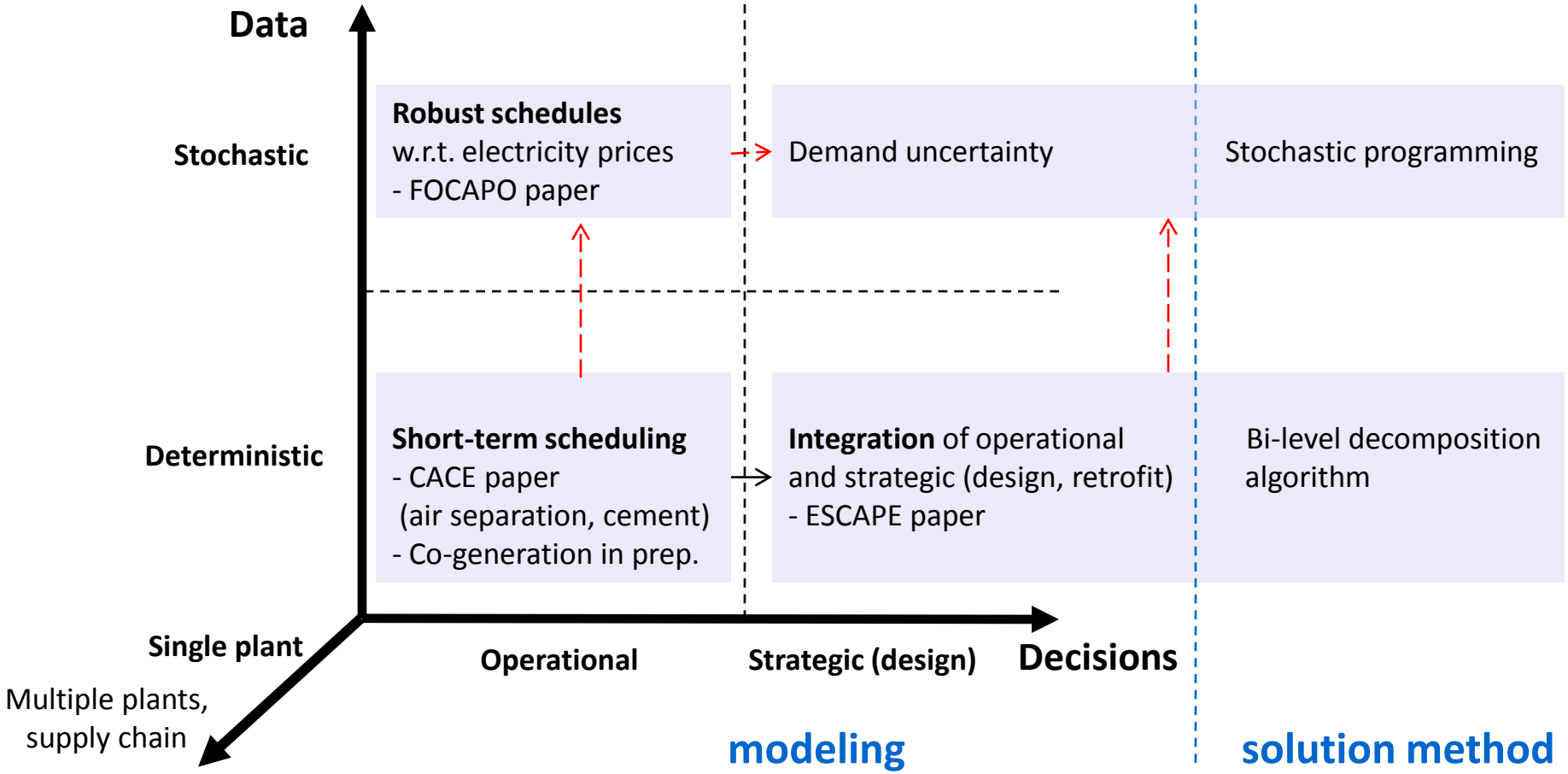
- Process improvements, retrofits **(Energy efficiency)**
- Additional storage

- Demand/economic uncertainty

* Demand Side Management (DSM) consists of Demand Response (DR) and Energy Efficiency (EE)

Multi-scale nature of problem might cause difficulties in realizing the full DSM potential.

Main question: How to design flexible processes such that operational savings are realized?



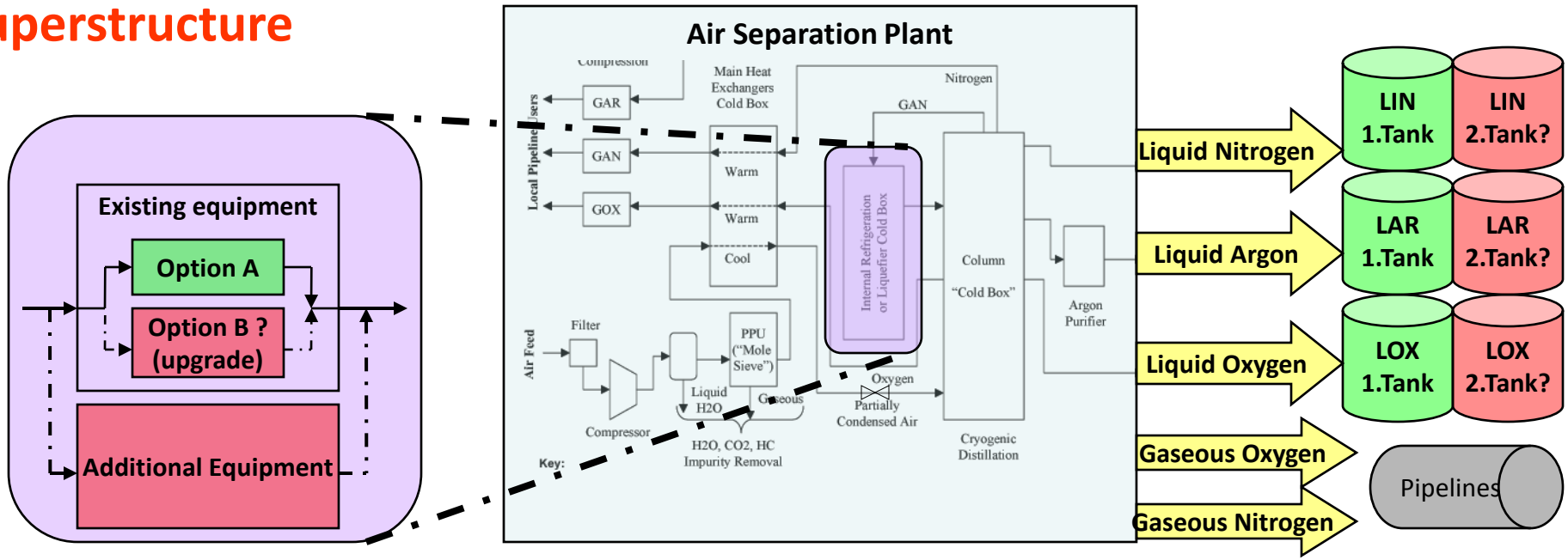
Mitra, S.; Grossmann, I.E.; Pinto, J.M.; Arora, N., Optimal Production Planning under Time-sensitive Electricity Prices for Continuous Power-intensive Processes, Computers & Chemical Engineering, 2012, 38, 171-184.

Mitra, S.; Grossmann, I.E.; Pinto, J.M.; Arora, N., Robust Scheduling under Time-sensitive Electricity Prices for Continuous Power-intensive Processes, FOCAPO 2012.

Mitra, S.; Grossmann, I.E.; Pinto, J.M.; Arora, N., Integration of strategic and operational decision- making for continuous power-intensive processes, ESCAPE 2012.

Retrofitting an air separation plant: selection and timing of design alternatives are degrees of freedom

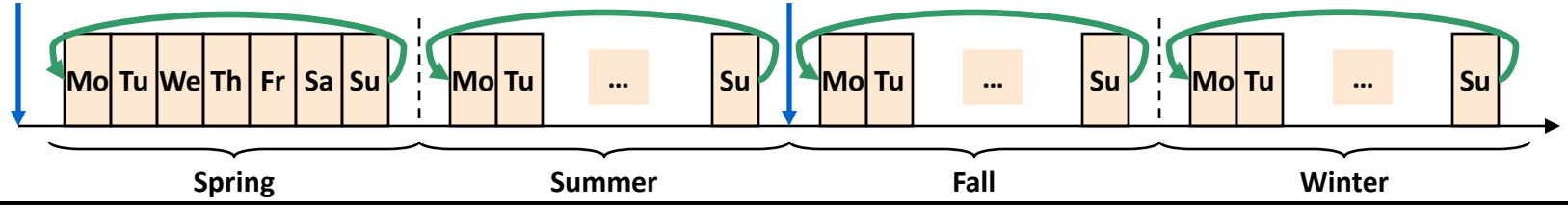
Superstructure



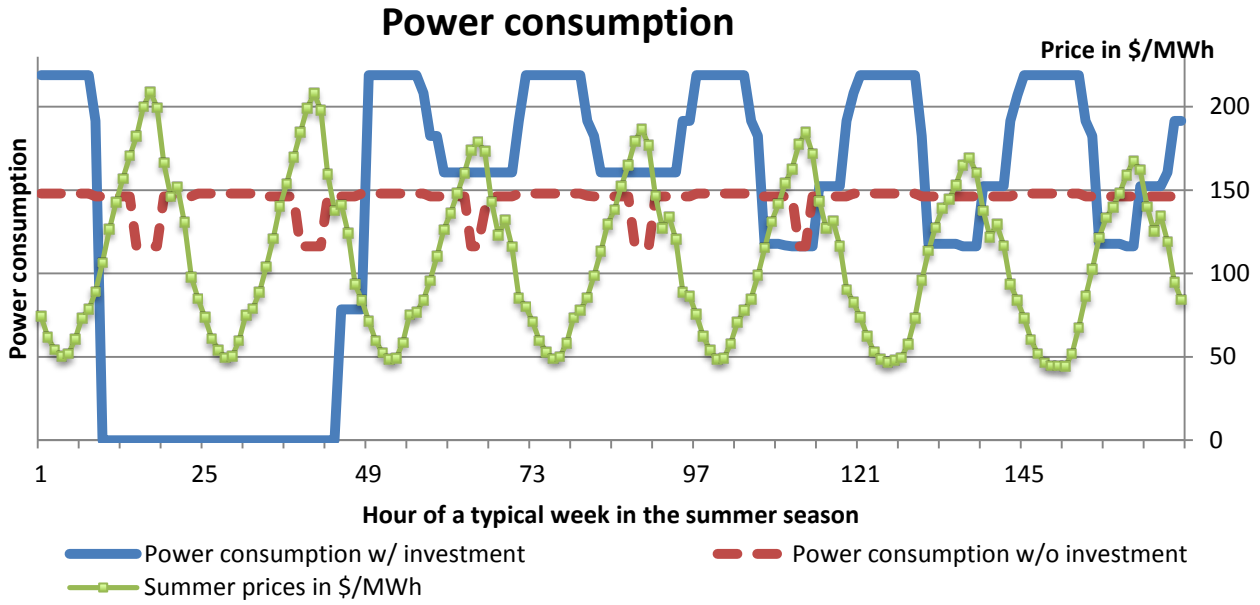
Time

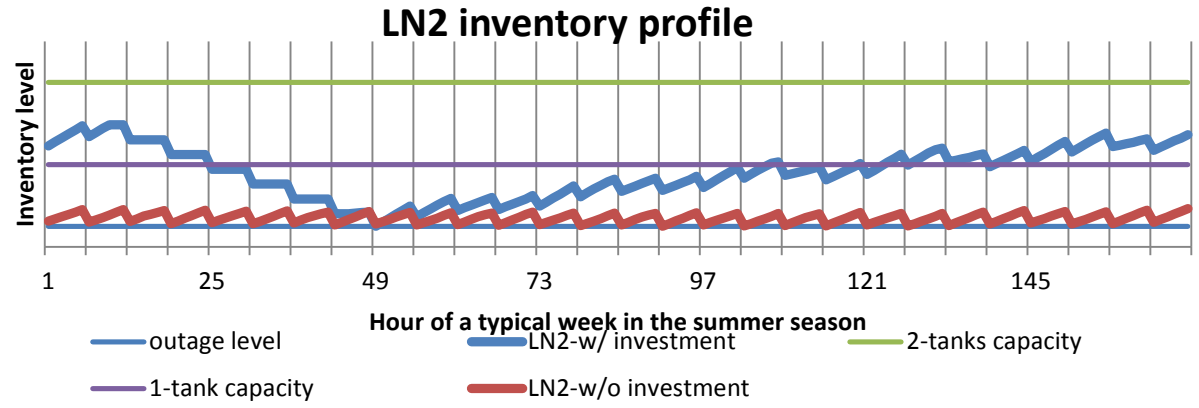
Spring - Investment decisions: (yes/no)
- Option B for existing equipment?
- Additional equipment?
- Additional Tanks?

Fall - Investment decisions: (yes/no)
- Option B for existing equipment?
- Additional equipment?
- Additional Tanks?



Investments in additional production and storage capacity increase flexibility and help realizing savings.



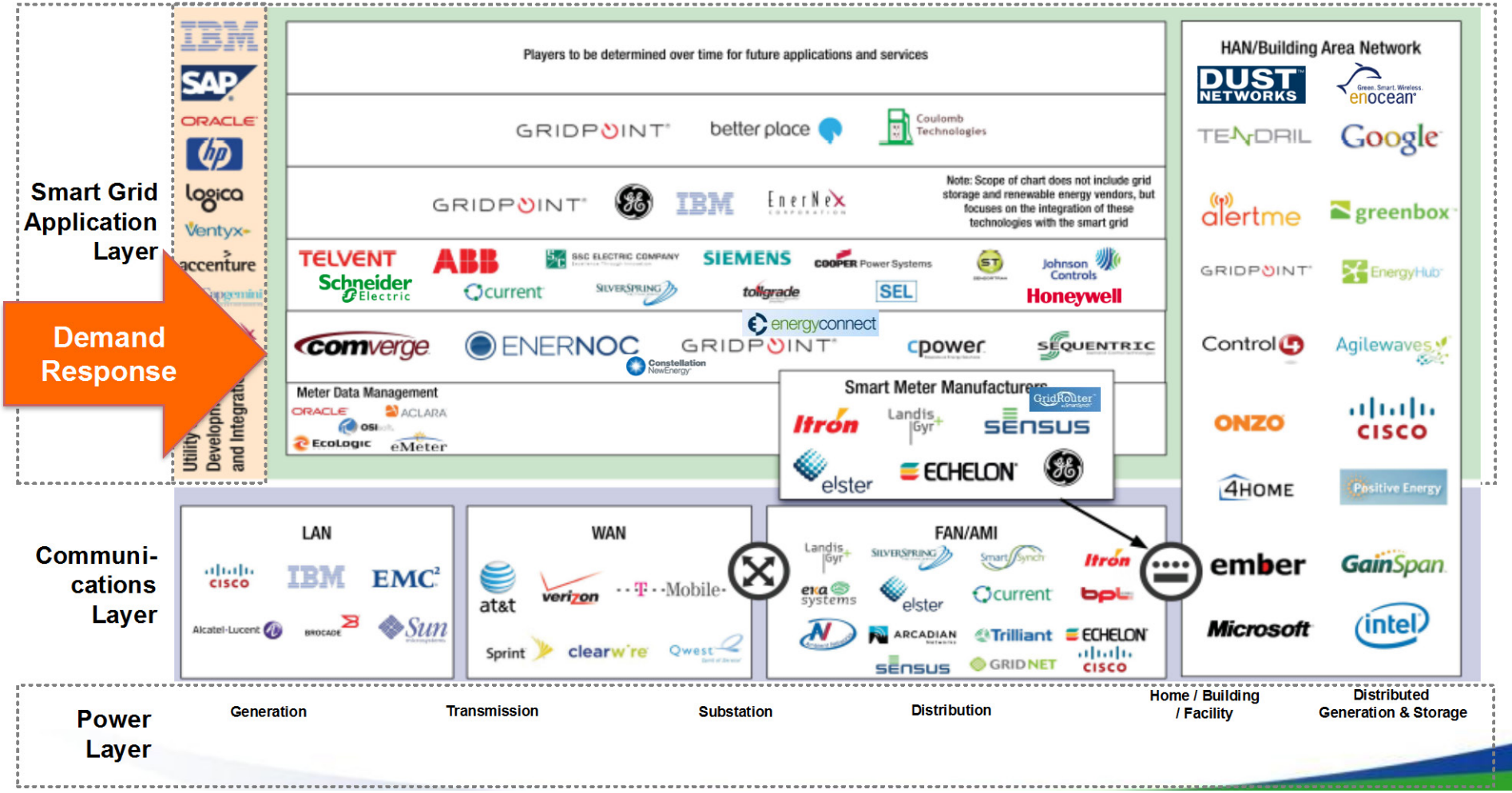


Remarks on case study

- **Annualized savings: ~7%**
- Buy new liquefier in the first time period
- Buy additional LN2 storage tank
- Don't upgrade existing equipment
- Take-away message on operational level: *Reduce production when prices are high and build up LN2 when prices are low.*
- Utilization of existing equipment: 97%.

Source: CAPD analysis

Smart grid: The competitive landscape is diverse*



[*] According to Entelios (Germany's first demand response aggregator).