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European Energy Policy Conference

Utilities of the future

Tomás Gómez

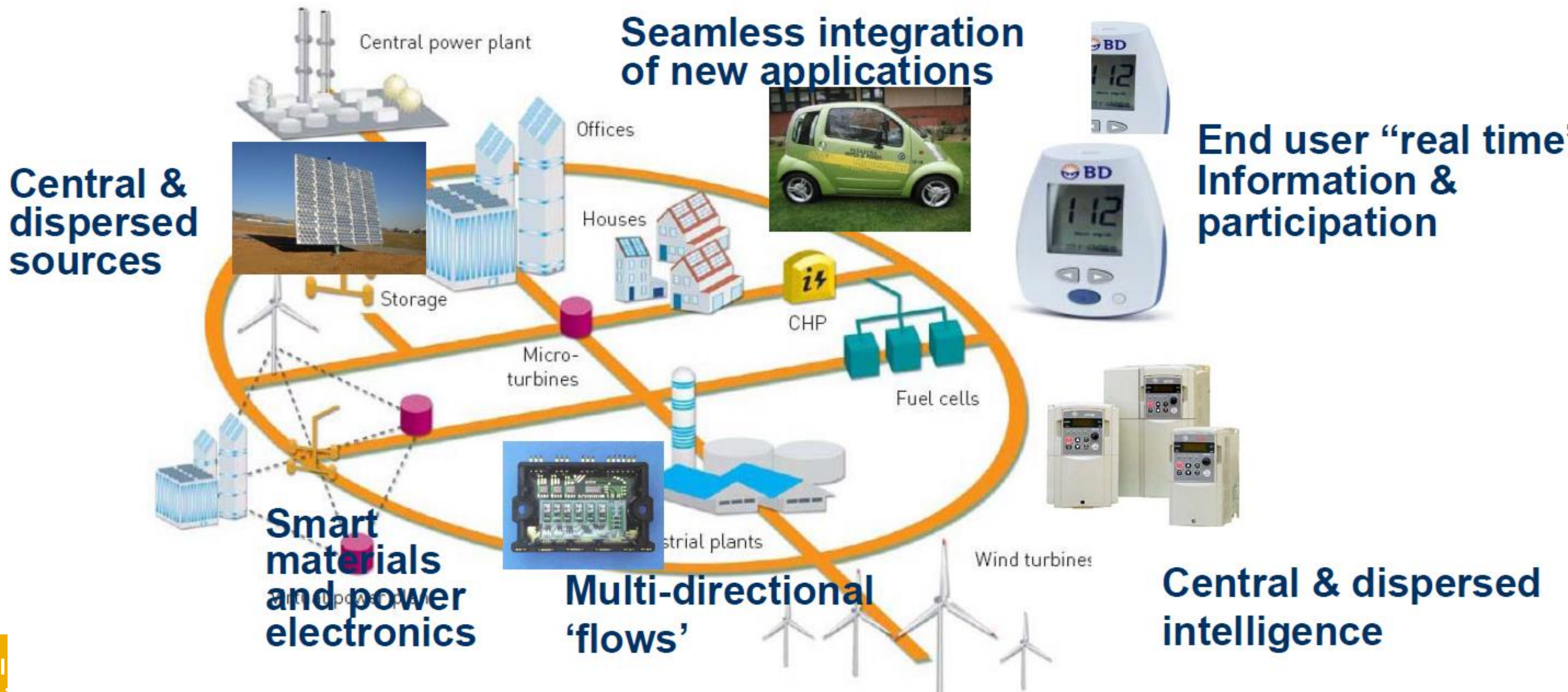
Madrid, 2-3 July 2014

Contents

- **Research focus**
- From technologies to business models
- Analytical models
- Future research

Context: “Utility of the future” project

- A MIT and IIT-Comillas research team
- Focus : “*analyze* ***the future of the delivery of services that electricity can provide****, either in a* ***centralized*** *or* ***decentralized*** *manner, identifying successful* ***business models****,* ***regulatory trends*** *and* ***transformative technologies****, within the global framework of an increasingly decarbonized power sector*”



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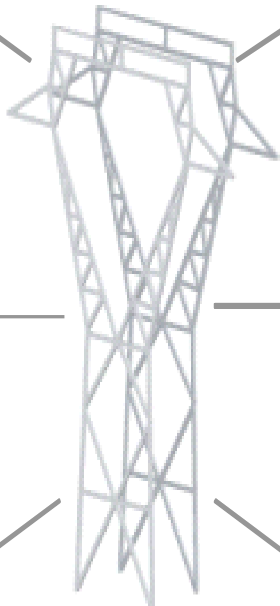
Centralized vs decentralized resources

Limited interconnections

Big pow er generation plants

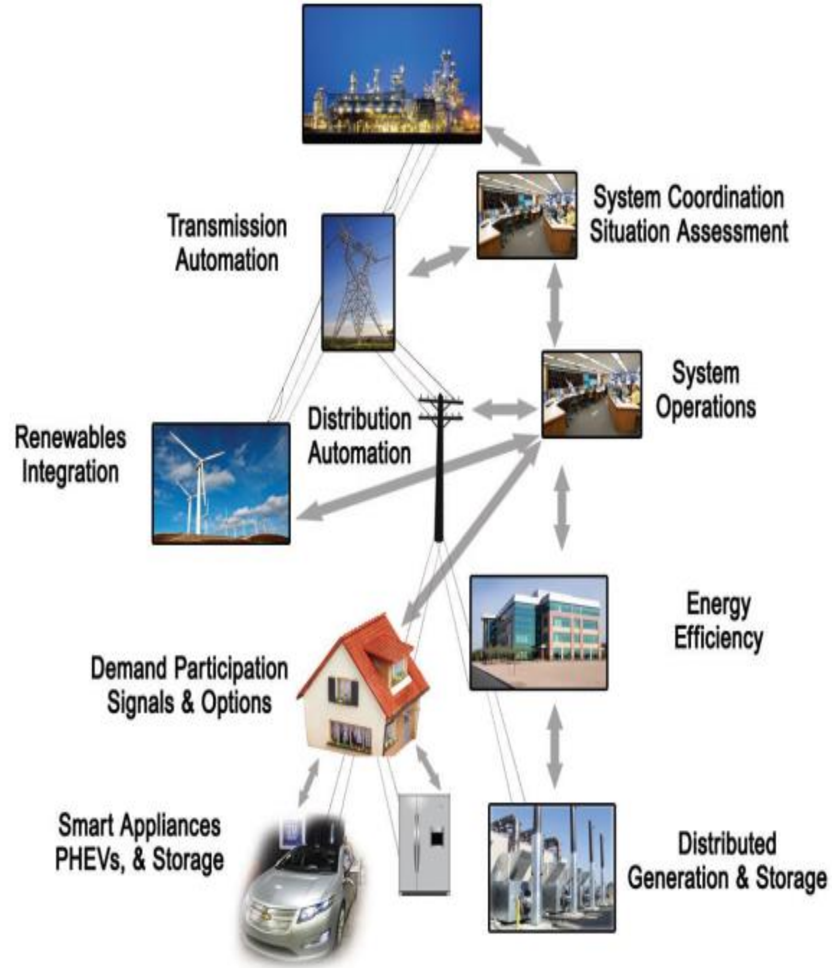


Centralised control

Technically optimized to fit local demand

Outdated technology (more than 100 years old)

Regulatory deficiencies in commercial framew ork



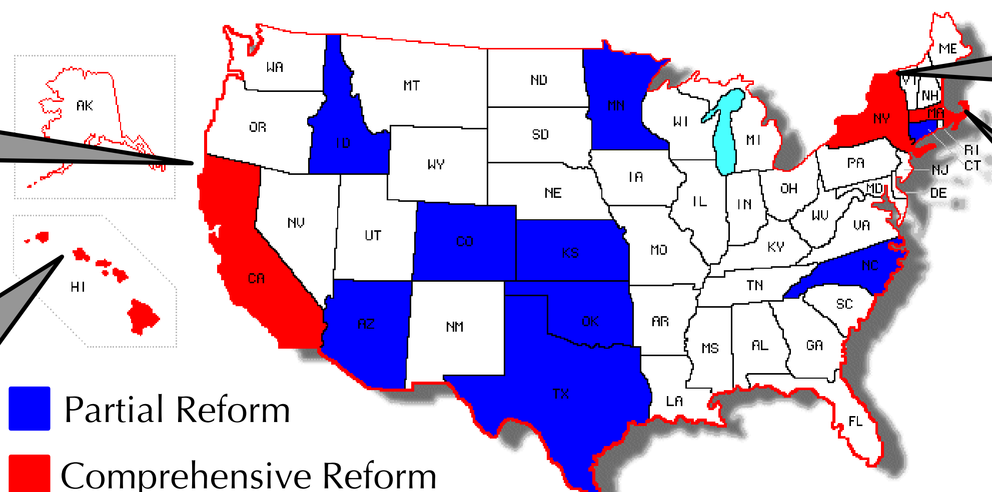
Source: *Smart Grid System Report. US DoE. 2009*

Policy drivers for transformation

- Transition towards a low-carbon economy
- EU Energy policies
  - Support to renewable and CHP production
  - Energy efficiency action plans
  - R&D and D&D projects for smart grids
- US State regulatory commissions: plans to integrate more DER and reform regulatory models

CAPUC: Assembly Bill No. 327

HIPUC: “Inclinations on the Future of Hawaii’s Electric Utilities”



NYPSC: “Reforming the Energy Vision”

MADPU: Grid Modernization Proceedings

Technology drivers

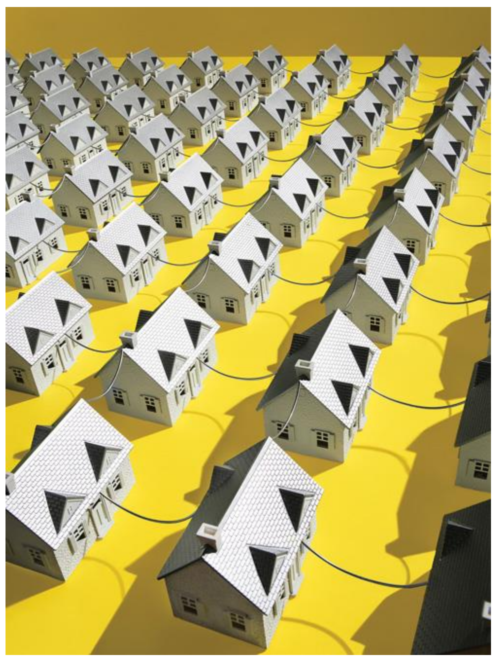
- Information and communication technologies

- Distributed energy resources
  - Flexible demand (demand response): smart meters, building and home EMS, virtual storage
  - Distributed on-site generation: PV, CHP, biogas, back-up units
  - Plug-in electric vehicles (dumb and smart charging, V2G)
  - Power storage: batteries
  - Power electronics and control for integration of resources

- Converging infrastructures: energy (electricity, gas, heat), transportation, communications (smart cities)

Socio-economic drivers

- Sustainability
- Self-sufficiency
- Affordability
- Self-governance
- Example: The rise of the personal power plant (IEEE spectrum)



8 Technologies That Will Shape the Future

The Next 50 Years

"Smart and agile power systems will let every home and business generate, store, and share electricity"

System-wide impacts

- If the provision of electricity services becomes more diverse and decentralized (in a fundamental and sustainable manner)
  - Greater competition for centralized generators
  - Changes to transmission and distribution system investment and operation
  - Changes in energy mix, with implications for climate change

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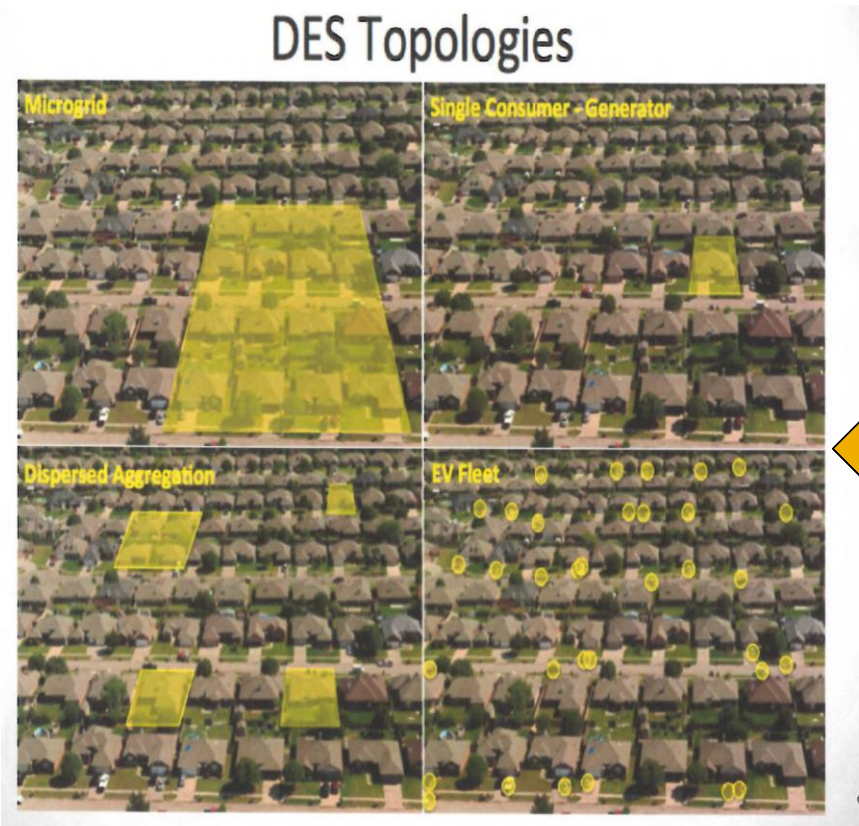
From technologies to business models



Services provided by business models

- Service categories provided by business models to end-users
  - Capacity / peak demand reduction
  - Energy /self-generation and exports
  - Resilience against grid outages
  - Multi-energy services

Solar City-Tesla: PV installer/car-battery maker
NRG Beacon 10: solar-natural gas-battery: 15 kW of electricity + heat + hot water
Stem: batteries networked with EMS
Coda Energy: renewable + batteries reducing building energy bills

Business Model Attributes	Own	Operate	Finance	Build	Aggregate
Customer-sited DES: Solar City-Tesla	✓	✓	✓	✓	✓
Customer-sited DES: NRG Beacon 10		✓	✓	✓	✓
Microgrids: General Microgrids		✓	✓	✓	
Networked Battery & EMS: Stem		✓	✓	✓	✓
Customer-sited DES: Coda Energy		✓	✓	✓	

Aggregator business model

DSS: Decision Support System

EB: Energy Box

WSN: Wireless Sensor Network

S: Sensor

A: Actuator

RS: Remote Sensor

RA: Remote Actuator

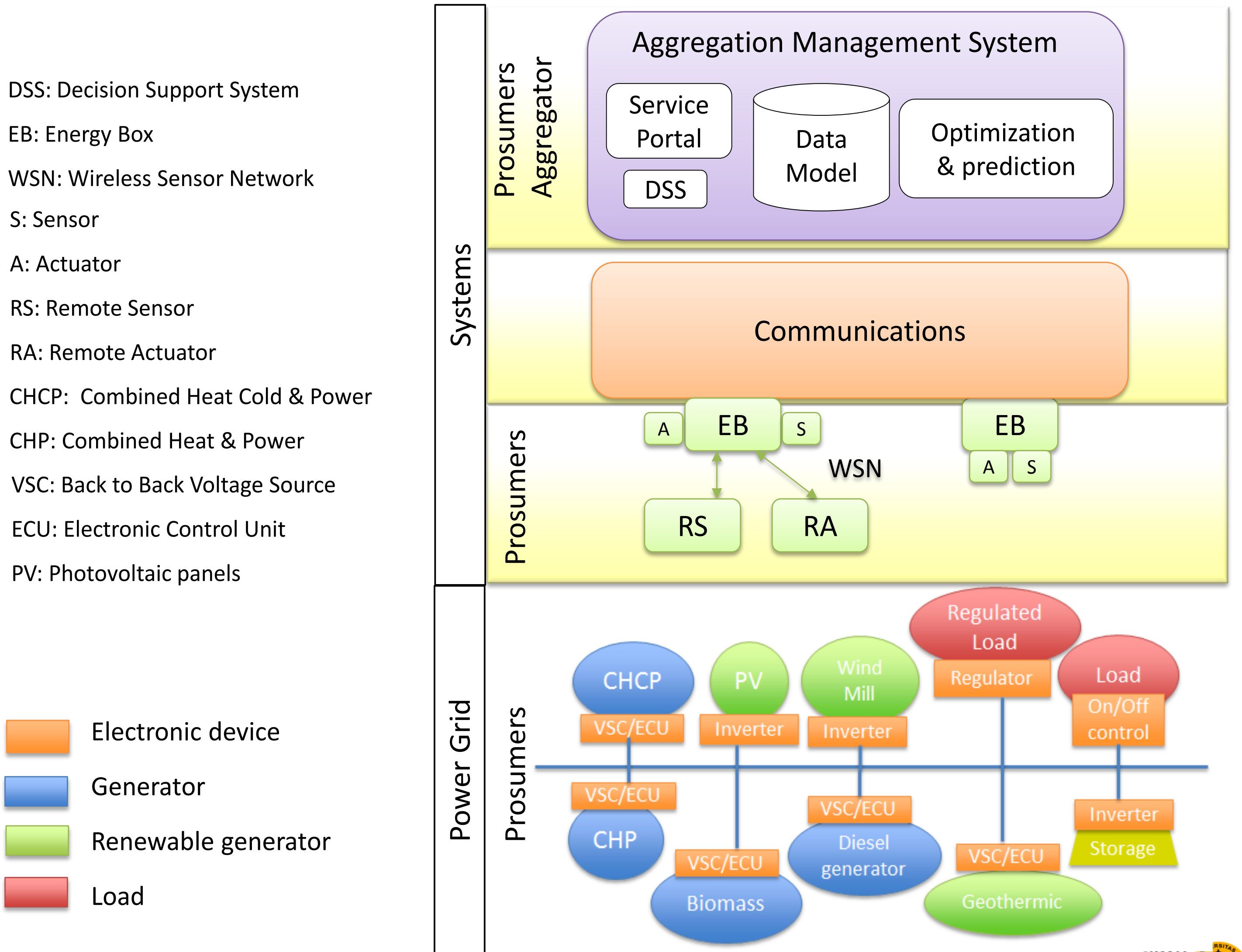
CHCP: Combined Heat Cold & Power

CHP: Combined Heat & Power

VSC: Back to Back Voltage Source

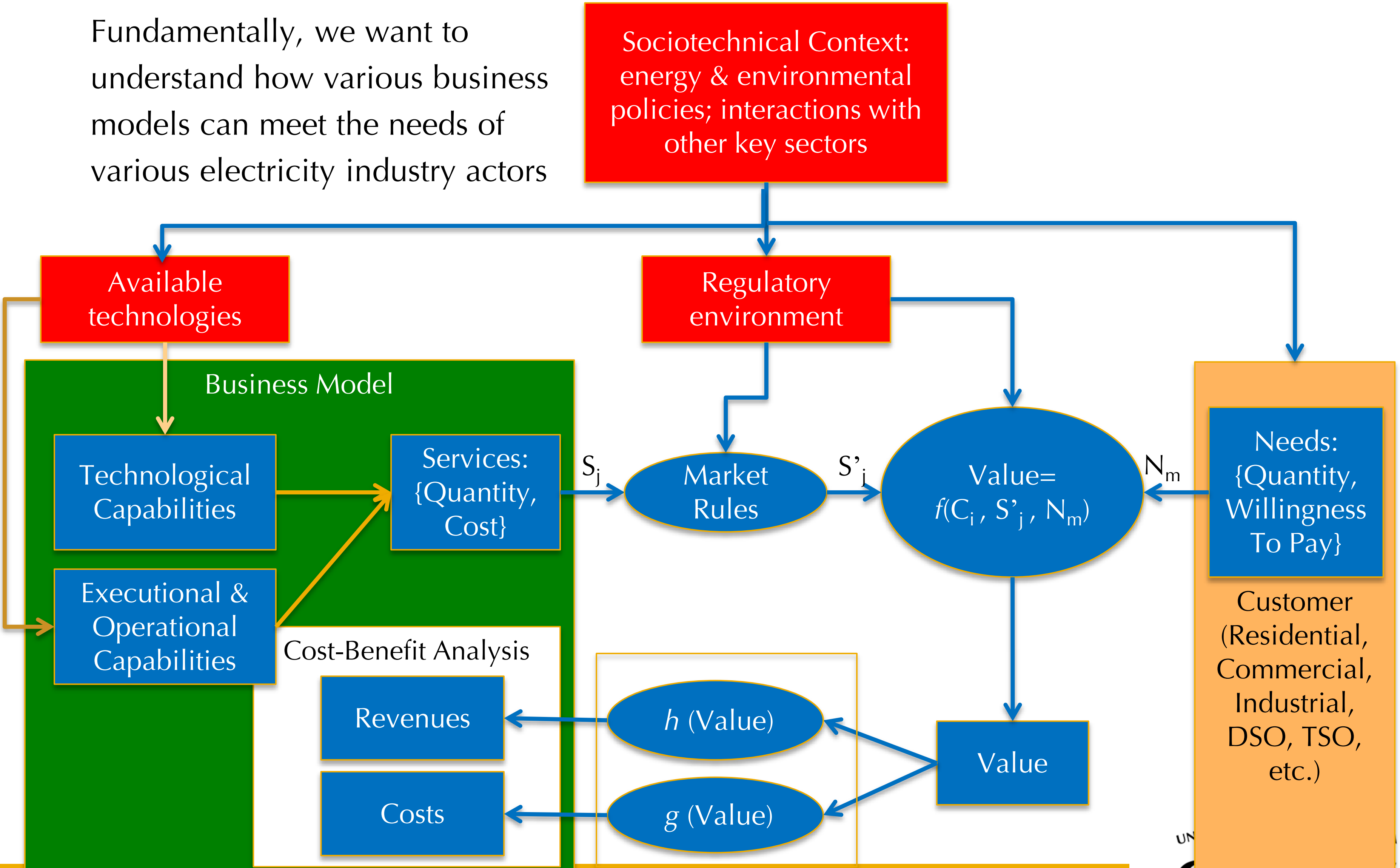
ECU: Electronic Control Unit

PV: Photovoltaic panels



Business Model Analysis: Framework

Fundamentally, we want to understand how various business models can meet the needs of various electricity industry actors



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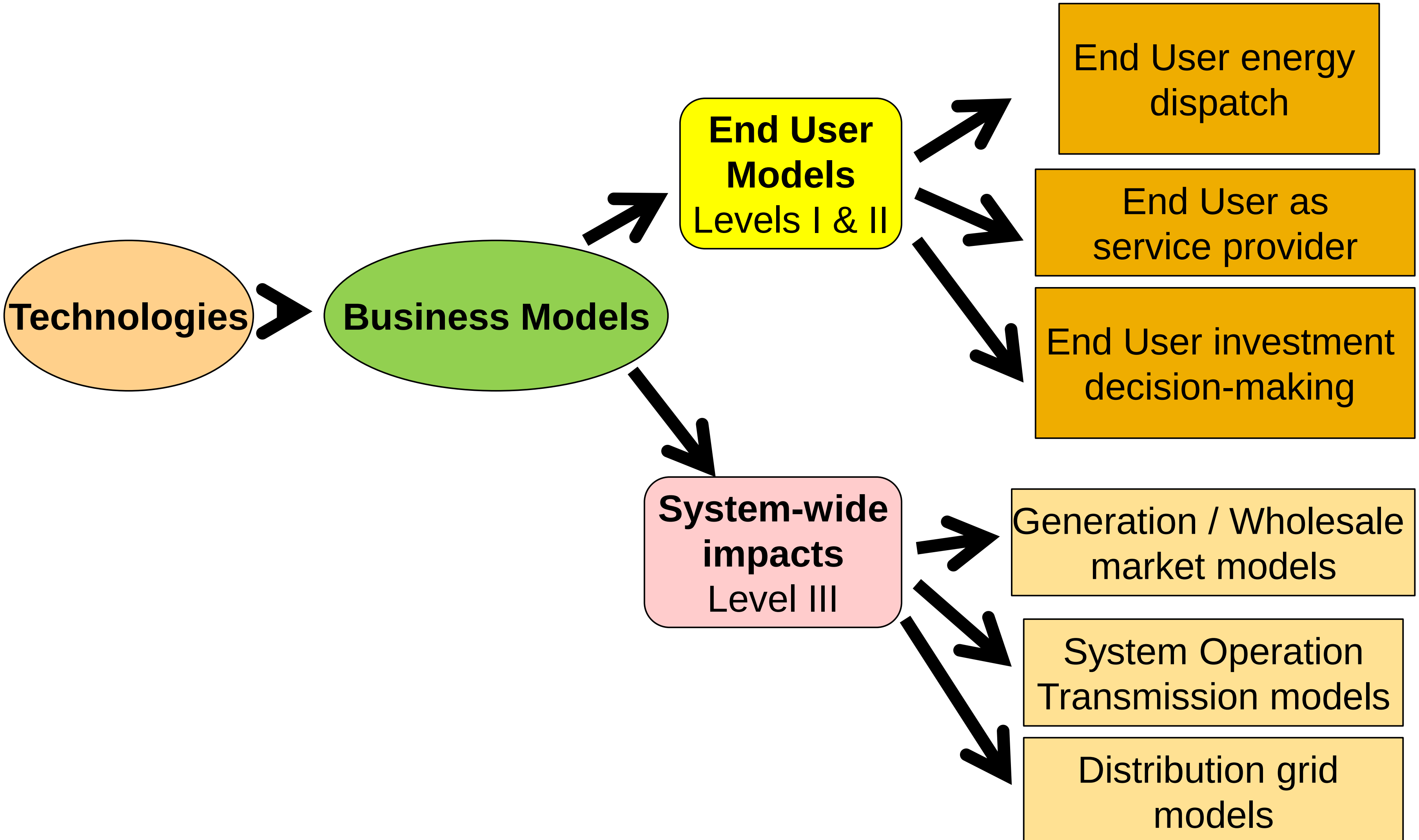
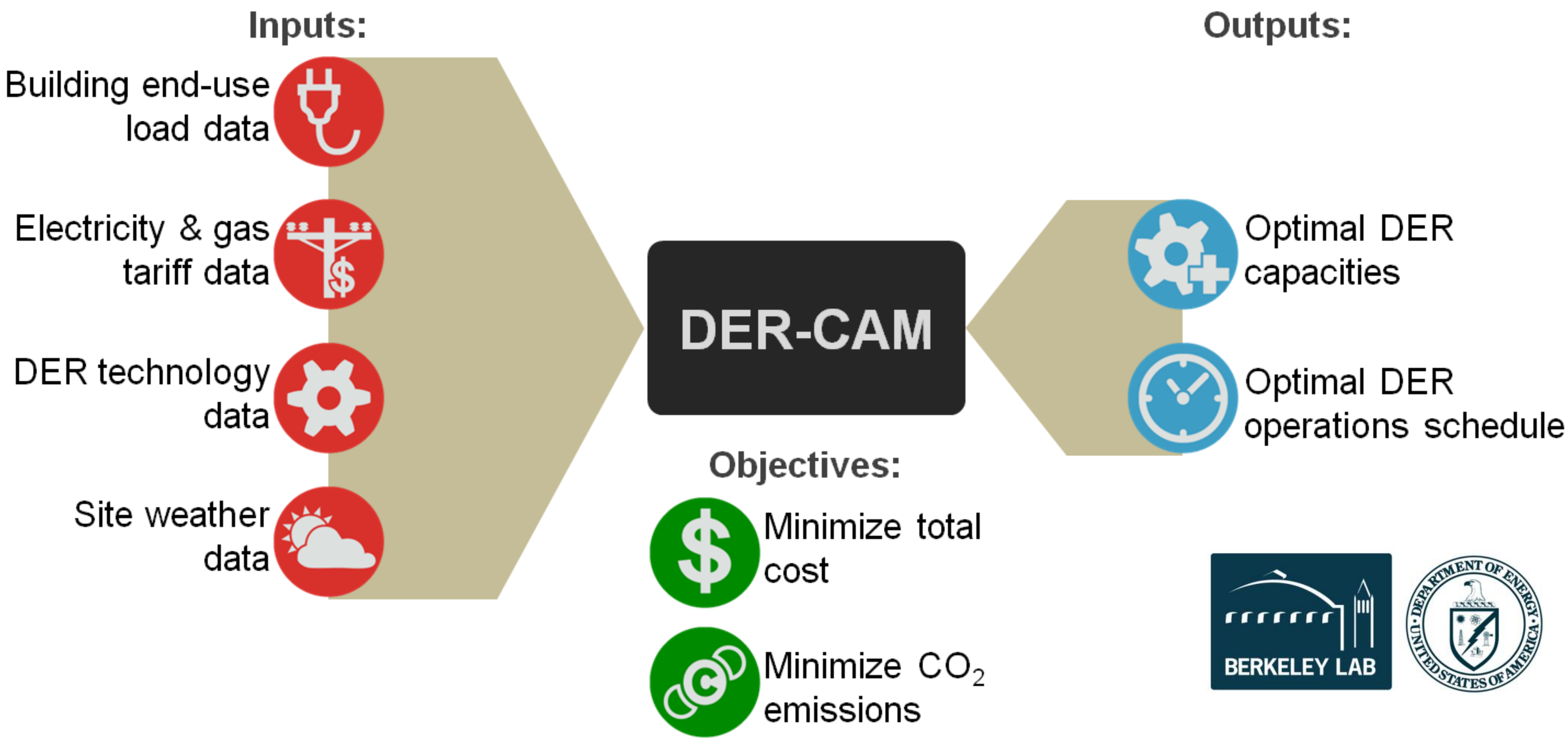
Analytical models



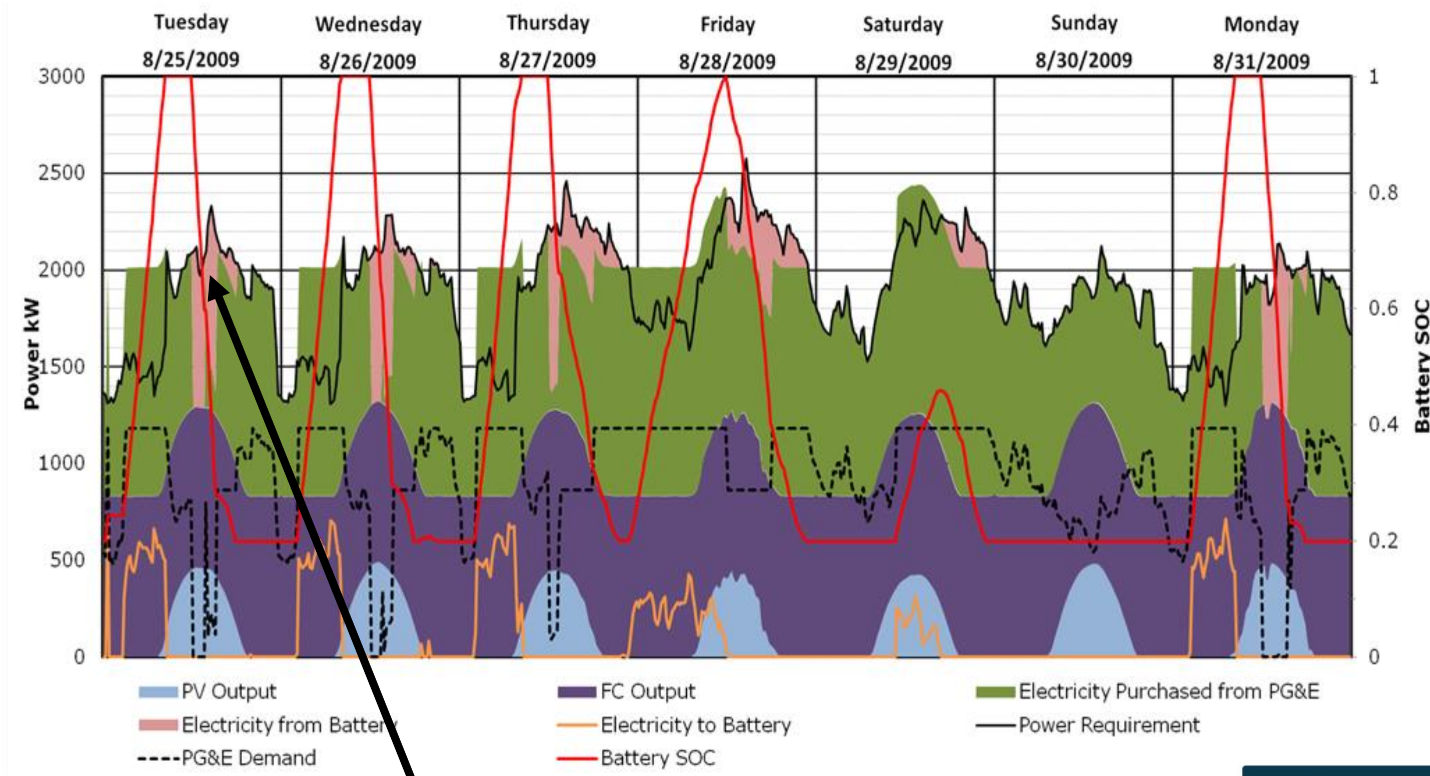
Distributed energy resources – Customer adoption model (DER-CAM)



- **Investment & Planning:** determines optimal equipment combination and operation based on *historic* load data, weather, and tariffs
- **Operations:** determines optimal week-ahead scheduling for installed equipment and *forecasted* loads, weather and tariffs

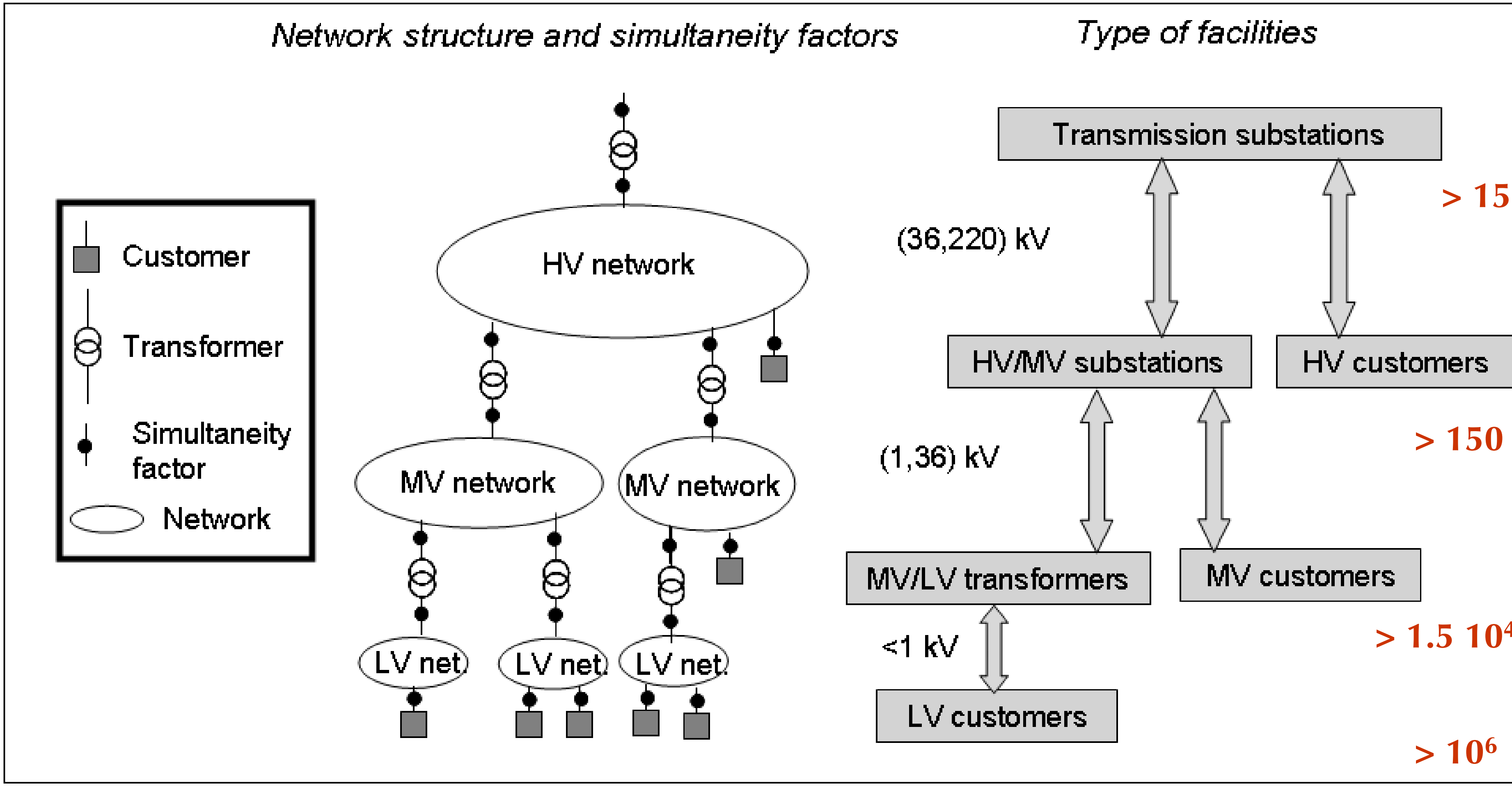
Optimal schedule of resources: An example

- End User (building) energy bill minimization



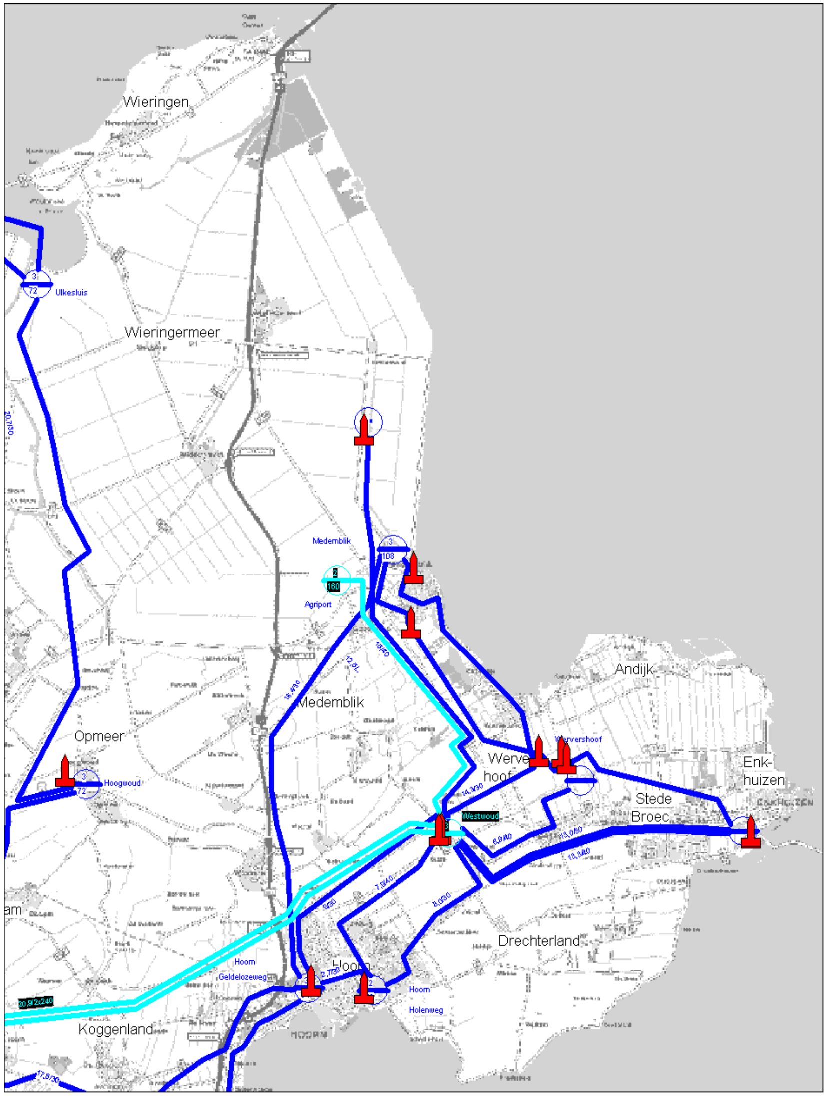
DER-CAM minimizes on-peak purchases due to high demand charge

Large-scale distribution grids planning - Reference Network Models



- *Input Data: HV, MV and LV customers, and transmission substations*
- *Results of the model: LV, MV & HV network, HV/MV and MV/LV substations*

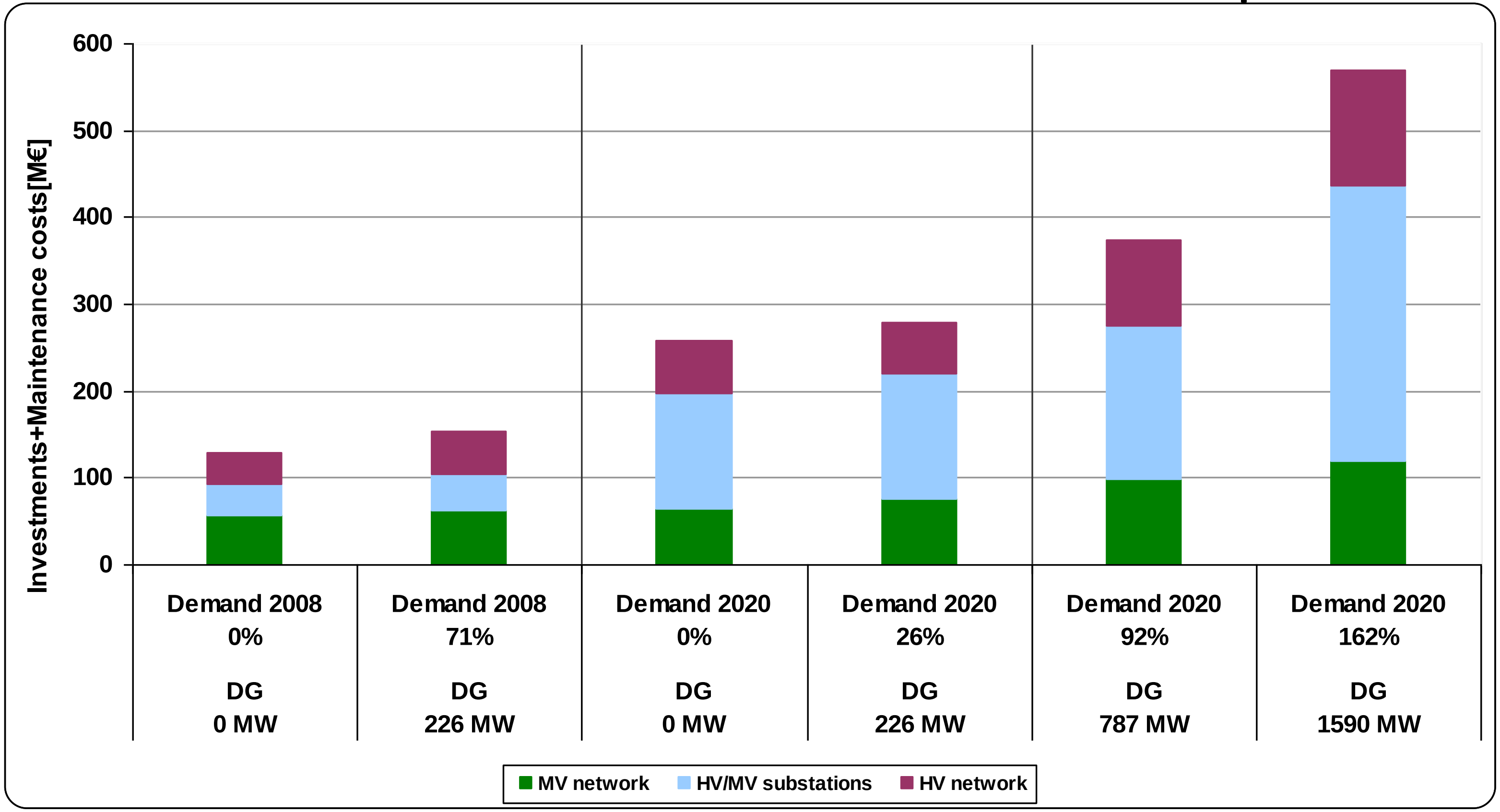
DG penetration (RNM): Netherlands - Kop van Noord



- Rural/sub-urban area
- Approx. 80,000 loads (~675 km²)
- Grid: HV (150kV-50kV) and MV (10kV)
- LV loads aggregated at MV points
- Present DG already high in relation to local demand
- Major developments expected in DG (especially at MV):
  - Attractive area for further growth of wind energy
  - Mayor developments in agriculture: CHP for horticultural greenhouses

Grid investment planning with increasing DG (RNM)

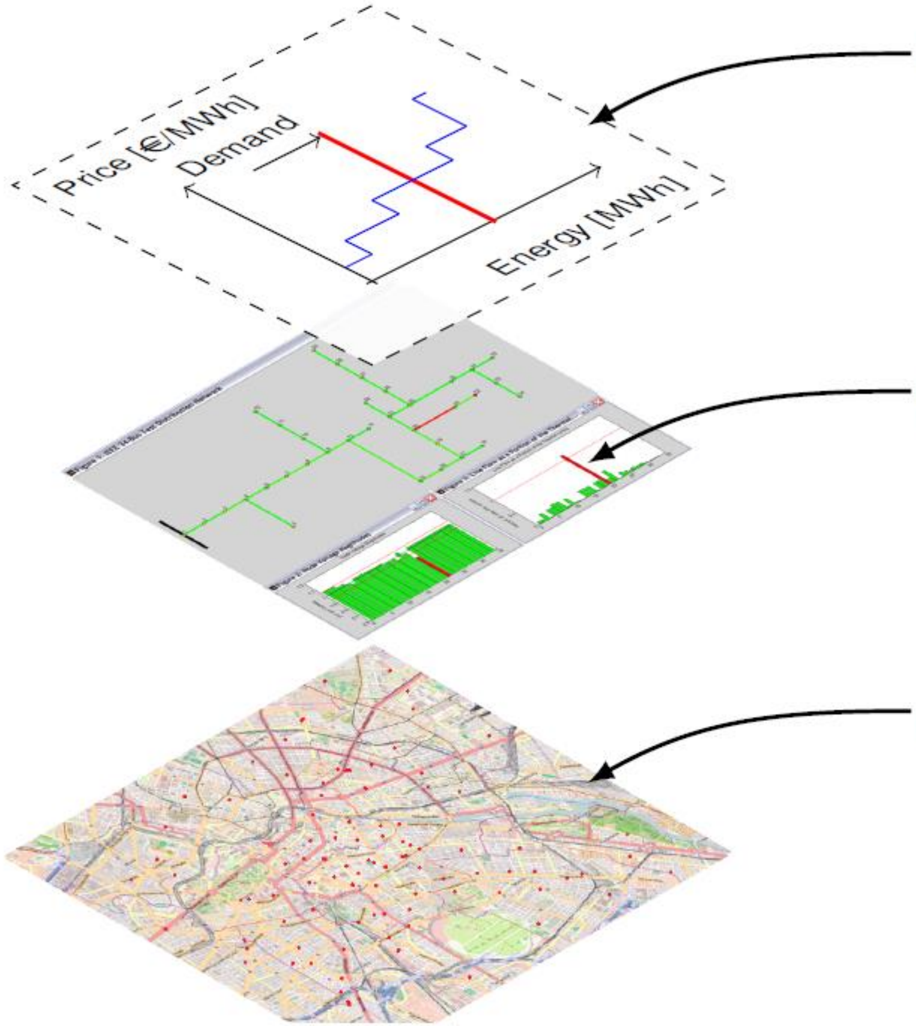
- 2020 DG scenarios: Netherlands - Kop van Noord



Present value of investment and maintenance costs

R. Cossent, L. Olmos, T. Gomez, C. Mateo, P. Frias, "Distribution network costs under different penetration levels Of distributed generation" European Transactions on Electrical Power 2011(21): 1869-1888.

Plug-in electric vehicles – PEV Aggregator (PEVAGG)



Electricity Market - PEV Aggregator

- Takes market decisions on multiple trading floors
- Exposed to uncertainty in prices, fleet availability and demand

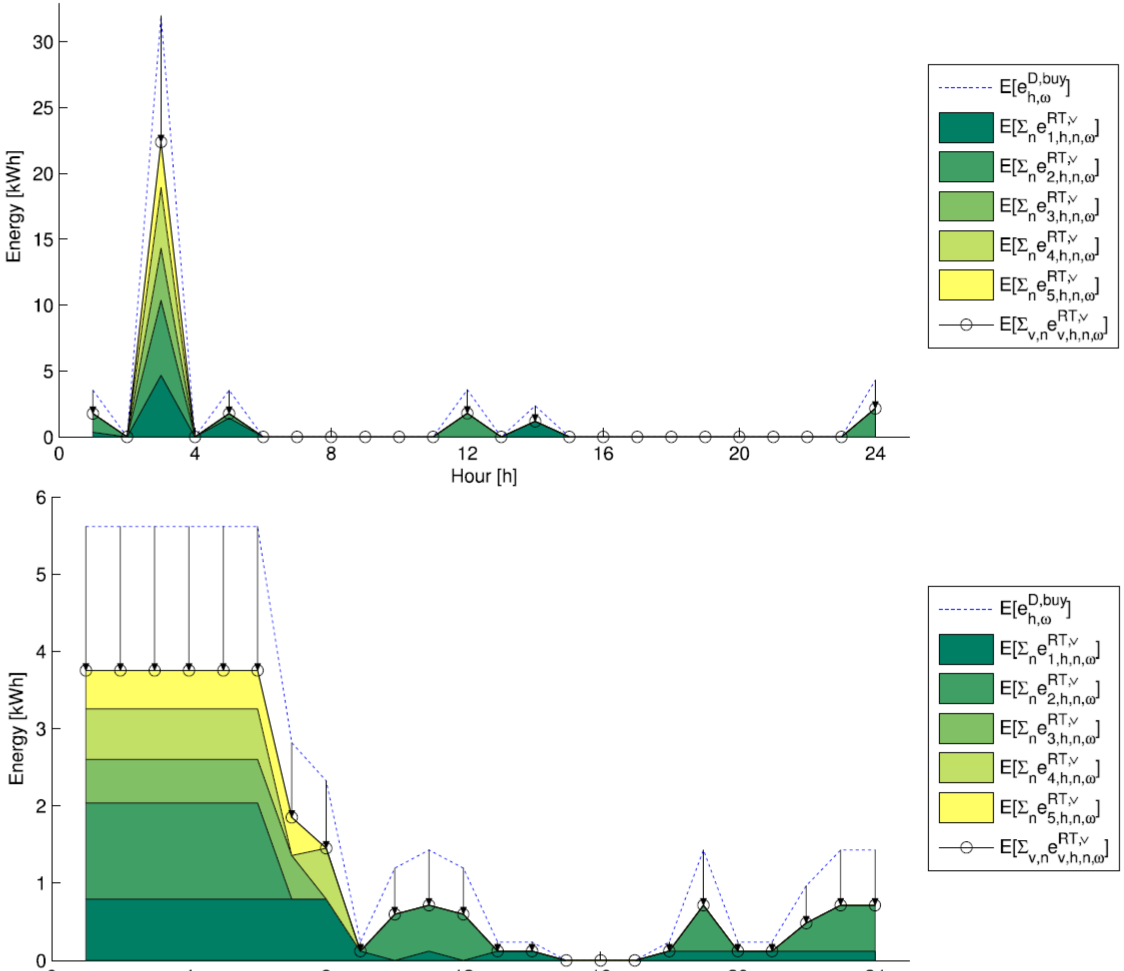
MV/LV Distribution Grid - DSO

- Network expansion planning
- Operates the grid in secure conditions (voltages, line currents)
- Calculates network use-of-system fees

PEV Mobility - Final customers

- Drive and connect at supply points
- Require energy for mobility

PEVAGG – Stylized example

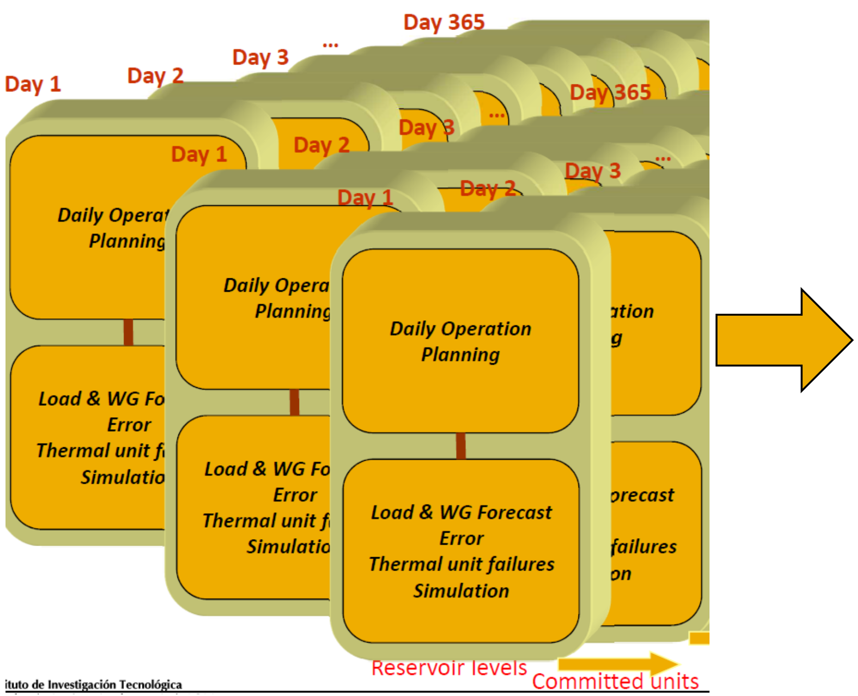


The effect of network charges \$/kW

I. Momber, T. Gómez, and L. Söder, "PEV Fleet Scheduling with Electricity Market and Grid Signals," in International Conference on the European Energy Market (EEM), Stockholm, Sweden, May 2013.

System-wide impacts of distributed resources (ROM)

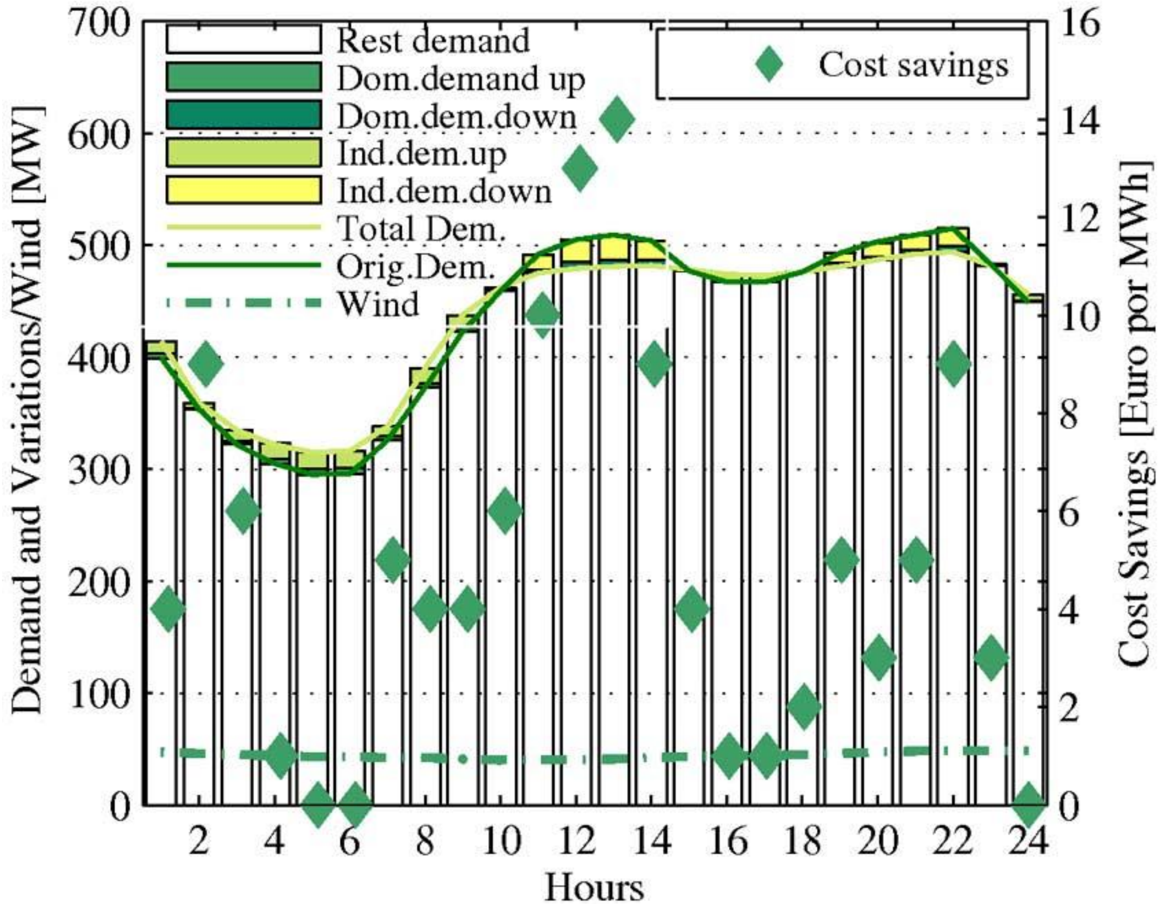
- Reliability and operation model of generation/wholesale
- Simulation of system operation with integration of renewables
- Effects of large penetration of distributed resources: e.g. demand flexibility



RESULTS

- Operation
  - Output of different technologies (thermal, hydro, pumped hydro)
  - Fuel consumption
  - Primary energy (wind or hydro) surplus
- Emissions
  - Carbon emissions
- System reliability
  - EENS (Expected Energy Not Served)
  - LOLP (Loss of Load Probability)
  - LOLE (Loss of Load Expectation)
  - XLOL (eXpected Loss Of Load)
- System Marginal Costs

ROM: demand shifting (cost minimization)



Dietrich, K., Latorre, J.M., Olmos, L., Ramos. "Demand Response in an Isolated System With High Wind Integration", IEEE Transactions Power Systems, 2012(27), 20–29.

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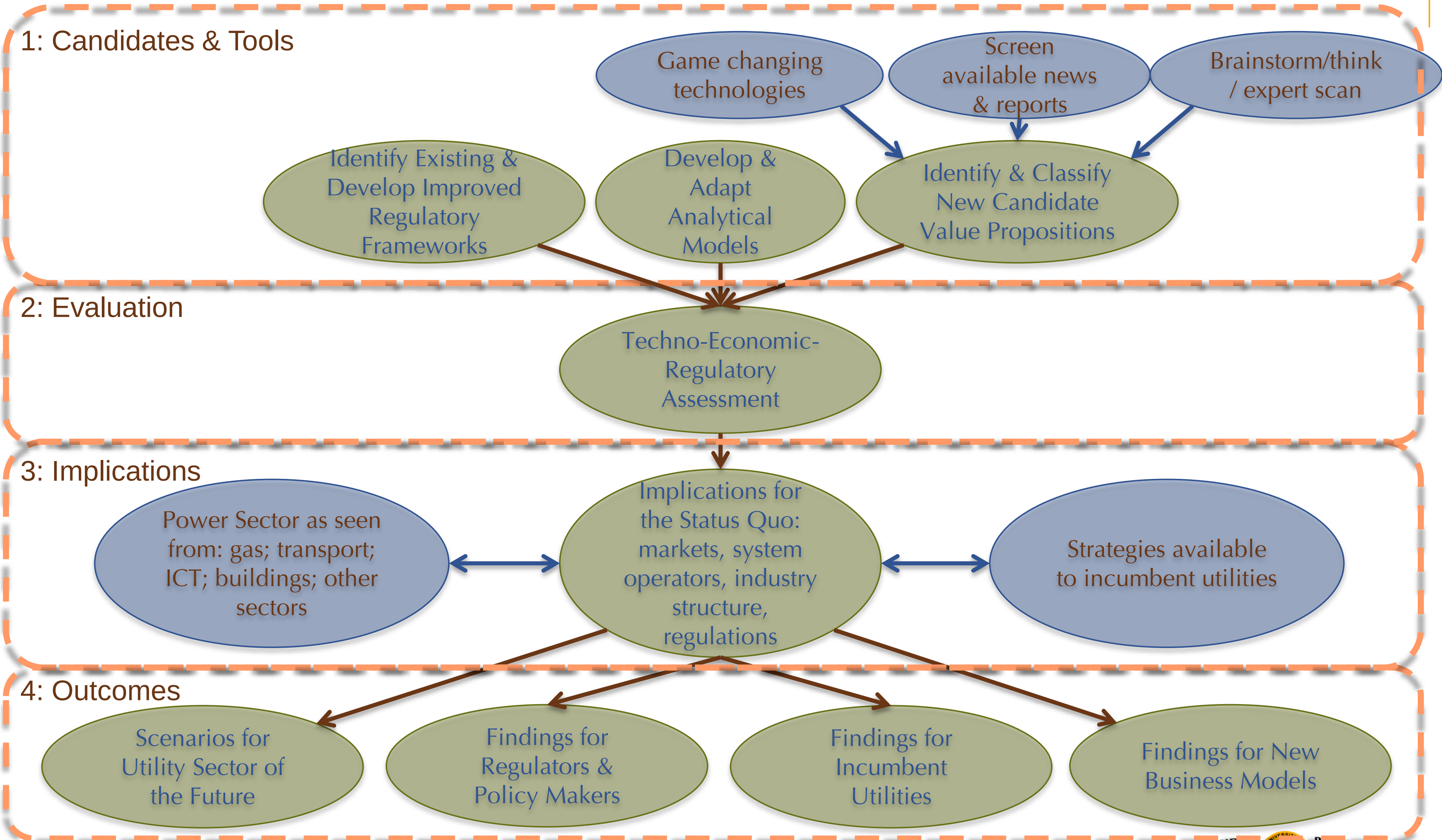
Major implications

- If provision of electricity services becomes **increasingly diverse and decentralized**, it has important implications for a number of interrelated issues:
  - **Climate**: future generation mix, policy and regulatory environment
  - **Economy**: societal/economic benefits of a more decentralized system
  - **Policy**: trade-off between short and long-term roadmaps and continuous adaptation to new situations and environments
  - **Regulation**: Regulation and markets may need to be reformed to create a level playing field of new electricity services and products
  - **Technology**: New technologies and operational paradigms can emerge in a distributed future
  - **Industrial Organization**: The electric power industry could change dramatically as new players and organizations reshape the way electricity services are delivered

The MIT Utility of the Future Study
Research tasks



Major Questions

- What new business models (BMs) could succeed?
  - Which factors determine success & failure?
- How these BMs could complement / compete with / add to the services provided by the incumbent utilities?
  - How much could these BMs penetrate?
- How other sectors *(gas, ICT, buildings, transportation)* could be affected / participate in this transformation?
- What major shortcomings exist in current regulation to be taken advantage of by BMs?
  - How to fix them to create a level playing field?
- What are some realistic scenarios of the delivery of electricity services in 2025?

Thank you for your attention !!!

"Utility of the Future" Project Team:

Principal Investigators: Profs. Ignacio Pérez-Arriaga & Christopher Knittel

Faculty Committee: Profs. John Deutch, Tomas Gómez, Stephen Leeb,

Richard Lester, Les Norford, Nancy Rose, Richard Schmalensee

Project Directors: Drs. Richard Tabors & Raanan Miller

Research Team: Ashwini Bharatkumar, Scott Burger, Jose Pablo Chaves,

Jesse Jenkins, Raanan Miller, Richard Tabors & Nora Xu

Advisors: Profs. Carlos Batlle, Pablo Frías, Javier Reneses,

Michel Rivier & Alvaro Sánchez

Instituto de Investigación Tecnológica
Santa Cruz de Marcenado, 26
28015 Madrid
Tel +34 91 542 28 00
Fax + 34 91 542 31 76
info@iit.upcomillas.es

UNIVERSIDAD PONTIFICIA ICAI ICADE COMILLAS MADRID