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CÁTEDRA BP DE ENERGÍA Y SOSTENIBILIDAD

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Grupo de Reflexión sobre Energía y Desarrollo Sostenible (GREDS)

The utility of the future

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Center for Energy & Environmental Policy Research, MIT

The utility of the future…

Why is this a suitable topic for a chair on "Energy & Sustainability"?

Why the "utility of the future"?

- **The electric power sector is the central front to the energy transition to a low carbon economy** (80% reduction of GHG by 2050). Why?
  - Credible options to replace fossil fuels for zero-carbon alternatives exist only or primarily in the electricity sector
  - The only way to get to the 80% reduction in 40 years requires expanding the use of low carbon electricity
  - There are no other large-scale low-carbon forms of energy in the 2050 horizon

➜ Electricity must be the **dominant future form of energy** & **utility models** has become a critical issue

Source: R. Lester & D. Hart, "Unlocking energy innovation", MIT Press, 2012

The utility of the future...

How can we know?

Fred Schweppe knew (in 1978)…

Power systems '2000': hierarchical control strategies

Multilevel controls and home minis will enable utilities to buy and sell power at 'real time' rates determined by supply and demand

Because more devices for customer generation and storage of energy will be in operation by the year 2000, the customer—residential, commercial, or industrial—will be considered a vital part of the electric power systems of the future. New types of central-station generation, storage, transmission, and distribution will be available, and there will be basic changes in the total energy picture as well.

Control systems adapt to changing technology and public needs. Capital and fuel costs will continue to rise rapidly, which will justify the expenditure of more and more money to improve the economics of power system operation. Other factors that will influence future changes will include the following:

- New types of central-station generation, storage, and transmission/distribution systems will be installed. Environmental right-of-way/siting concerns will make it necessary to demand ever-higher degrees of performance for installed facilities. Thus, future control systems will be called on to handle ever-more-complex problems under increasingly stringent and demanding conditions.
- The future will see the introduction of more customer generation and/or energy storage, including solar heating, cogeneration, and eventually solar photovoltaic. These local devices will place new demands on control systems.
- Public attitudes toward power will change in the future. The energy marketplace that will come into operation will change the basic nature of future control strategies.
- Demand depends on weather. Introduction of solar, wind generation, wet/dry cooling, etc., will greatly increase weather dependence. Environmental considerations of air and thermal pollution will increase and add even more weather dependence. Very sophisticated systems for monitoring the weather and environment will be integrated into future control systems along with models for forecasting weather and environmental impacts.
- Research on behavior of power plants, loads, etc., will make it possible to have mathematical models that approximate actual behavior at least some of the time. Future control systems will use these mathematical models in real-time operation.
- Computing and communication are among the few things left in our society that are decreasing in cost. Furthermore, data-network communications and mini- and microcomputer technology are evolving at a rate that parallels the needs of electric power systems. Future control systems will exploit this technology extensively.

Fred C. Schweppe
Massachusetts Institute of Technology

This writer's prediction of the control systems of 2000 is based on the foregoing predictions of influencing factors. The implications are that the future will see more sophisticated control systems involving many sensors and computers, all interconnected via extensive data networks. The need exists, the technology is available, and the dividends from its use will justify the expense.

Already an electric power system is the largest physically interconnected system man has invented. The only way to control such a complex network is to break it down into levels defined by the issues of concern (Fig. 1). The elements at Level 0 are the direct-acting devices for automatic local control—the relays, governors, regulators, firing controls, thermostats, etc. For higher elements (I, II, and III), controls may be viewed as a combination of information-processing and decision-making systems (Fig. 2).

In brief, the controllers at Level 0 receive the actual sensor signals from the various physical devices and use a control law to determine the signals to be sent to control actuators. Level III makes no decisions; Level II decides on goals and targets; Level I decides on such matters as set points and gains for the control laws; and Level 0 uses these control laws to generate control signals.

In terms of information flows, Level I receives measurements from Level 0 and sends models of the Level I elements to Level II. Level I can also receive models from Level II about other nearby Level I elements. Level II trades models with Level III in a similar fashion.

Control hardware/software

Almost all of the Level 0 control logic will be implemented on digital microcomputers. In many cases the sensors themselves will furnish the digital outputs and the actuating devices will accept digital inputs. This digital structure will make communication between Level 0 controllers and higher-level controllers easy to implement. In a given power plant, the same basic microcomputer control packages will often be used for both voltage regulators and boiler-firing controls, even though the control laws themselves are radically different.

Control functions at Level I will be implemented by human operators teamed with digital computers. Prepackaged control rooms with minicomputers and cathode-ray tubes for display will be used for similar elements, including fossil plants, nuclear plants, and substations. Residential customers and small businesses will be able to choose from a wide spectrum of standardized microcomputer display systems, depending on their own needs and preferences. (By the year 2000, relative af-

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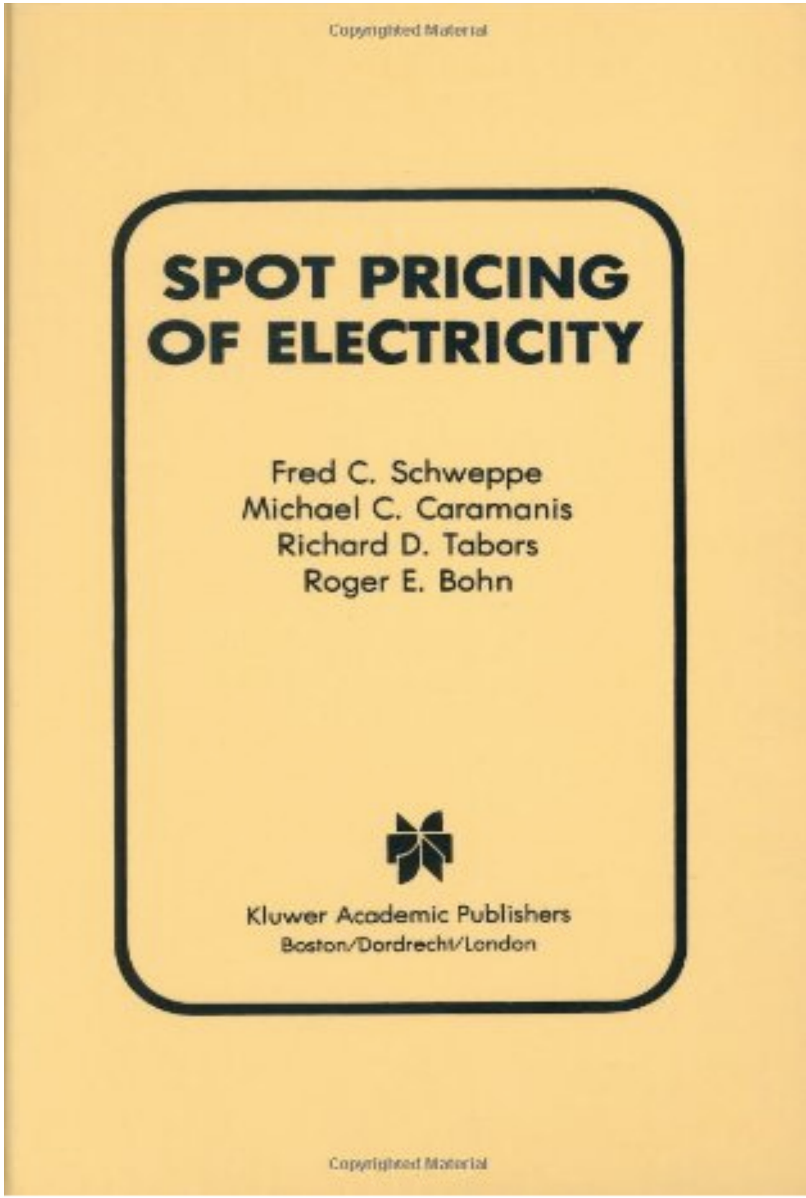
Fred Schweppe (again) et al. and Paul Joskow & Richard Schmalensee set the foundations for changes to come…



… since the crystal ball does not seem to be working today, let’s try to follow a methodological approach to this matter

Outline

- Identification of **game changers** in the power sector
- Review of efforts & findings in on-going research on four major topics
  1. Integration of intermittent renewables in **wholesale** markets
     - Do we need to radically change the rules of electricity markets?
  2. Integration of **gas & electricity** markets
     - Are they coming so close that a market redesign may be required?

Outline *(continuation)*

- Review of efforts & findings…

3. Viable **utility** *(& non utility)* **business models** for **universal access** to electricity
    - Is it possible **to leap-frog the classical utility model** & develop other scalable models to cope with this massive problem?
4. A potential revolution at distribution level: From distribution networks to **smart distribution** systems
    - New approaches in the **regulation of the distribution networks**: remuneration of the activity & network charges
    - **New roles of the Distribution System Operator** & its interaction with all the stakeholders (TSO in particular)

The utility of the future…

Which are the game changers?

Where are any game changers coming from?

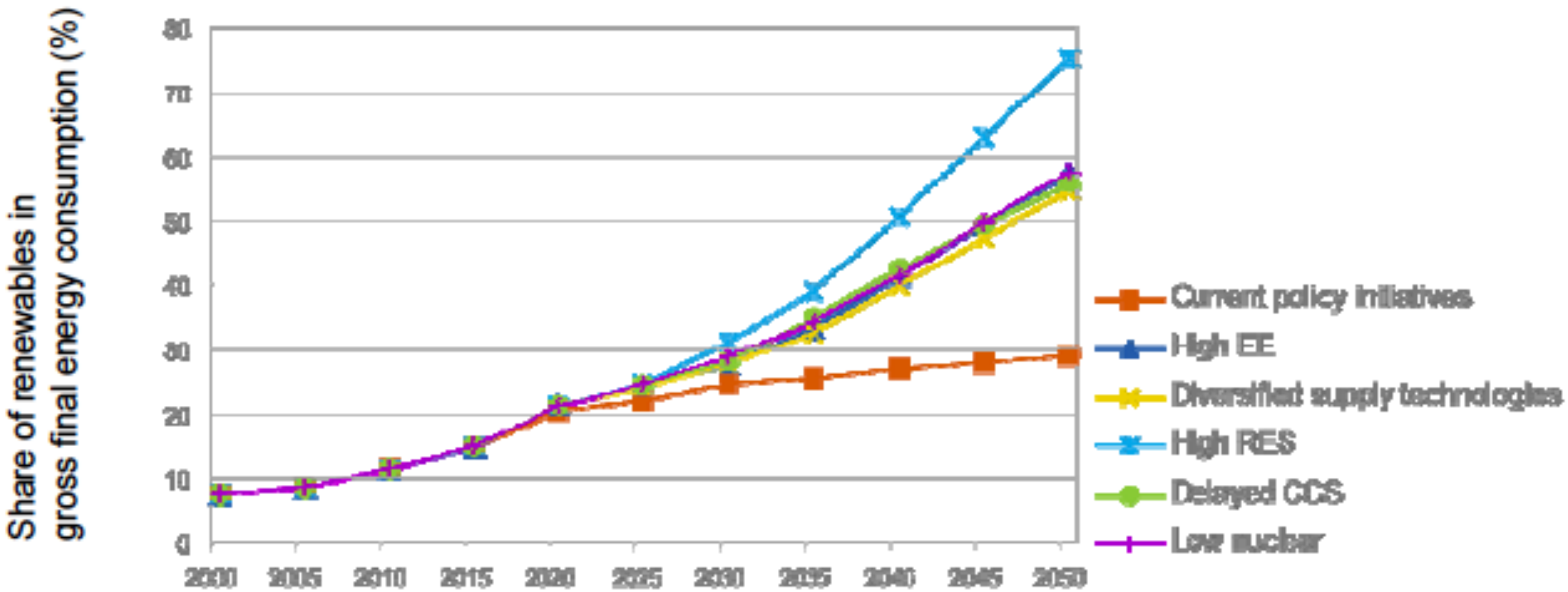
- **Policy driven:** A decarbonized economy requires radical changes in the power sector in the long run, with major implications now ➜ the push for **renewables**
- **Technology driven**: Progress in **new technologies** makes multiple new business models possible

➜ a plethora of open *regulatory* issues ➜ Need to **adapt the regulation** of markets & networks

The EU Energy Roadmap 2050

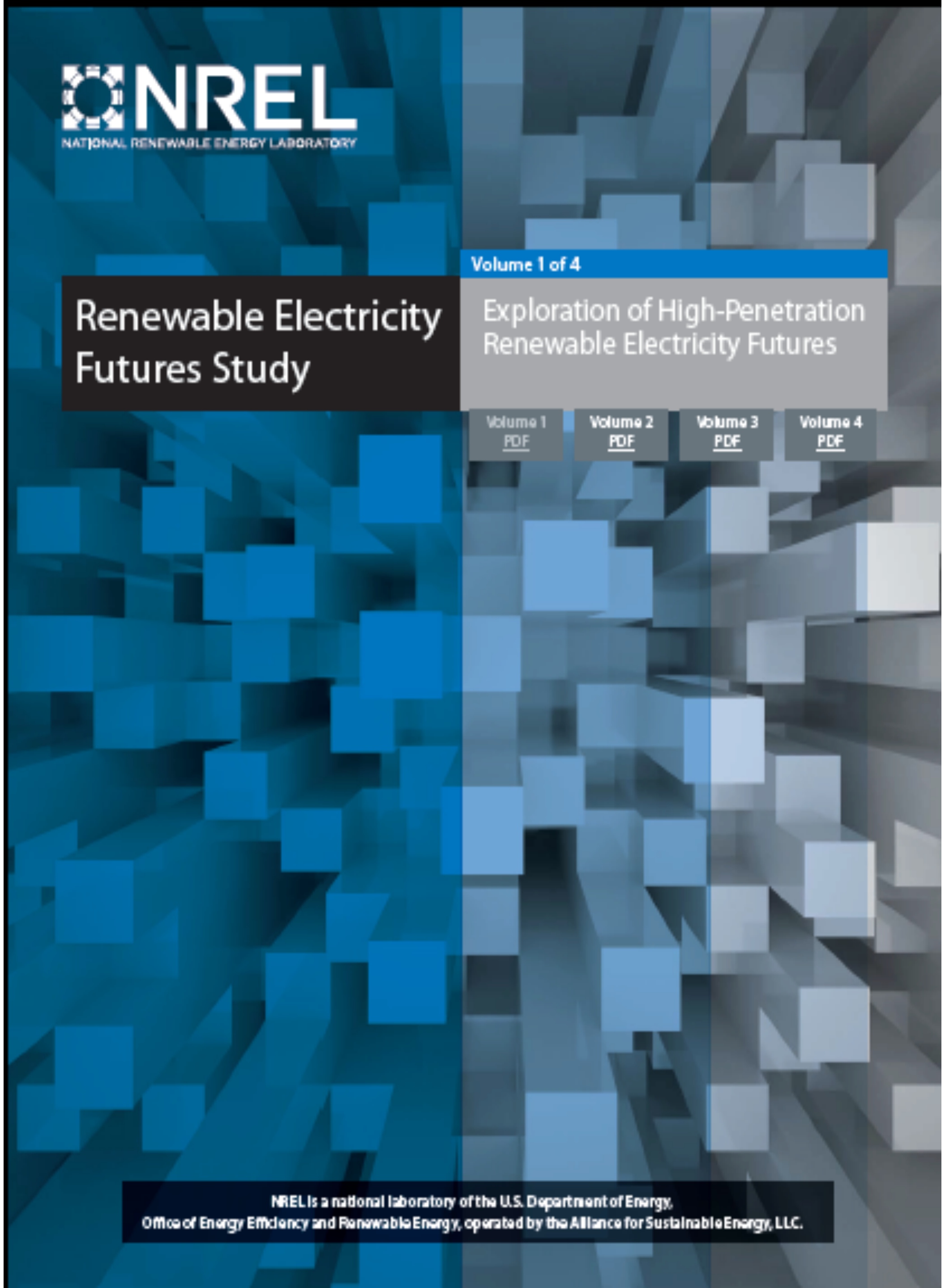
European Commission

Renewables move centre stage



Source: Helen Donoghue, DG Energy, EU Commission.

Source: European Commission |


NREL
NATIONAL RENEWABLE ENERGY LABORATORY
Renewable Electricity Futures Study
Volume 1 of 4
Exploration of High-Penetration Renewable Electricity Futures
Volume 1 PDF
Volume 2 PDF
Volume 3 PDF
Volume 4 PDF
NREL is a national laboratory of the U.S. Department of Energy,
Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

Renewable electricity futures study

(NREL, 2012)

“**Renewable electricity generation** from technologies that are commercially available today, in combination with a **more flexible electric system**, is more than adequate to **supply 80% of total U.S. electricity generation in 2050 (at least 50% of total from wind & solar)** while meeting electricity demand on an hourly basis in every region of the country.

THINK

http://think.eui.eu

Topic 12

From Distribution Networks to Smart Distribution Systems: Rethinking the Regulation of European Electricity DSOs

Final Report
June 2013

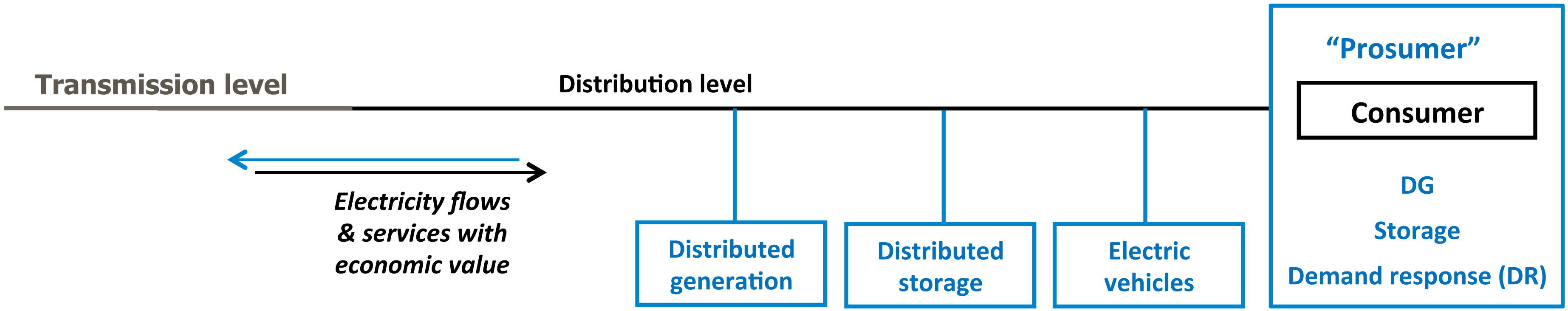
Project Leader: Ignacio Pérez-Arriaga
Research Team Leader: Sophia Ruester
Research Team: Sebastian Schwenen
Carlos Batlle
Jean-Michel Glachant

Project Advisors: François Lévêque
Władysław Mielczarski

THINK is financially supported by the EU's 7th framework programme

Technological advances are reshaping today's electricity market

Advent of "Distributed Energy Resources (DER)"



Challenges:

- Network users will not be what they used to be
- Much variation and uncertainty of flows in D grid and at T interface (even reverse flows)
- Distribution network architecture is becoming more complex & expensive

Potentials:

- Diversity of services with economic value in local electricity markets
- DER may successfully compete with centralized generation
- New tools for system control by the DSO

Edison Electric Institute
Power by Association

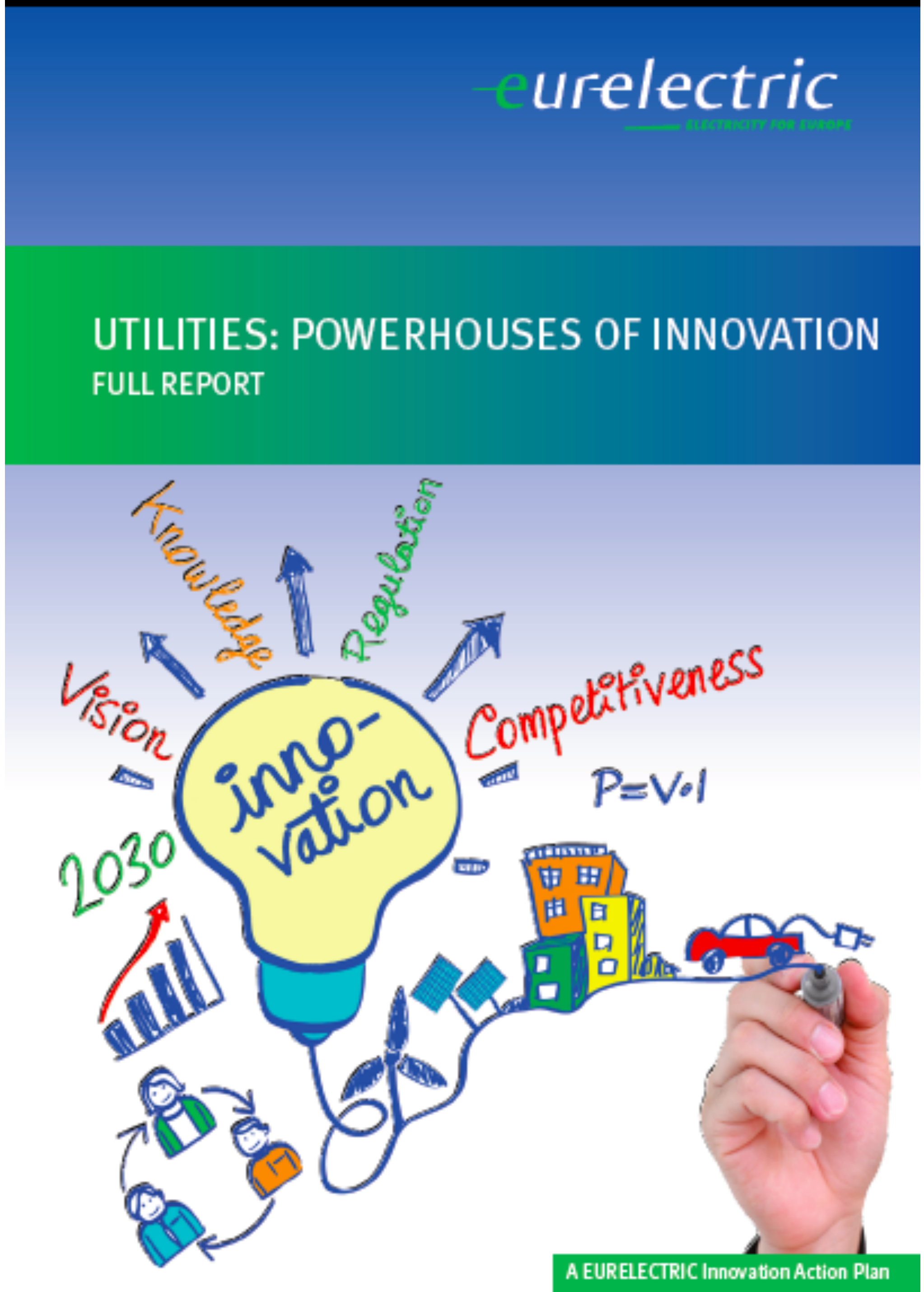
Disruptive Challenges:

Financial Implications and Strategic Responses to a Changing Retail Electric Business

Prepared by: Peter Kind
Energy Infrastructure Advocates

Prepared for: Edison Electric Institute

January 2013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A EURELECTRIC Innovation Action Plan

1. Future Power and Energy Systems

Transmission system modeling and simulation

Transmission system planning: TSO of the future

Control methods and real-time operation

System integration of RES

Advances in RES technology

Advances in forecasting techniques

HVDC

Energy market operation and simulation

Regulatory issues

Application of optimization techniques to power systems

Large-scale storage systems

Transition from power to energy system

Reliability and protection

HV equipment testing

2. Low Carbon Distributed Energy Systems

Distributed energy sources: grid integration and control

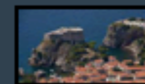
Distribution system planning: DSO of the future

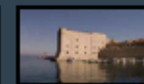
DC and AC microgrids: concepts beyond isolated power systems

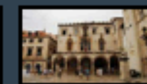
Off-grid solutions

Smart buildings as energy islands

Venue - Dubrovnik
Click to see more photos







Topics

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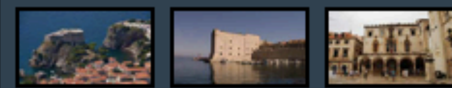


IEEE INTERNATIONAL ENERGY CONFERENCE & EXHIBITION ENERGYCON 2012 TOWARDS USER-CENTRIC SMART SYSTEMS

IEEE International Energy Conference ENERGYCON 2010 Towards Sustainable Energy

Regulacion del s

#1

Integration of intermittent renewables in wholesale markets*

Do we need to radically change the rules of electricity markets?

(*) From “MIT Future of Solar Study” and other research projects, with participation of IIT-Comillas. Results obtained with the LEEMA computer model, Institute for Research in Technology, Comillas University (Madrid, Spain). Researchers: Carlos Batlle, Pablo Rodilla & Andrea Veiga.

Research question: Should future wholesale markets be completely redesigned?

- How does intermittent generation *(wind & solar PV)* output **affect generation dispatch** & **spot market prices** in a specific power system?
- How should a **well-adapted generation mix**, with a strong presence of intermittent generation, look like?
  - Does this mix *(flexible but efficient generation, with much cycling and low capacity factor)* **need any regulatory support** *(ad hoc ancillary service, capacity instrument, other)* under market conditions?

A case example

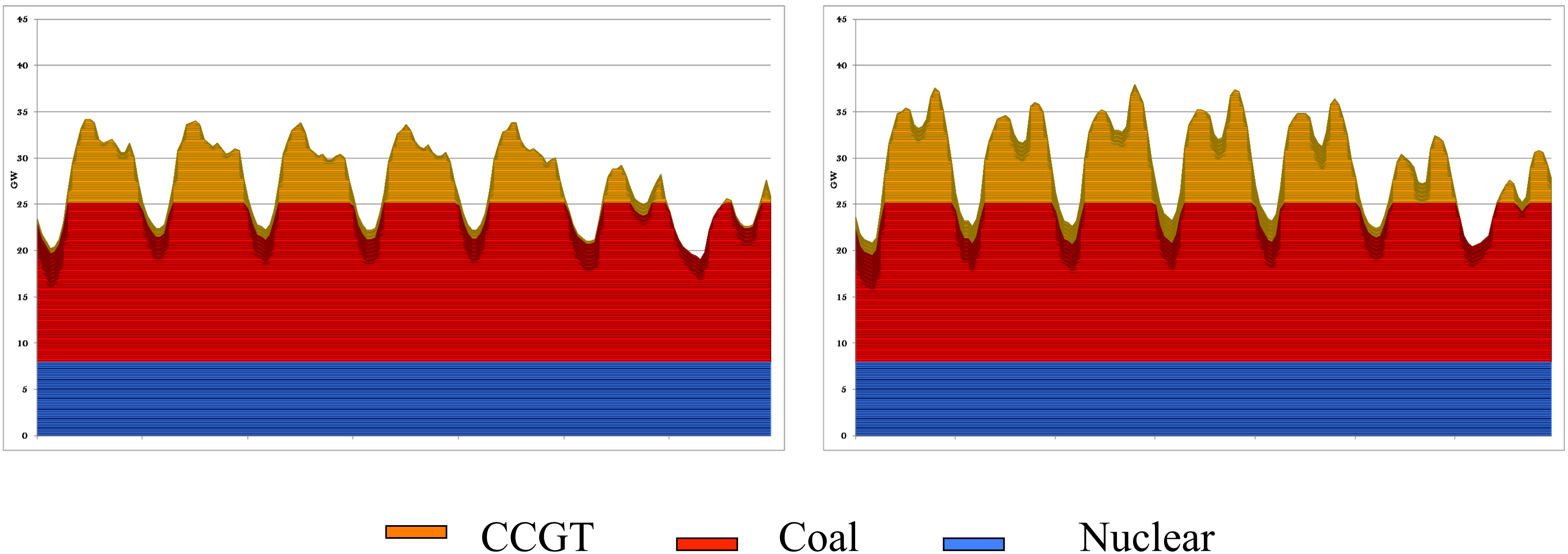
- How do solar & wind output affect generation dispatch & investment *(& for gas-fired plants, in particular)* in a specific power system?
- How do solar & wind penetration affect the optimal generation mix *(horizon 2030, starting from some existing mix in 2012)*?
- **Case example**:
  - 2 representative weeks in a system of the size & demand pattern of the Spanish power system, but with just nuclear, coal & CCGT
  - Different levels of penetration of wind and solar
  - Nuclear is frozen; only coal & CCGT respond, both adapting the generation mix & in the operation

Results obtained with the LEEMA computer model, Institute for Research in Technology, Comillas University (Madrid, Spain). Collaboration Comillas-MIT Energy Initiative.

Base case escenario: No PV

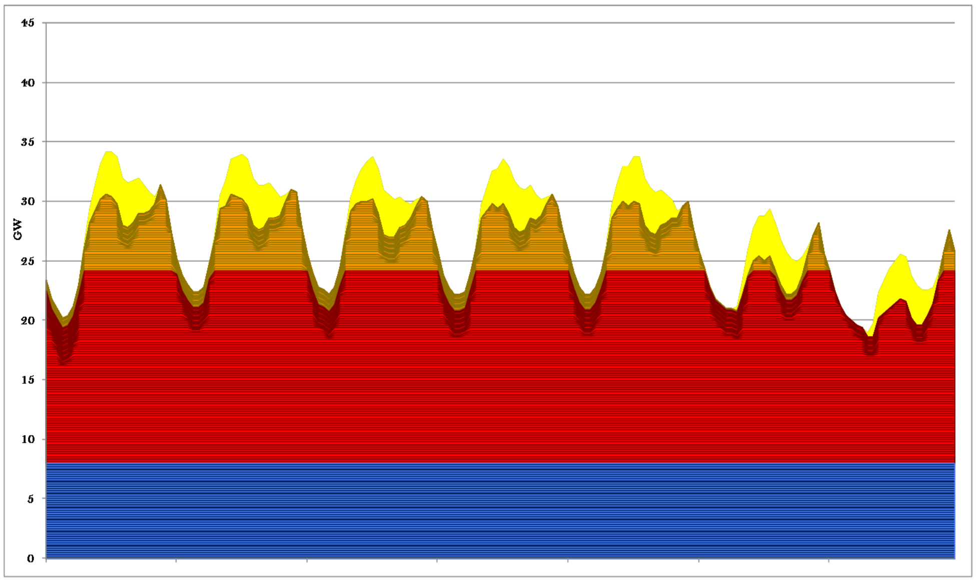
14-20 June

8-14 November



5 GW non dispatchable solar PV

14-20 June



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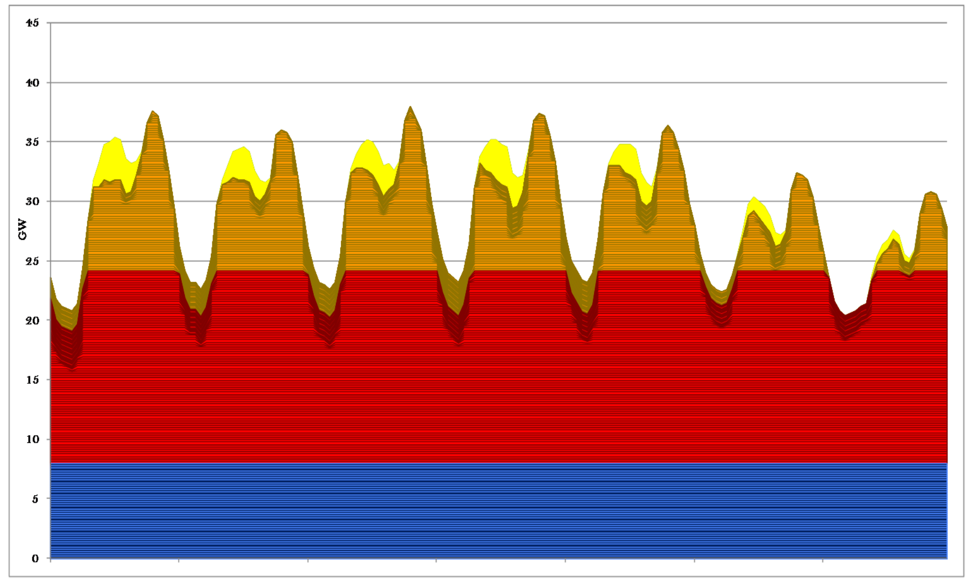
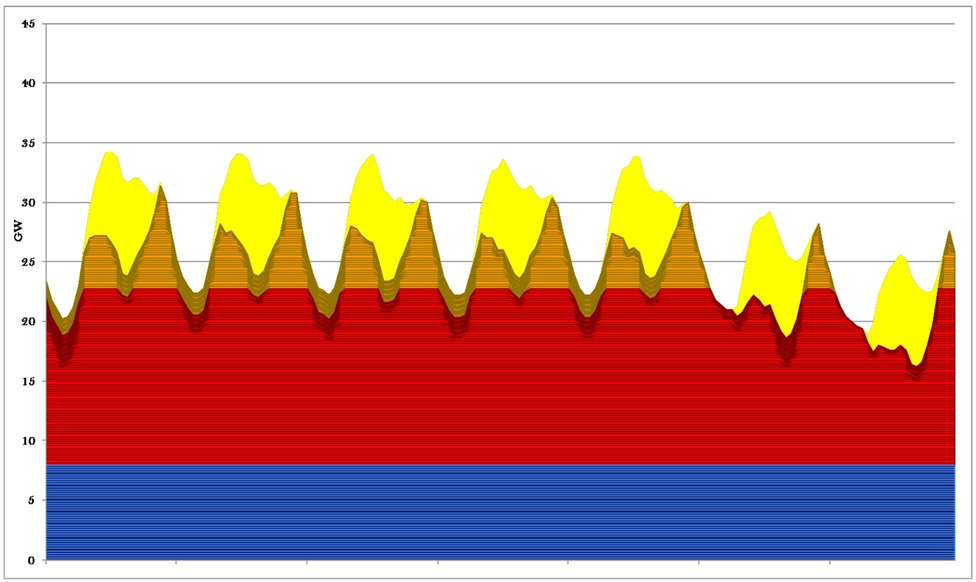


CCGT Coal Nuclear

10 GW non dispatchable solar PV

14-20 June



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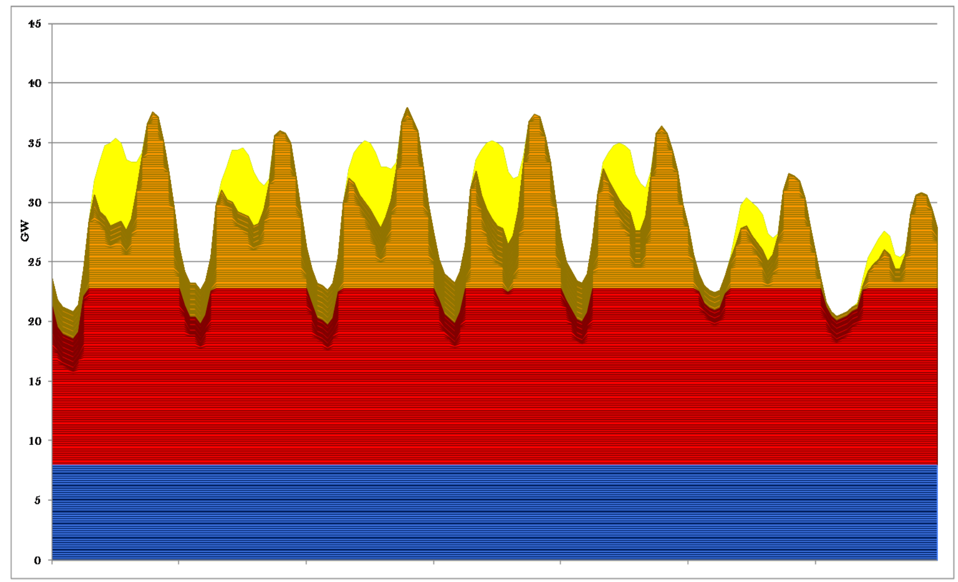
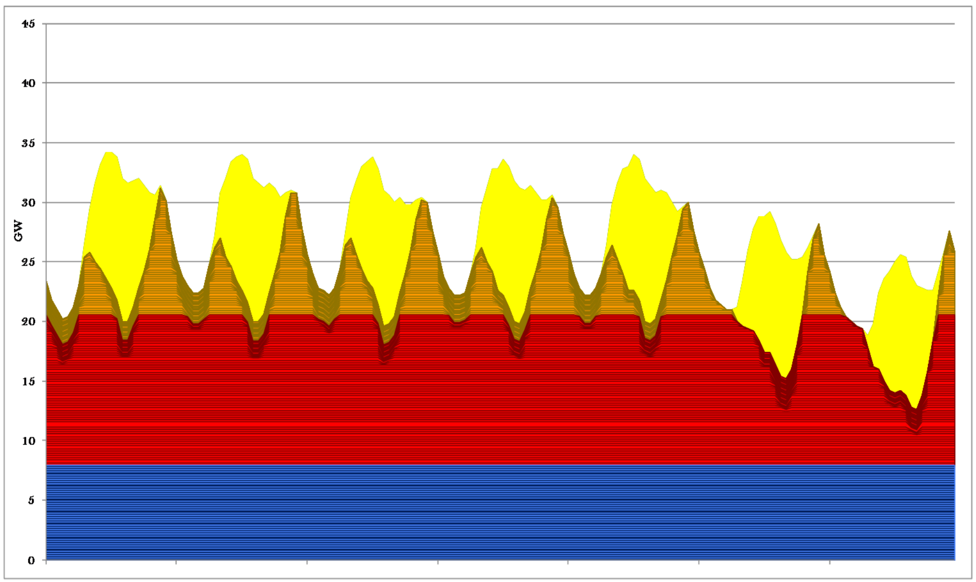


CCGT   Coal   Nuclear

15 GW non dispatchable solar PV

14-20 June



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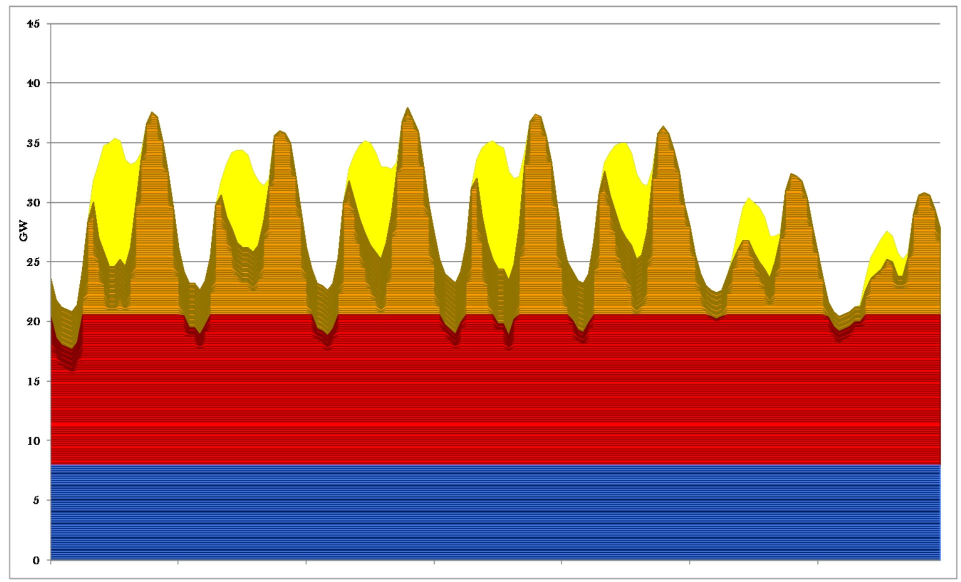
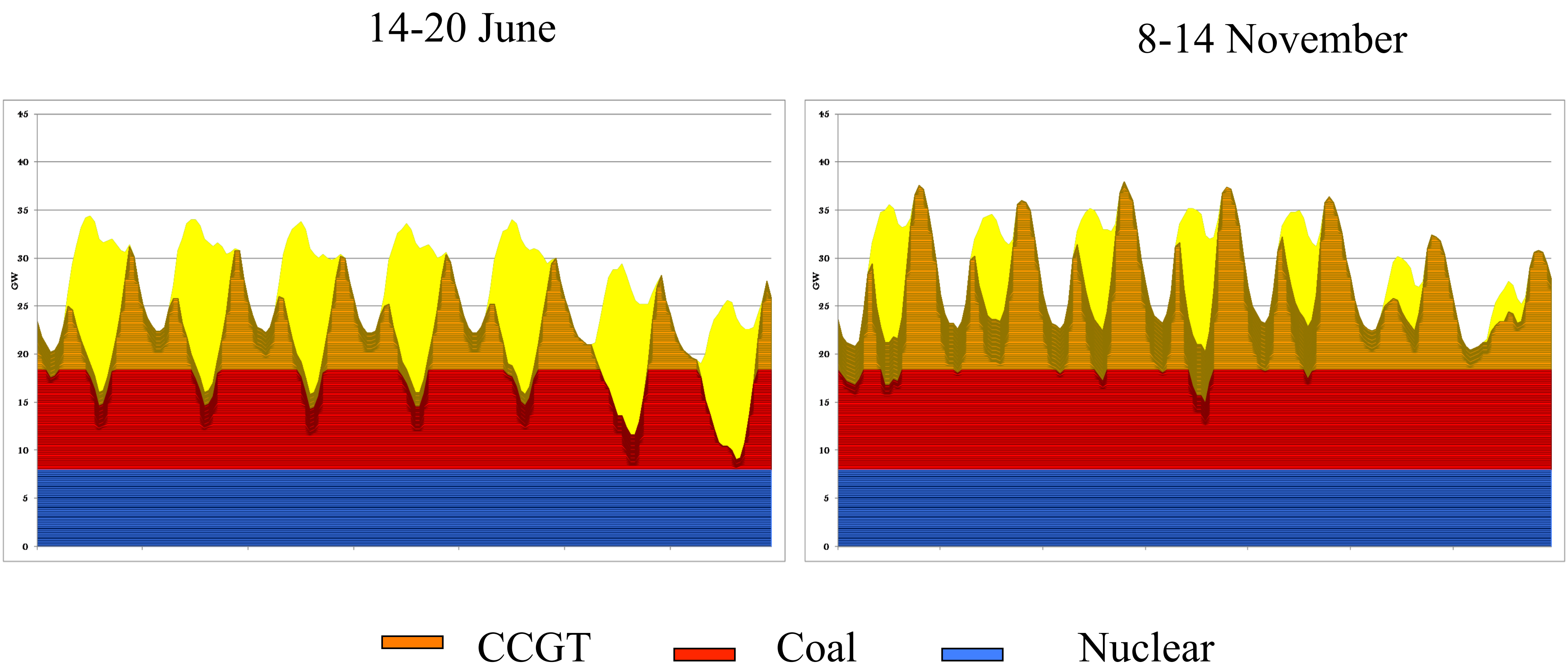
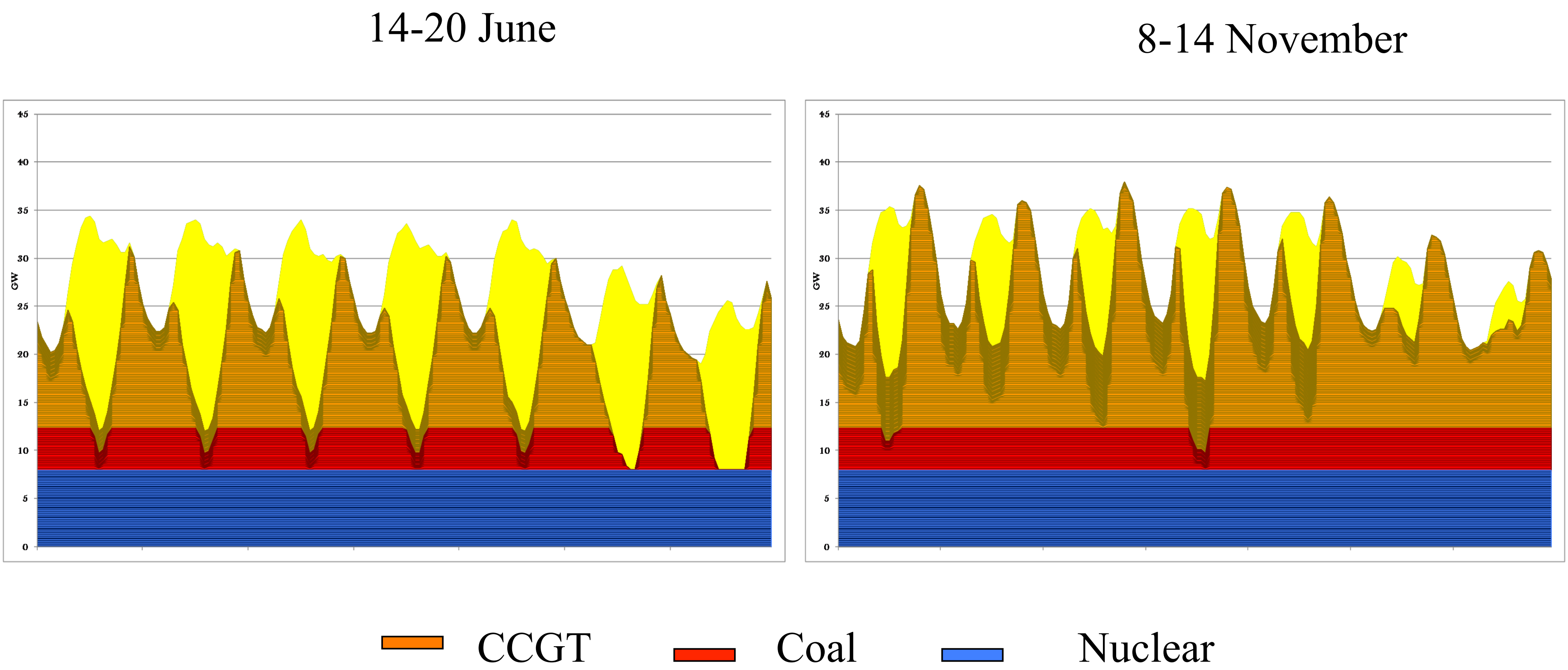


CCGT Coal Nuclear

20 GW non dispatchable solar PV



25 GW non dispatchable solar PV



30 GW non dispatchable solar PV

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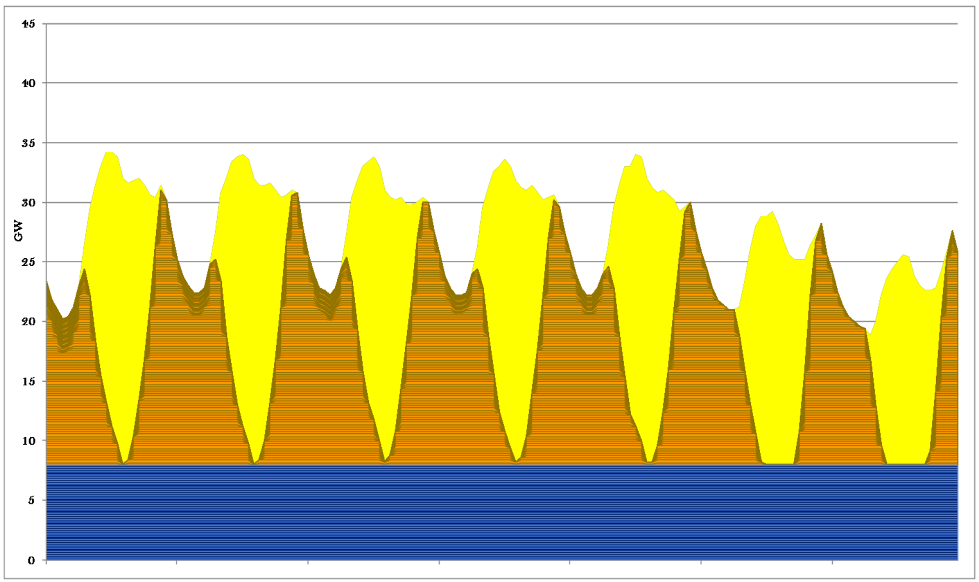

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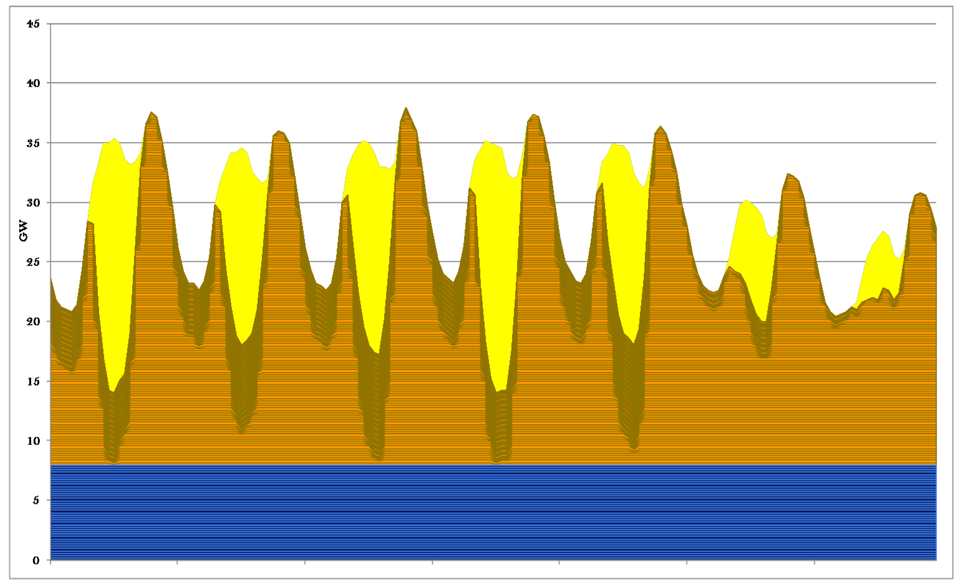

CCGT Coal Nuclear

35 GW non dispatchable solar PV

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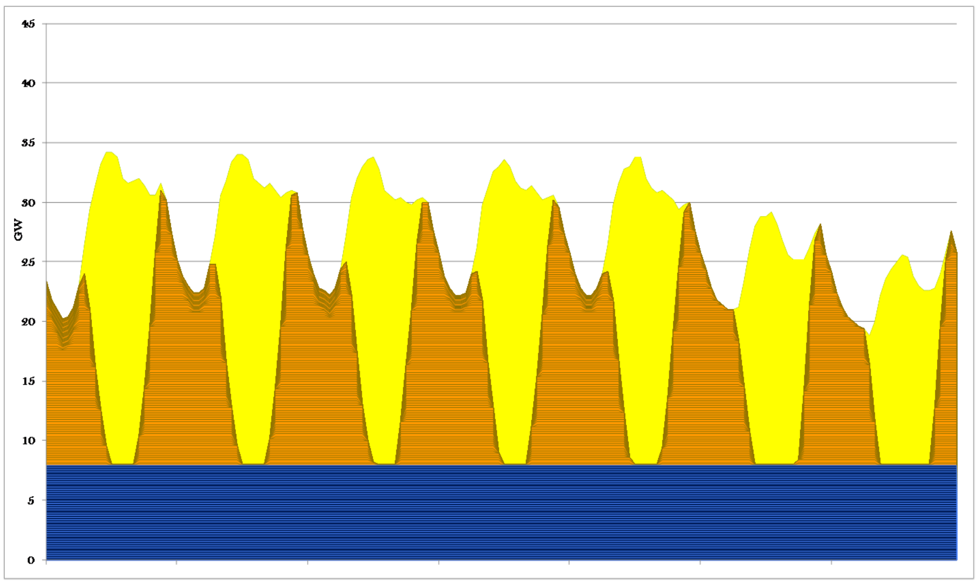

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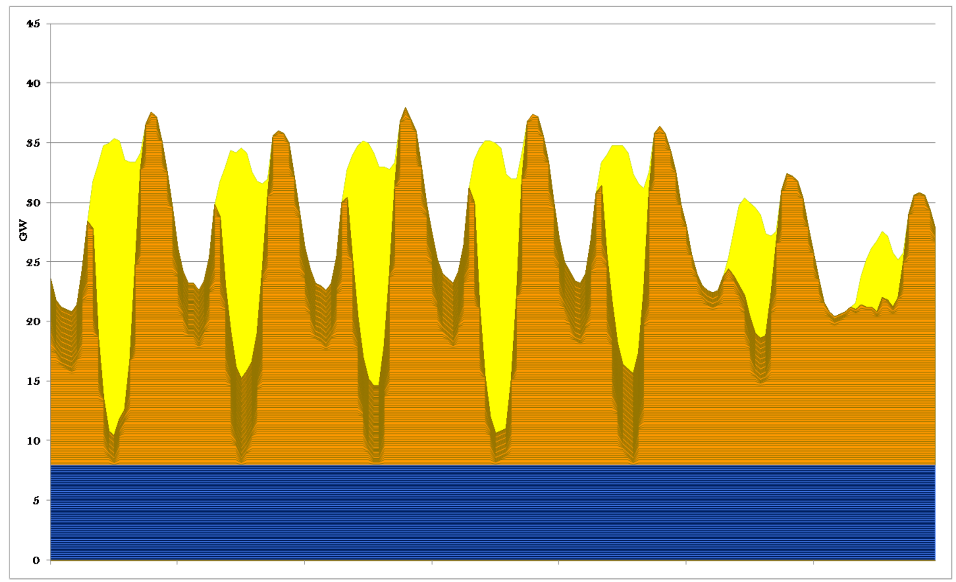

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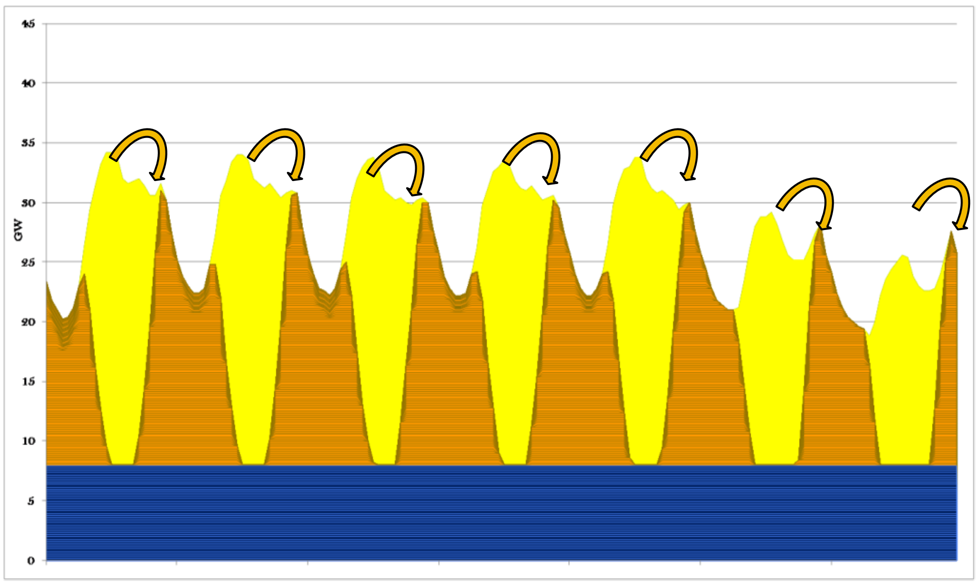

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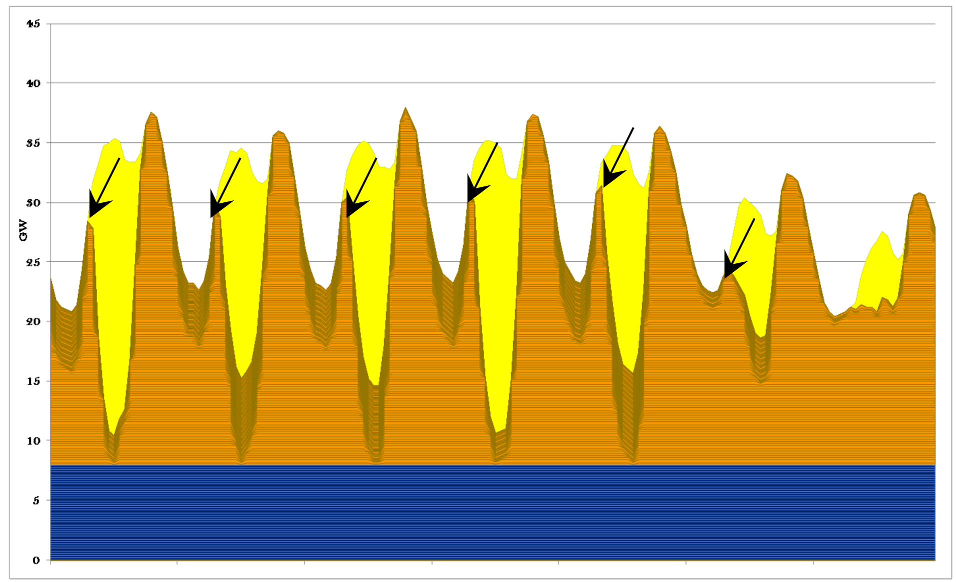

CCGT Coal Nuclear

Base case scenario: no wind

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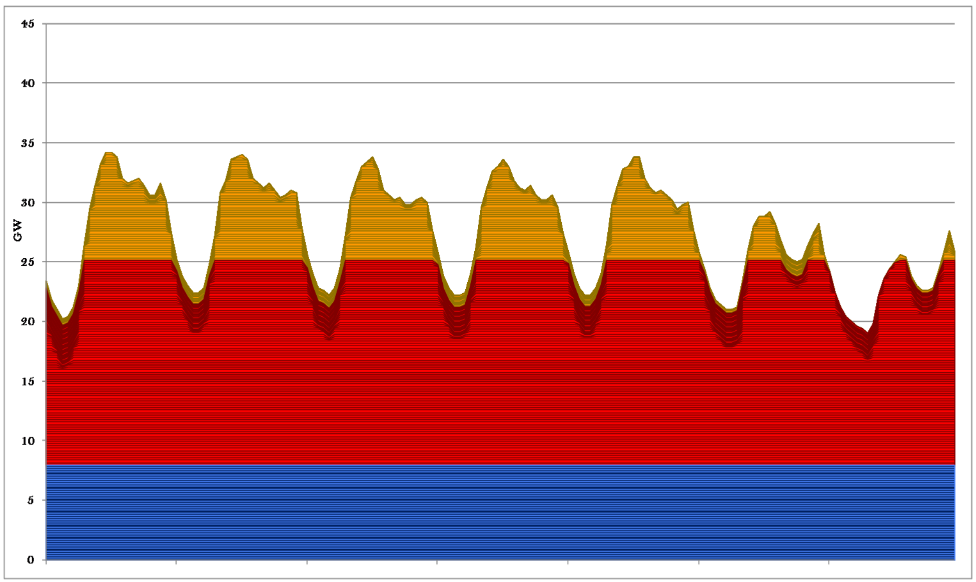

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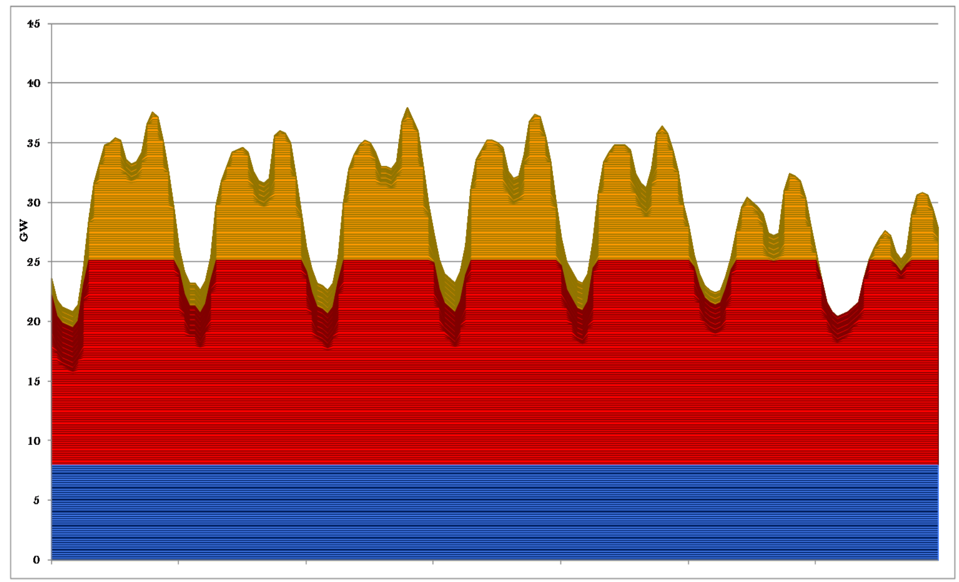

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5 GW wind

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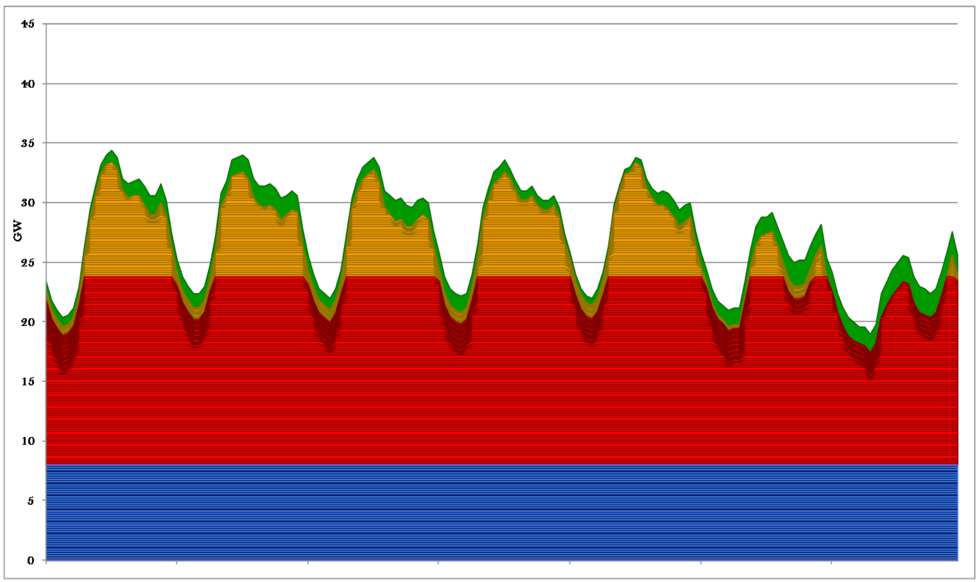

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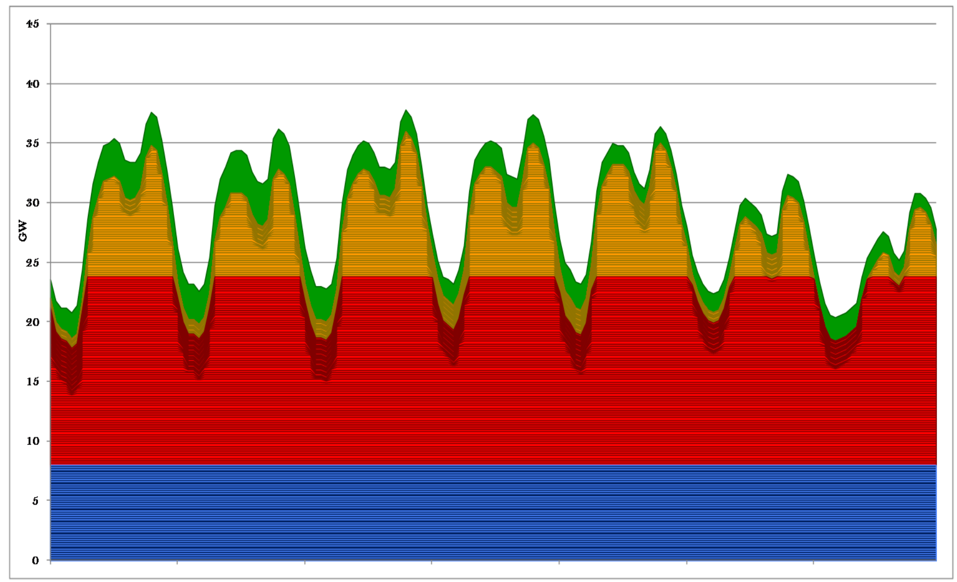

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10 GW wind

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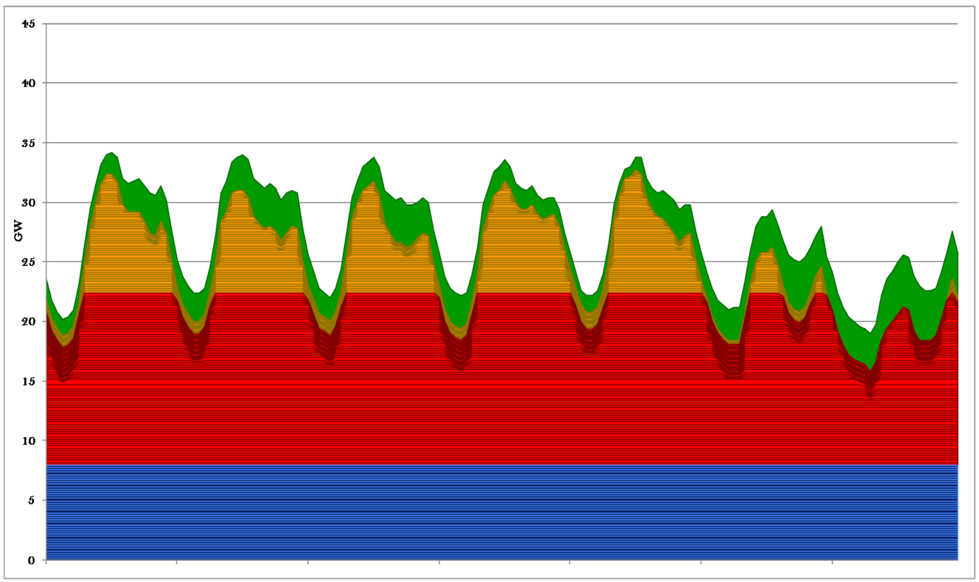

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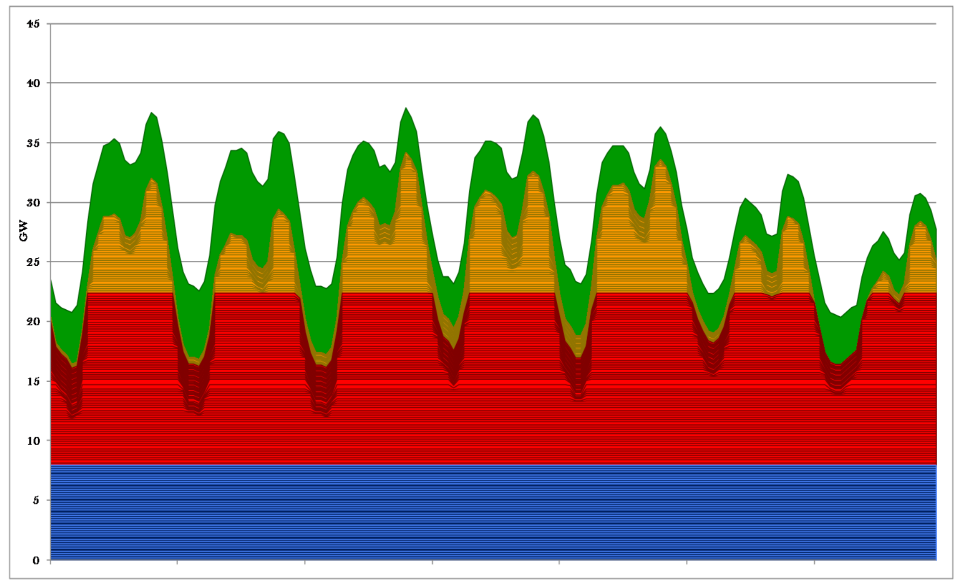

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15 GW wind

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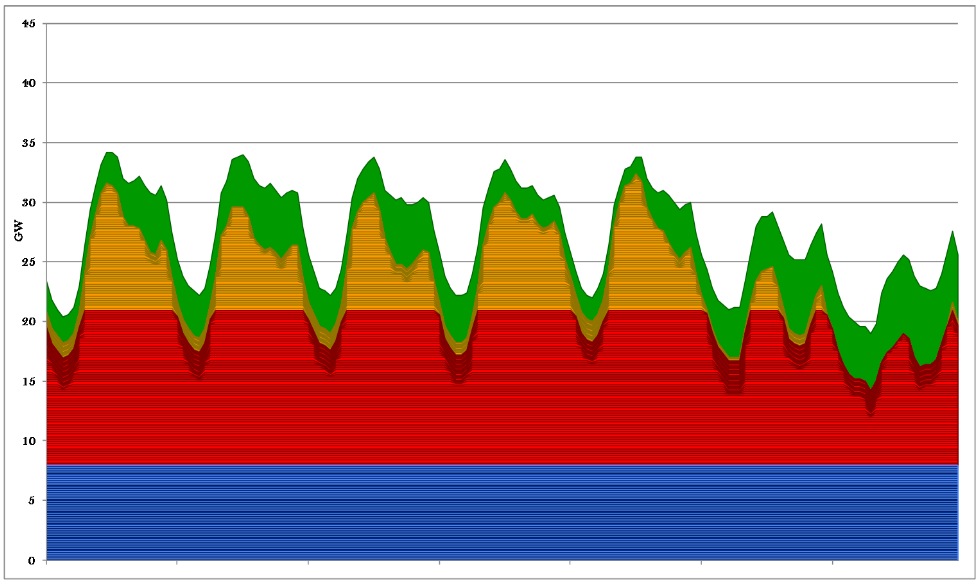

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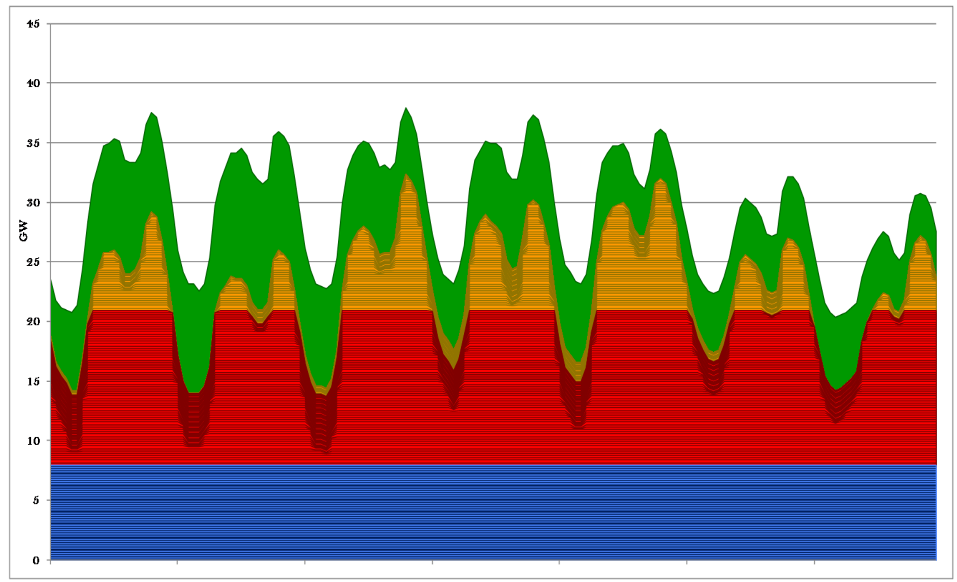

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20 GW wind

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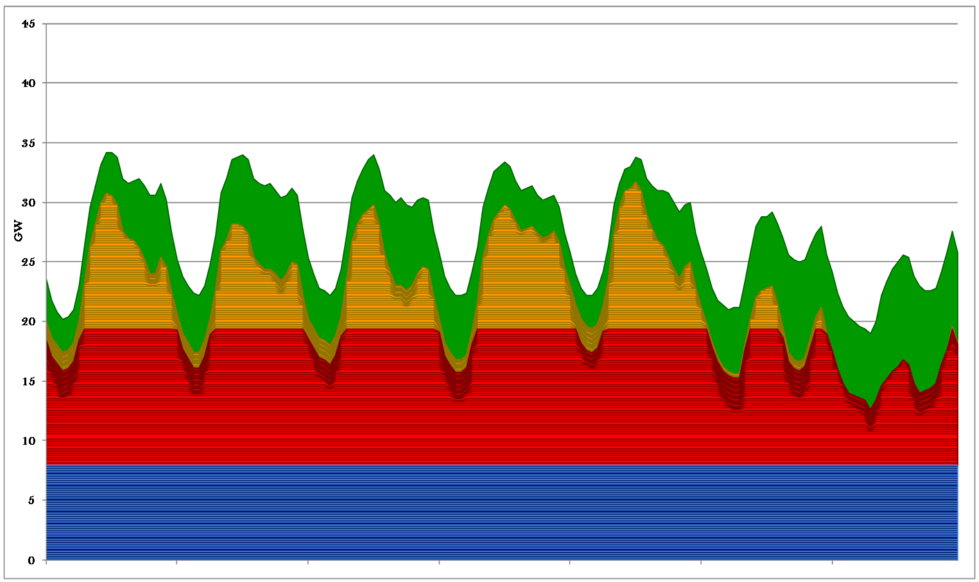

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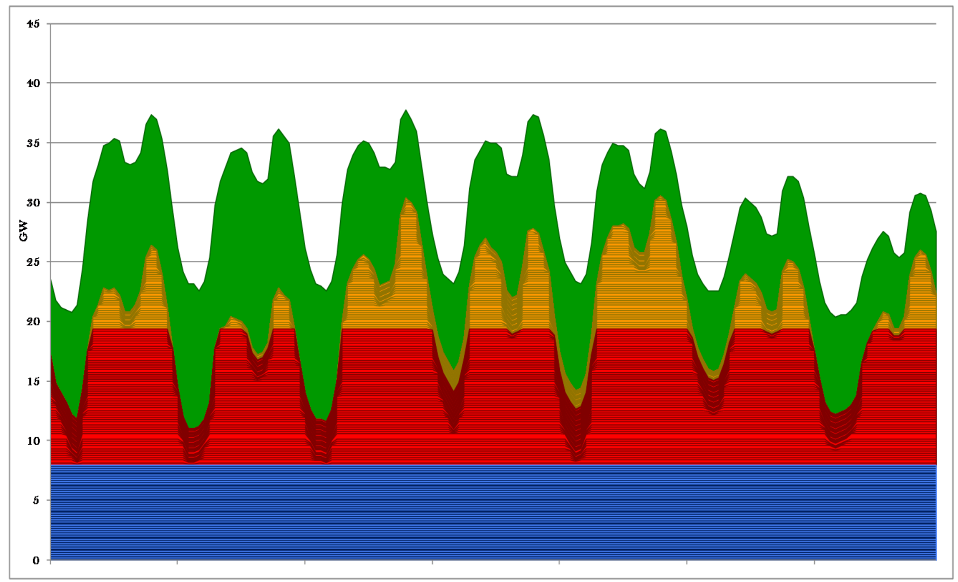

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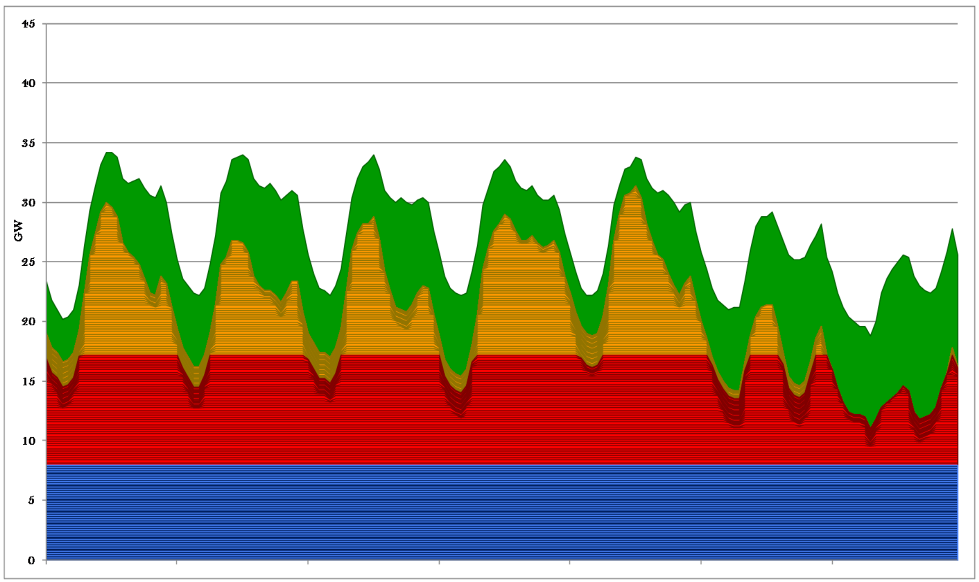

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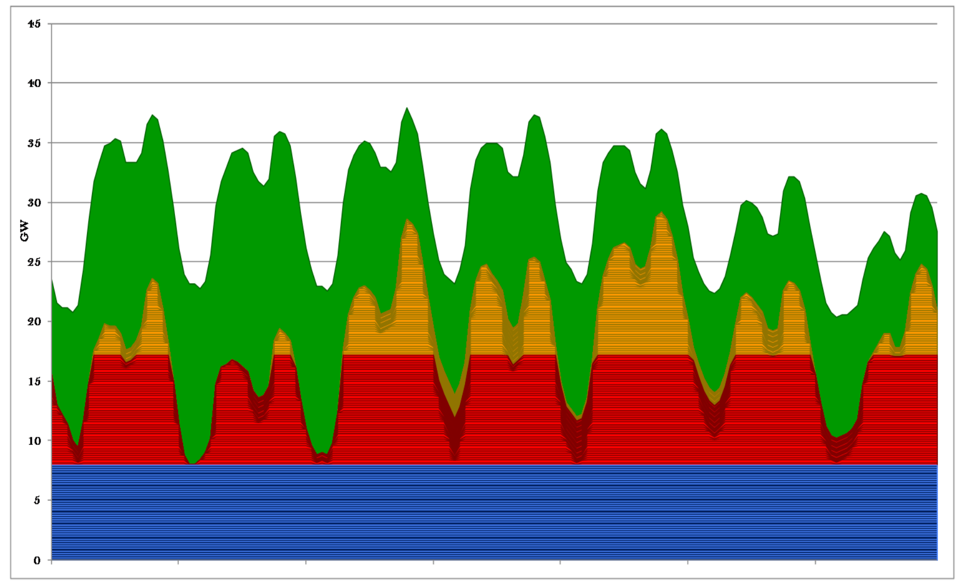

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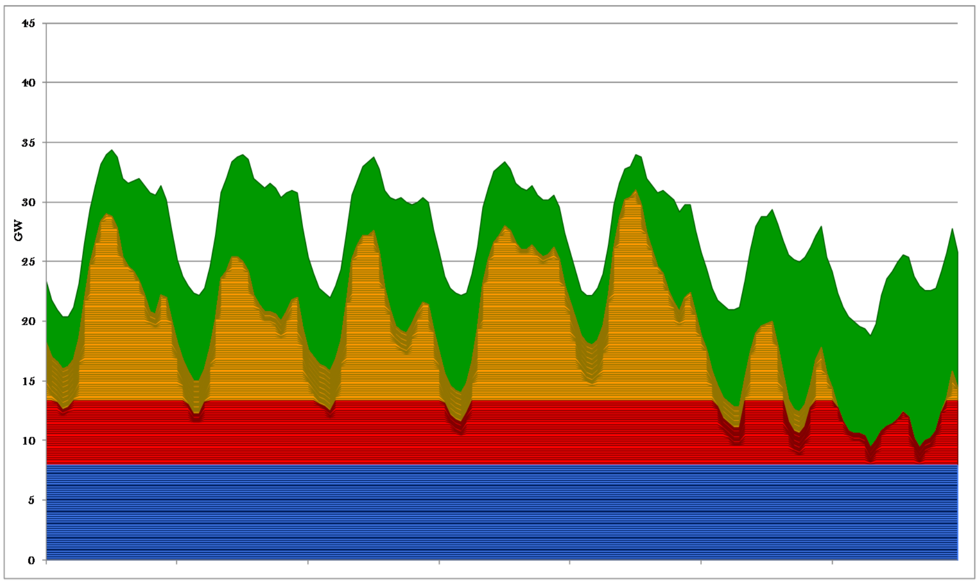

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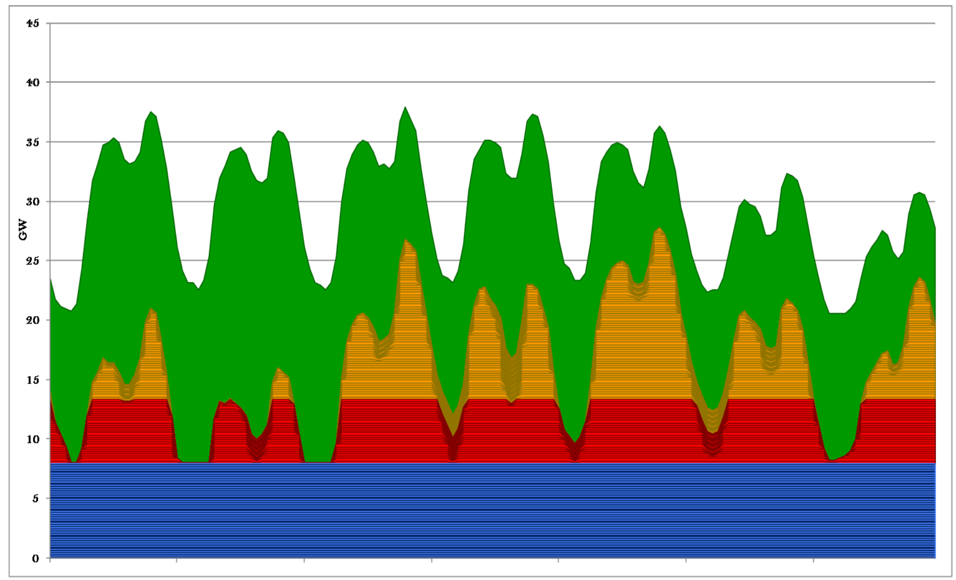

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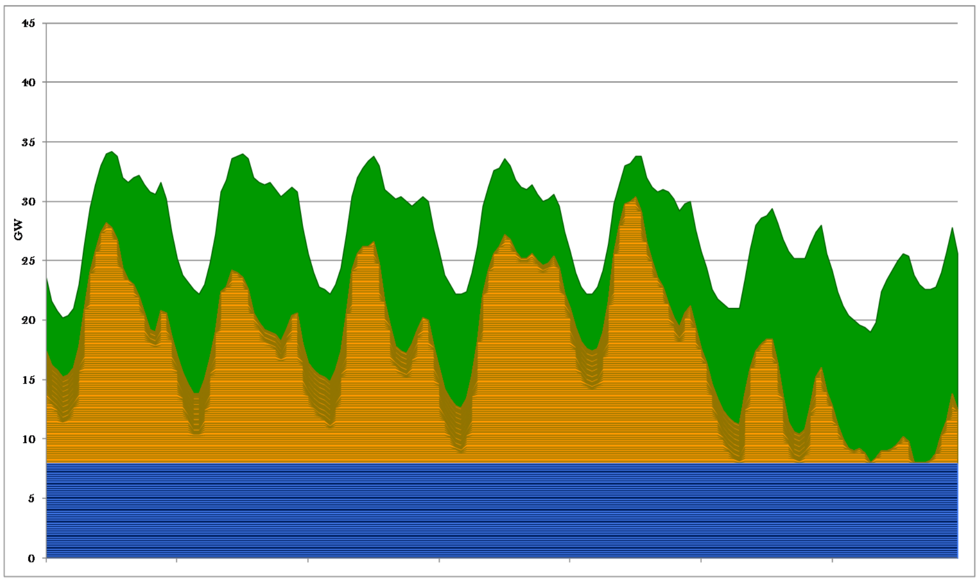

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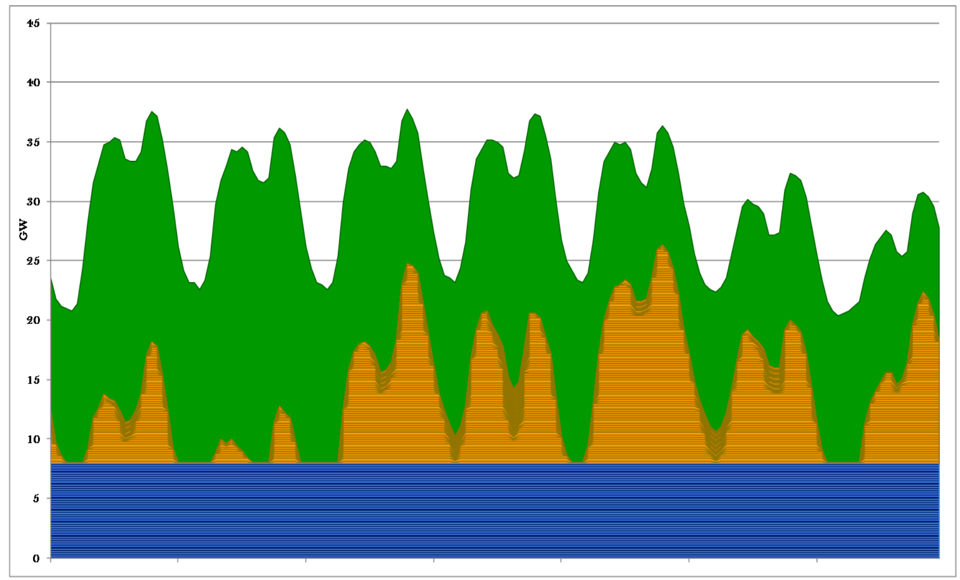

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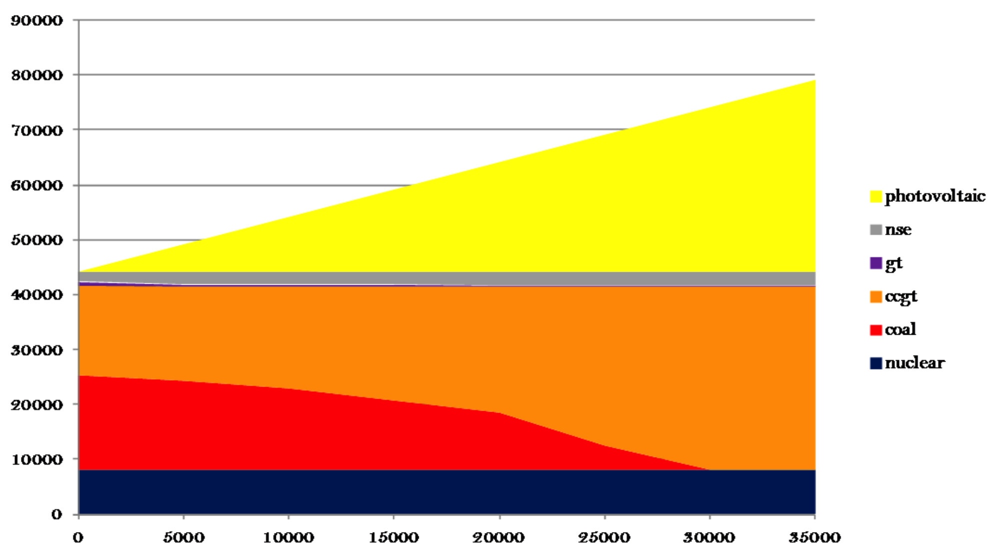
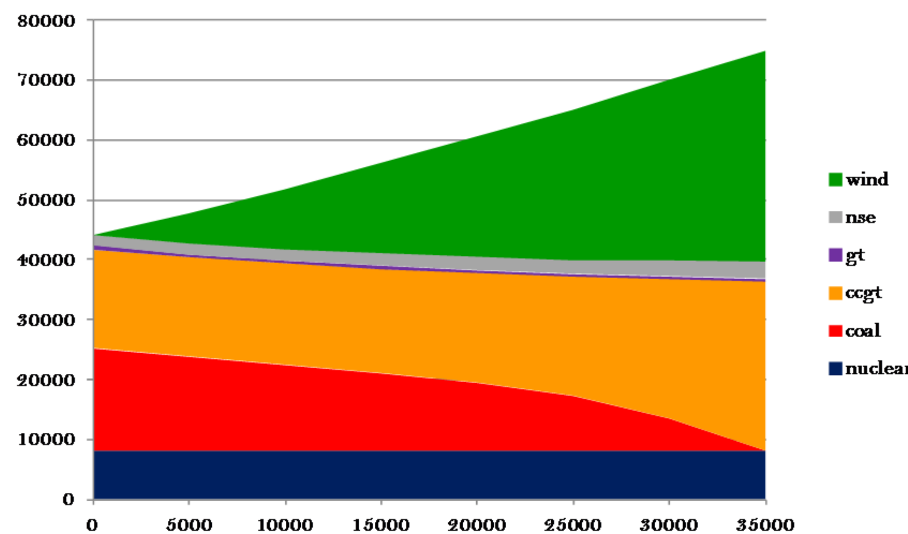
Optimal generation capacity mix as a function of PV & wind penetration levels



Increasing PV penetration level (MW)



Increasing wind penetration level (MW)

Some preliminary findings for the utility of the future *(techno-economic impact)*

A **larger penetration** of solar PV or wind:

- **increases cycling** of conventional thermal plants, **changing the optimal generation mix** & leaves **less room for inflexible technologies**, both in operation & investment
- does **not reduce** much the **net peak load**, but peak **narrows** & **shifts** in time
- has several impacts on **market prices** (net load reduction, may displace cheap inflexible generation, increases start-up costs) ➔ net result depends on the particular case
- reduces prices that apply to solar/wind ➔ solar/wind **investment stops by itself**
- must be **accompanied by** a flexible generation technology with comparatively low operation & investment costs: **gas-fired plants**

Some preliminary findings for the utility of the future *(market regulation)*

- **Wholesale markets can function correctly** *(i.e., send efficient operation signals, attract investment)* under large intermittent penetration, even with very volatile prices
  - The **deterrent of investment is regulatory uncertainty**
  - No evidence of the need **for regulatory support** to **flexibility**
- Market **design flaws are amplified**
  - Differences in **market price rules** *(US-ISO vs. EU-PX: bid format, price formation, dispatch priorities)* significantly **impact remuneration**
  - **Priority of dispatch** for renewables (or production subsidies) results in **inefficient operation** & a different optimal **generation mix**

#2

Integration of gas & electricity markets*

Are they coming so close that a joint market redesign may be required?

(*) From MIT Spring 2013 Annual Symposium on *Growing Concerns, Possible Solutions: The Interdependency of Natural Gas and Electricity Systems*, on-going PhD theses by Tommy Leung (MITei) & Pablo Dueñas (IIT-Comillas) & research by Charles Pebereau

Integration of gas & electricity markets

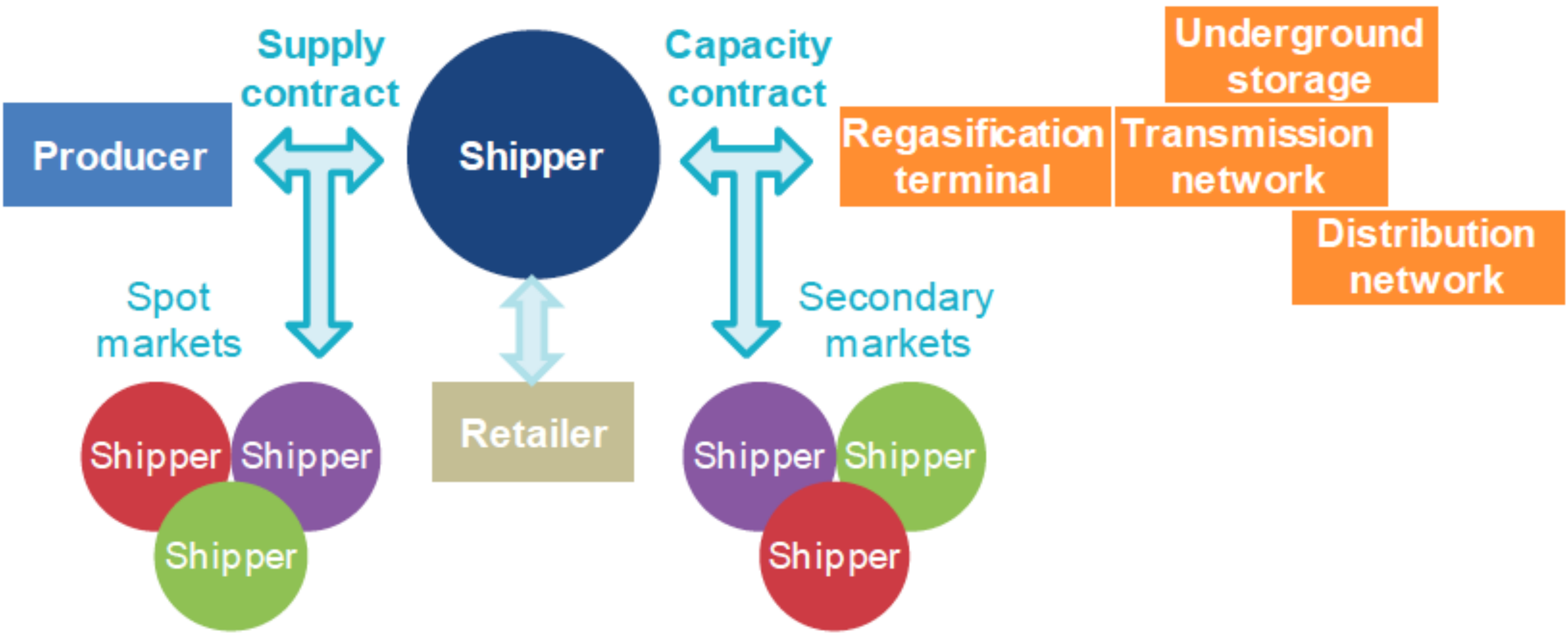
- The advent of **abundant natural gas supplies** & the increasing presence of **renewable technologies** results in
  - power systems dominated by **natural gas & renewables**
  - gas markets that exert **much influence** on electricity markets & viceversa

  Example
  - Power producers with gas-fired generation assets in systems with strong renewable penetration consume gas in a fundamentally different manner than the traditional utilities in the past & the industrial consumers.

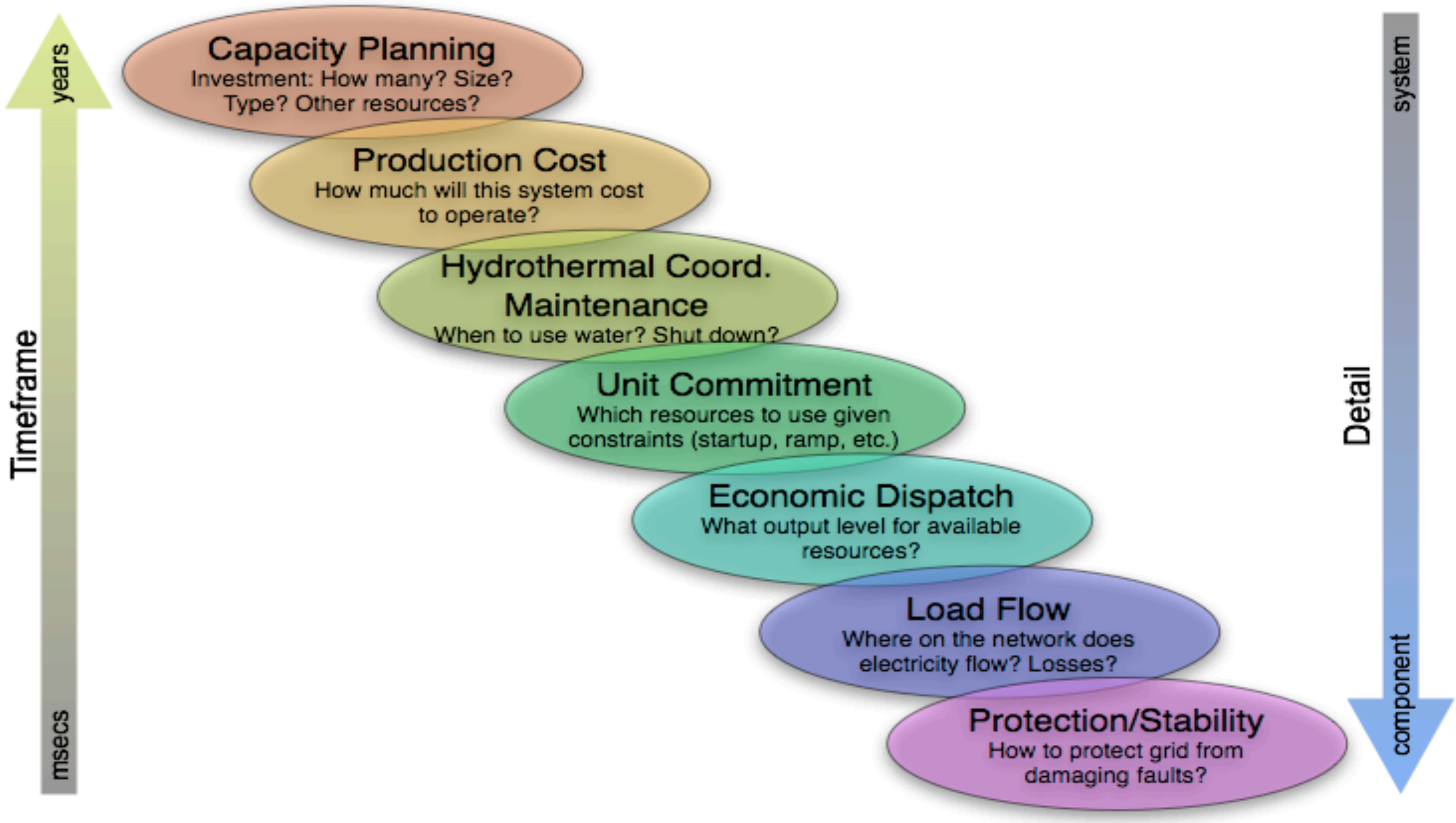
Integration of gas & electricity markets

- How does one **design a market** (electricity or gas) when agents in this market also **participate in another market** with its own, independent set of rules?
  - How do **changes to one market's rules** affect the optimal behavior of the agents in the other market?
  - How to design rules that lead to the **social optimal behavior**?

Business relations in downstream gas systems



Hierarchy of decisions in power systems



Source: Bryan Palmintier PhD thesis, MIT

Research question: How to manage the increasing interdependence of the gas & electricity markets & associated uncertainties?

- How to optimize the multi-stage decision-making process of the owner of a portfolio of natural gas-fired plants of electricity generation
  - to make ***strategic decisions*** about ***long-term fuel procurement contracts, long-term service agreements, forward capacity markets, spot market fuel purchases,*** & ***electricity bids***?
  - subject to ***short-term uncertainty*** from ***fuel & electricity prices, gas availability,*** and ***electricity demand?***

#3

Viable utility business models for universal access to electricity

Is it possible to leap-frog the classical utility model & develop scalable model to cope with this massive problem?

(*) From "MIT Future of Solar Study" and other research projects, with participation of IIT-Comillas. Results obtained with the LEEMA computer model, Institute for Research in Technology, Comillas University (Madrid, Spain). Researchers: Carlos Batlle, Pablo Rodilla & Andrea Veiga.

A plausible taxonomy of business models for electricity access

		Grid Extension	Connected Minigrid	Isolated Minigrid	Single User System	Pico Solar Systems
For profit	Small, decentralized	India (small reseller)	China, Nicaragua, Cambodia (local minigrid)	Cambodia, Ethiopia (local minigrid)	Argentina, Brazil, Kenya… (small retailer)	India, East Africa (local entrep. / international)
	Large, centralized	Argentina, Chile, Guatemala, Uganda (large concession)	Senegal (minigrid concession)	Senegal (minigrid concession)	Bangladesh, Bolivia… (off-grid concession)	Africa, Asia (emerging mkt. / brand builders)
Non profit	Cooperatives	Bangladesh, Costa Rica, USA (large cooperative)		Guatemala (small cooperative)	Guatemala (small cooperative)	
	Social enterprises				Bangladesh, Peru (small & large retailer, dealer)	Mexico (small dealer)
	Other community org.	Bolivia (community gateways)		Brazil, Cambodia … (community microgrids)	Argentina, Nicaragua (community SUS)	
	NGOs				Guatemala (EsF)	
Public	Small, decentralized	Brazil, Colombia (small state utility)		Bolivia (municipal microgrids)		
	Large, centralized	Botswana, Mozambique (large state utility)		Cambodia, Nicaragua (state owned minigrids)	Mexico (state owned SUS)	

#4

A potential revolution at distribution level: From distribution networks to smart distribution systems

- The network
- The new business models

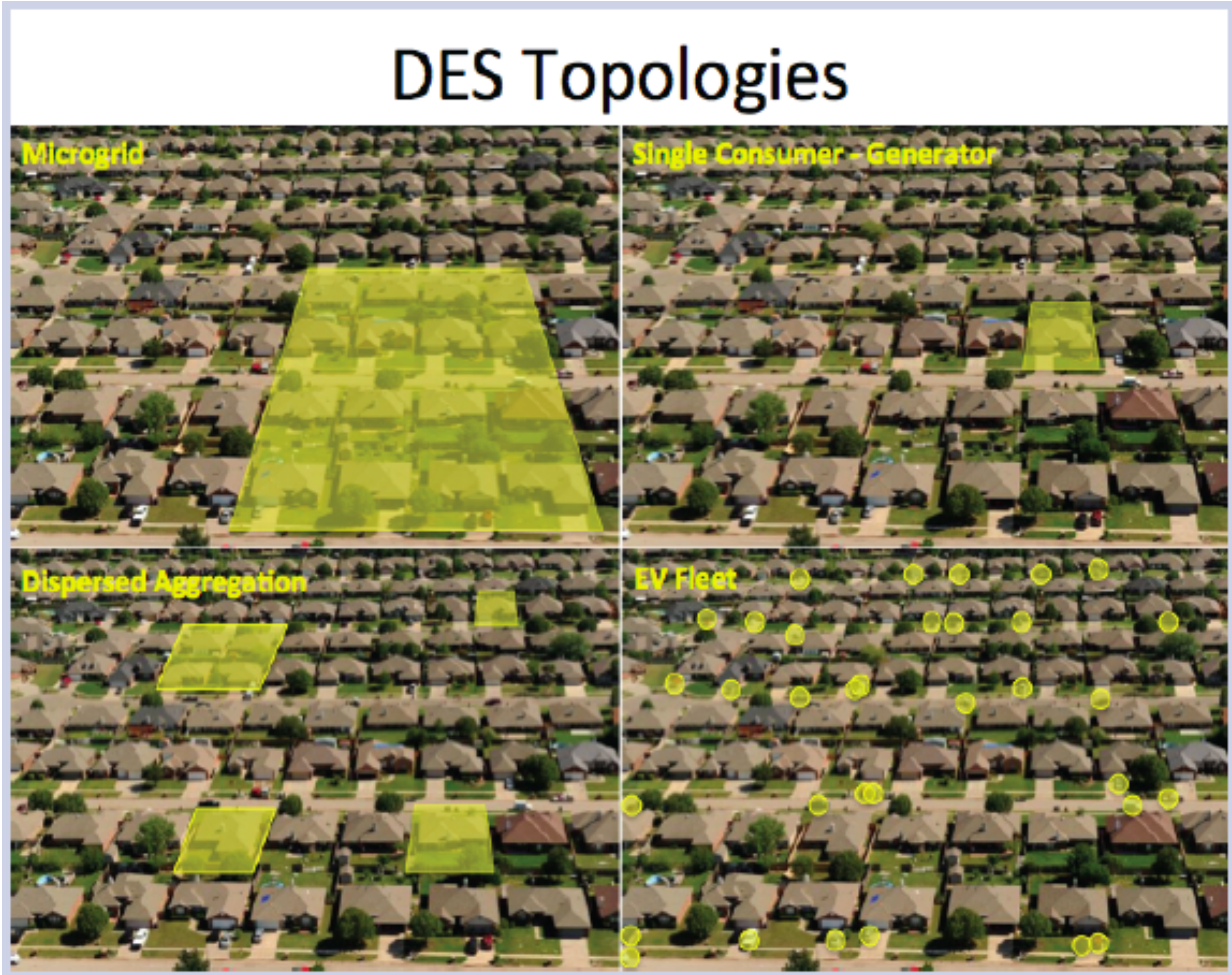
(*) Related activities: THINK project of the Florence School of Regulation for the European Commission, led by Ignacio Pérez-Arriaga and "The utility of the future" (a COMITES project).

The game changers

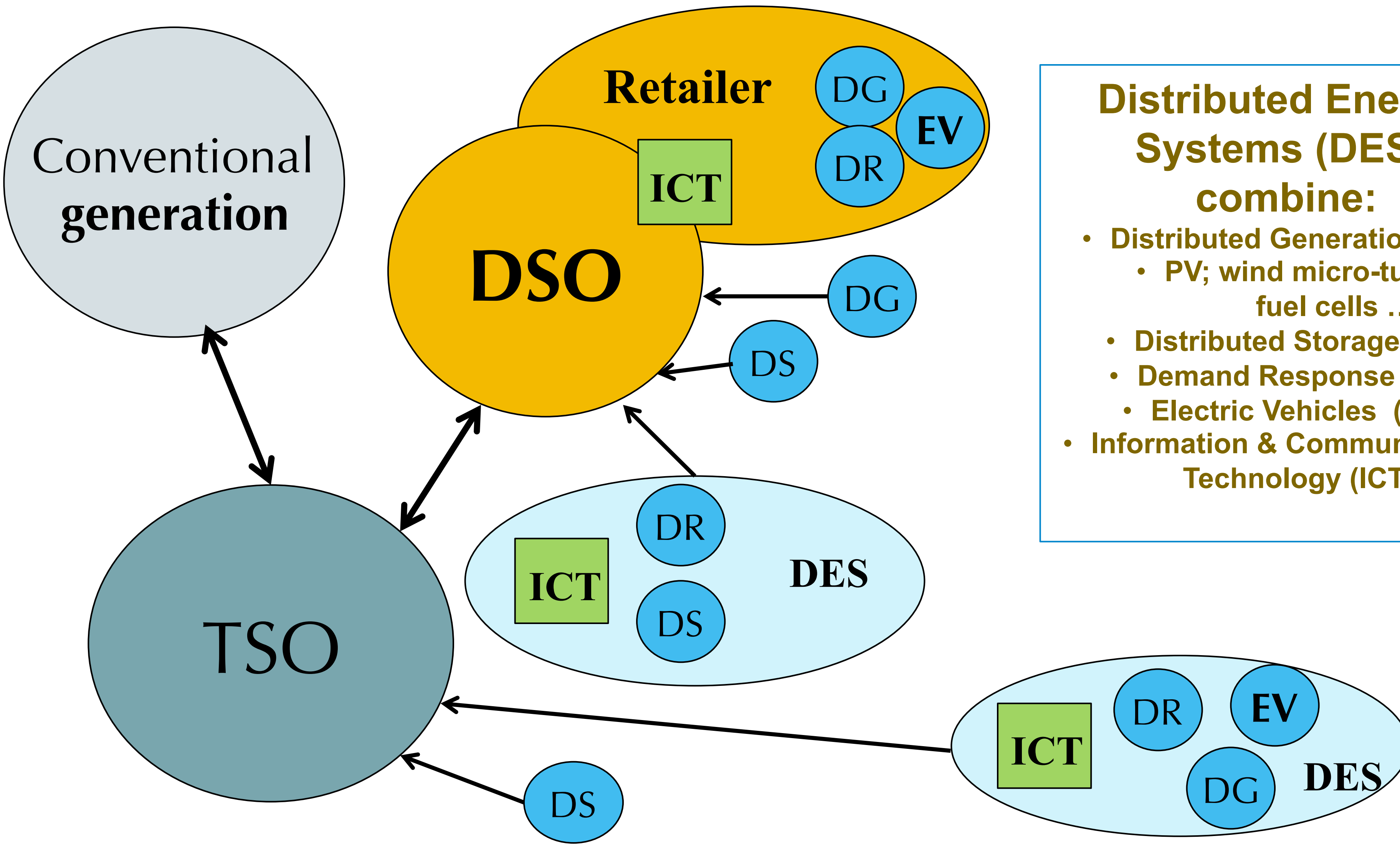
- The combination of
  - Information & Communication Technologies (**ICT**)
  - & various **distributed energy resources** (**DER**s) – including DG *(distributed generation)*, DS *(distributed storage)* & DR *(demand response)*

  will allow the creation and proliferation of new **Distributed Energy Systems** (**DESs**) *(from microgrids and virtual power plants to remote aggregation of controllable loads & smart charging systems for electric vehicle fleets).*

- These DESs will enable a diversity of **new business models** capable of providing value to end-use energy consumers and upstream electricity market actors.


DES Topologies
Microgrid
Single Consumer - Generator
Dispersed Aggregation
EV Fleet

Utility of the future: The industry structure



Distributed Energy Systems (DES) combine:

- Distributed Generation (DG)
  - PV; wind micro-turbines; fuel cells …
- Distributed Storage (DS)
- Demand Response (DR)
- Electric Vehicles (EV)
- Information & Communication Technology (ICT)

Elements for a vision from "the distribution edge"

- New & unfamiliar technologies for traditional utilities
- More sophisticated customers with unprecedented information & control over their energy use & expanded opportunities to produce their own energy
- Gas-fueled technologies enabling gas utilities to play an increased role in serving end-use demand for heat & electricity
- New market actors will proliferate: from ICT & DER technology providers to aggregators & operators of DESs
- Changes will be a threat to utilities, while also may add them value & enable them to better serve customers

The questions of interest

- Which of these DESs could be **viable**?
- How much does this viability depend on the **regulatory framework**?
- How much does the eventual success of the **new** (DES) **business models impact**
  - the **distribution** (wires) business?
  - the **retailing** business?
  - the **wholesale generation** business?

The technological perspective

Questions

- What **services** can be provided by DESs to **deliver value** to power system users & stakeholders?
- What technologies can **shift the existing electricity sector paradigm**?
- What is the status & likely evolution *("**tipping points**")* of these potential game changers?

Expected outputs

- Identify potentially **paradigm-changing technologies**, alone or in combination

The business model perspective

Questions

- What BMs are best suited to make use of different configurations of DESs in representative power system contexts to deliver value to all stakeholders?
- Choice or development of the right quantitative evaluation tools

Expected outputs

- Assessment of the viability of each BM
- Insight on how these BMs may impact the significance of the centralized paradigm

The business model conceptualization

Business model pillar	Description
Value proposition	Is the bundle of products and services that creates value for the customer and allows the company to earn revenues.
Customer interface	Comprises the overall interaction with the customer. It consists of customer relationship, customer segments, and distribution channels.
Infrastructure	Describes the architecture of the company's value creation. It includes assets, know how, and partnerships.
Revenue model	Represents the relationship between costs to produce the value proposition and the revenues that are generated by offering the value proposition to the customers.

Source: Osterwalder, 2004; Osterwalder and Pigneur, 2009.

A question for debate

Potential advantages of DESs

- Does aggregation (DESs) have any advantage over individual responses of the different network users, assuming that they receive the right local economic signals?
  - What is the added value (if any) that might be captured by aggregation?
  - Is taking advantage of any regulatory flaws the only reason for aggregation?

A question for debate
Potential advantages of DESs

- Aggregation of DERs can reduce the risk for each individual DER to not meet its market commitments
- Aggregating otherwise relatively inflexible DER products to one DER product bundle furthermore increases the possibility for DER units to take part in the markets for system services.
- Aggregating DER can exploit arbitrage potentials if existing network charges preferentially treat larger devices from the same type, or aggregations of devices of different types.

A case example
German incumbent utilities & the new business models

Until some years ago, electricity generation in Germany had almost exclusively been the sphere of utilities. This is dramatically changing. By the end of 2012, the largest share of the installed renewable energy capacity in Germany is owned by private persons (34.9%). Further owners are independent project developers (13.8%), investments funds and banks (12.5%), farmers (11.2%), small and medium-sized companies and others (1.2%). Utilities own 11.9% of the overall renewable generation capacity.

With this development continuing and the energy transition just at the beginning, renewable energies create a serious threat to utilities' business models in the next years and decades.

Source: Business model innovation for sustainable energy: German utilities and renewable energy, Mario Richter in Energy Policy, 2013

A case example
German incumbent utilities & the new business models

The main conclusion from the results of this study is that **utilities lack the business model innovation capabilities to successfully master the fundamental changes of the energy transition**.

Several other topics in the industry will require massive changes in the coming years and decades & will be further challenges for utilities:

- adaptation of the grid infrastructure to the new generation technologies
- development of technologies and business models for large and small-scale electricity storage
- ways to introduce demand side management
- and the development of business models for energy efficiency will be further challenges for utilities.

Therefore, **utilities need to improve their business model innovation capabilities** to be able to pro-actively respond to the new business opportunities.

The regulatory perspective

Questions

- What are the **limitations of existing power sector regulations** & how are they shaping the emergence od DES-related BMs?
- **How can regulations be improved** to create a level playing field for multiple BMs based on new DESs or on conventional centralized generation?

Expected outputs

- Evaluation of the existing regulatory regimes & **proposal of a level playing field** regulatory framework that can be used as benchmark

THINK

http://think.eui.eu

Topic 12

From Distribution Networks to Smart Distribution Systems: Rethinking the Regulation of European Electricity DSOs

Final Report
June 2013

Project Leader: Ignacio Pérez-Arriaga
Research Team Leader: Sophia Ruester
Research Team: Sebastian Schwenen
Carlos Batlle
Jean-Michel Glachant

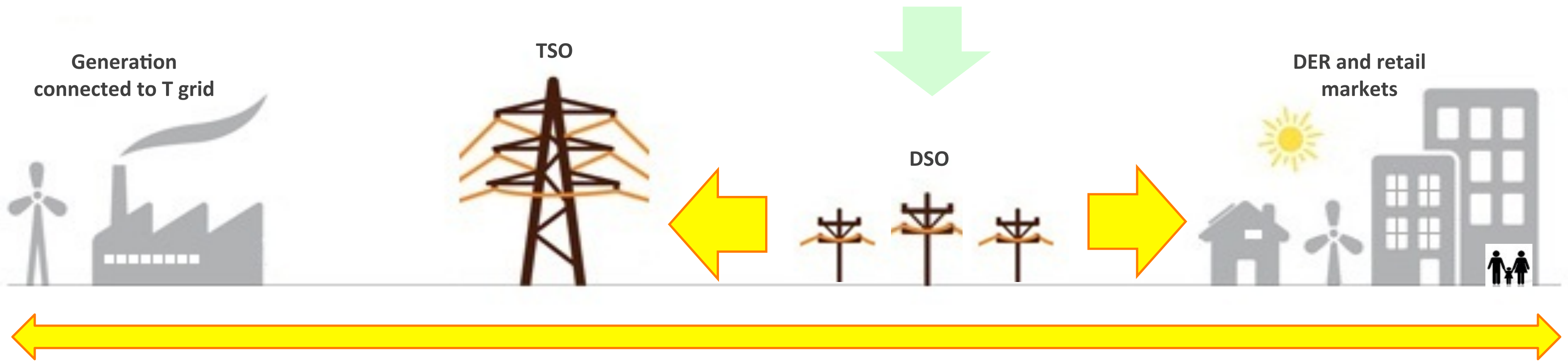
Project Advisors: François Lévêque
Władysław Mielczarski

THINK is financially supported by the EU's 7th framework programme

Regulation of the DSO is the critical issue
Four areas of regulation need to be reviewed

DSO as a network operator (and owner):

Revenue sufficiency, allocative efficiency



DSO along the value chain

Boundaries, roles, and coordination vs. system agents

1. Regulated DSO remuneration

2. Distribution network tarification

3. DSOs vis-à-vis markets

4. DSOs vis-à-vis the TSO

Four areas of DSO regulation need to be reviewed

- **Remuneration** of distribution network companies that better accounts for the costs and savings offered by a high penetration of DESs
- **Allocation of network costs** to its users to provide a level playing field for all DESs – this includes **redesigning network tariffs**
- Identification of the **new role(s) of the DSO** (functions & services with economic value) in a system with larger penetration of DESs
- Reassessment of industry structure and **interactions between network operators** (TSO/ISO & DSOs) and other market actors given increasing penetration of DESs.

#4.A

Remuneration

Integration of intermittent renewables in distribution networks*

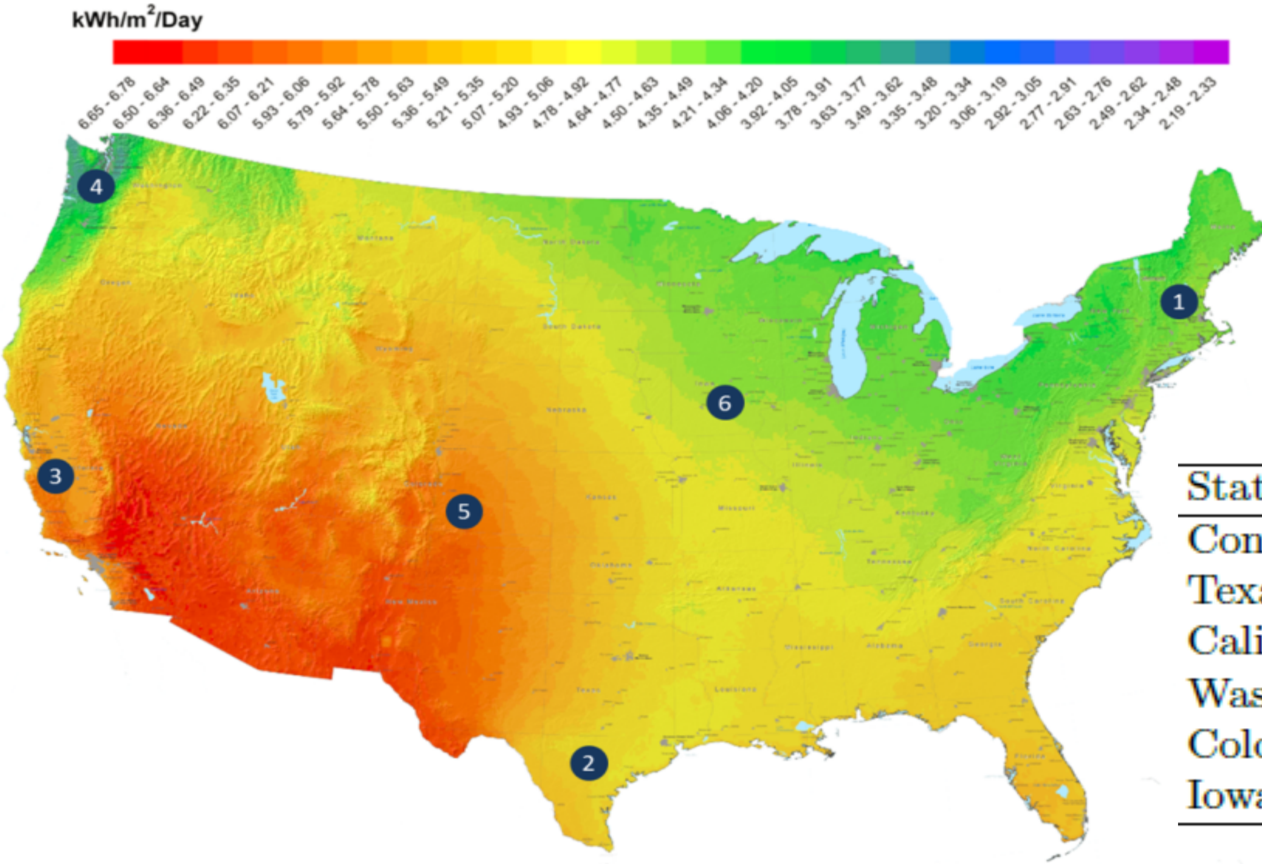
(*) From "MIT Future of Solar Study", with participation of IIT-Comillas

The approach

- Utilization of a **Reference Network Model*** to compute investments and operational costs for representative networks
- Examine several **prototypic representative systems**
- Penetration analysis for a single period
- Assessment of the **impact on network costs, tariffs and losses**

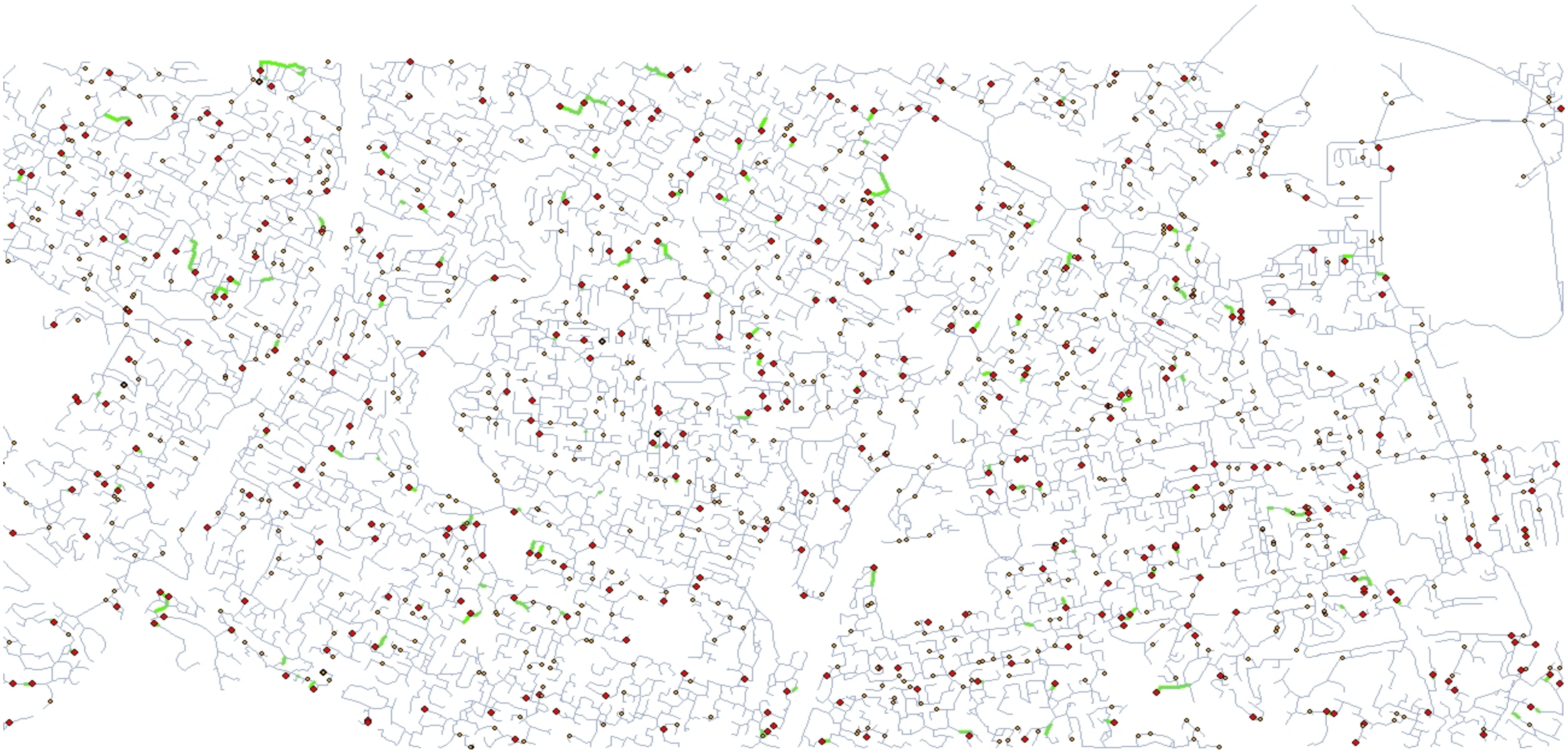
(*) Model RNM developed by IIT-Comillas University

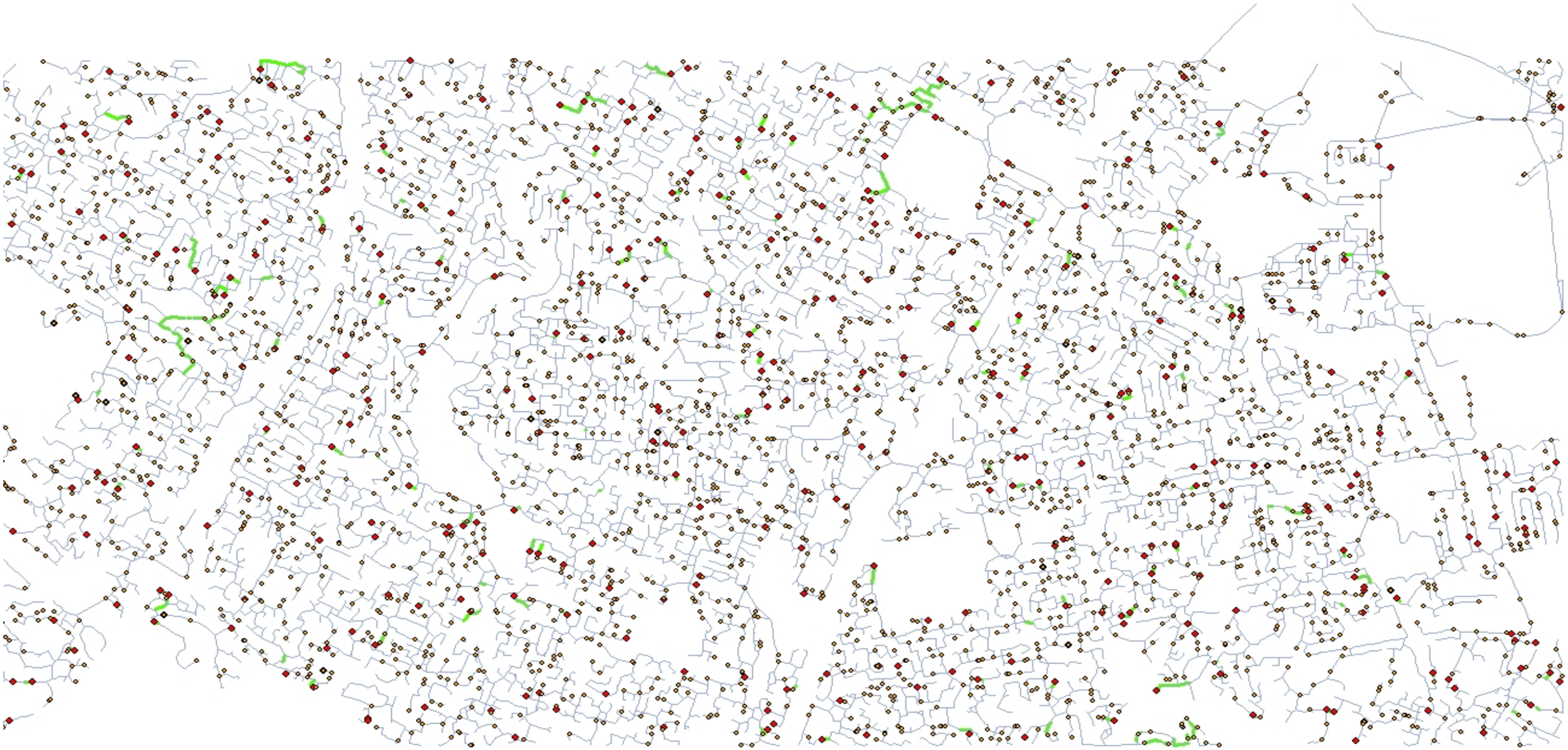
Considered sample of cases

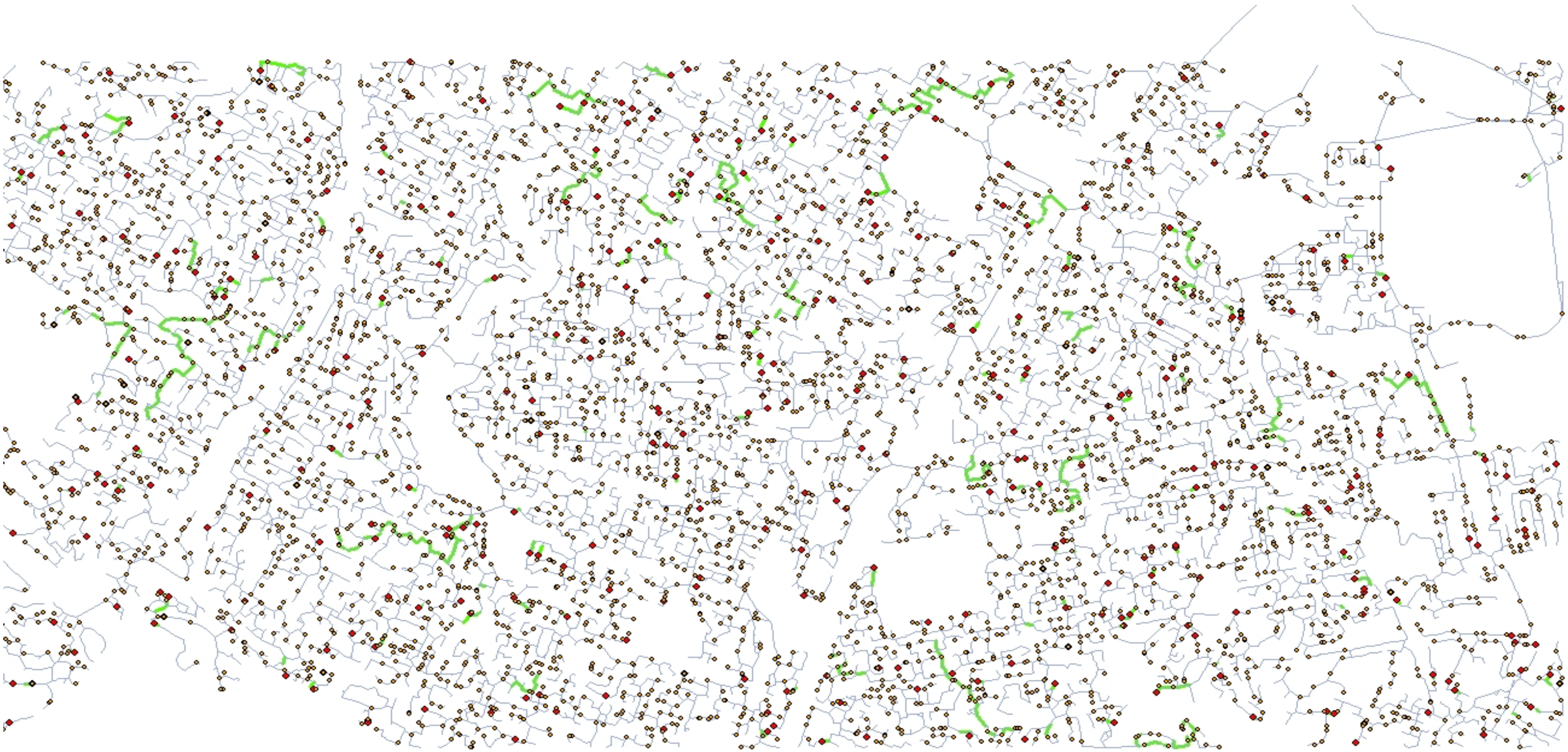


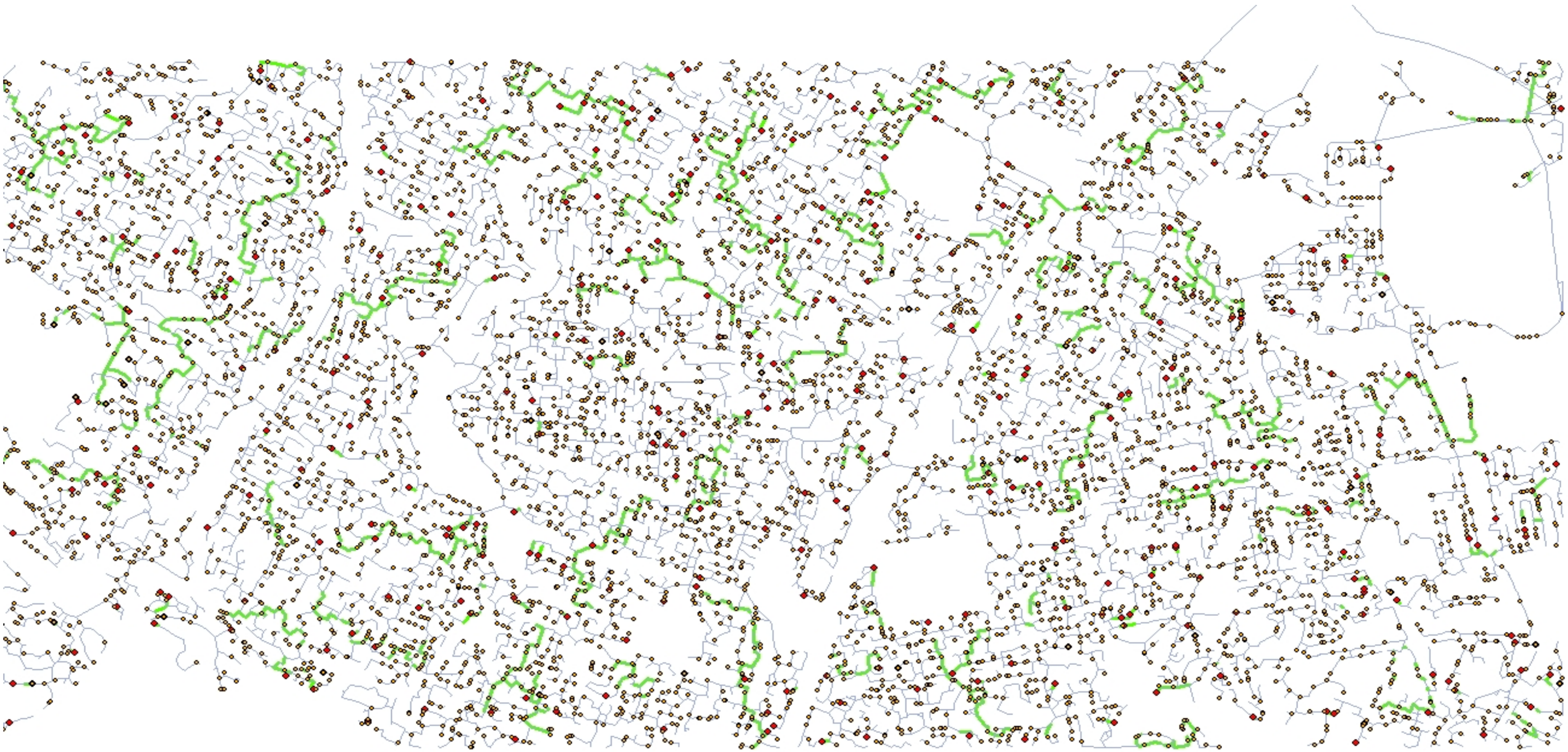
State	Rural	Urban
Connecticut	Torrington	Hartford
Texas	San Marcos	Austin
California	Lancaster	Los Angeles
Washington	Covington	Seattle
Colorado	Eaton	Boulder
Iowa	Altoona	Des Moines

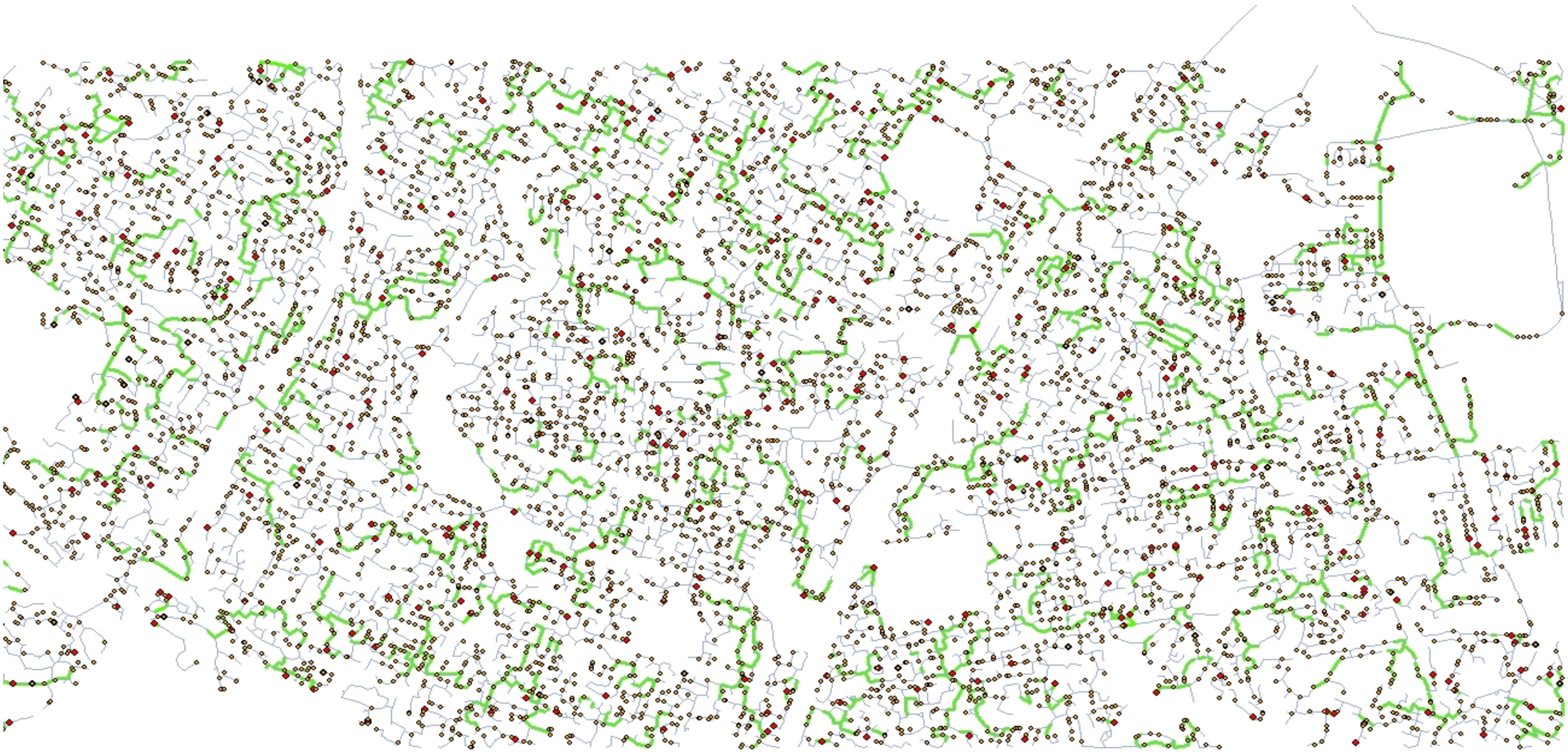
6 regions x 2 cities/location x 3 networks/city x 8 scenarios /network = 288 cases

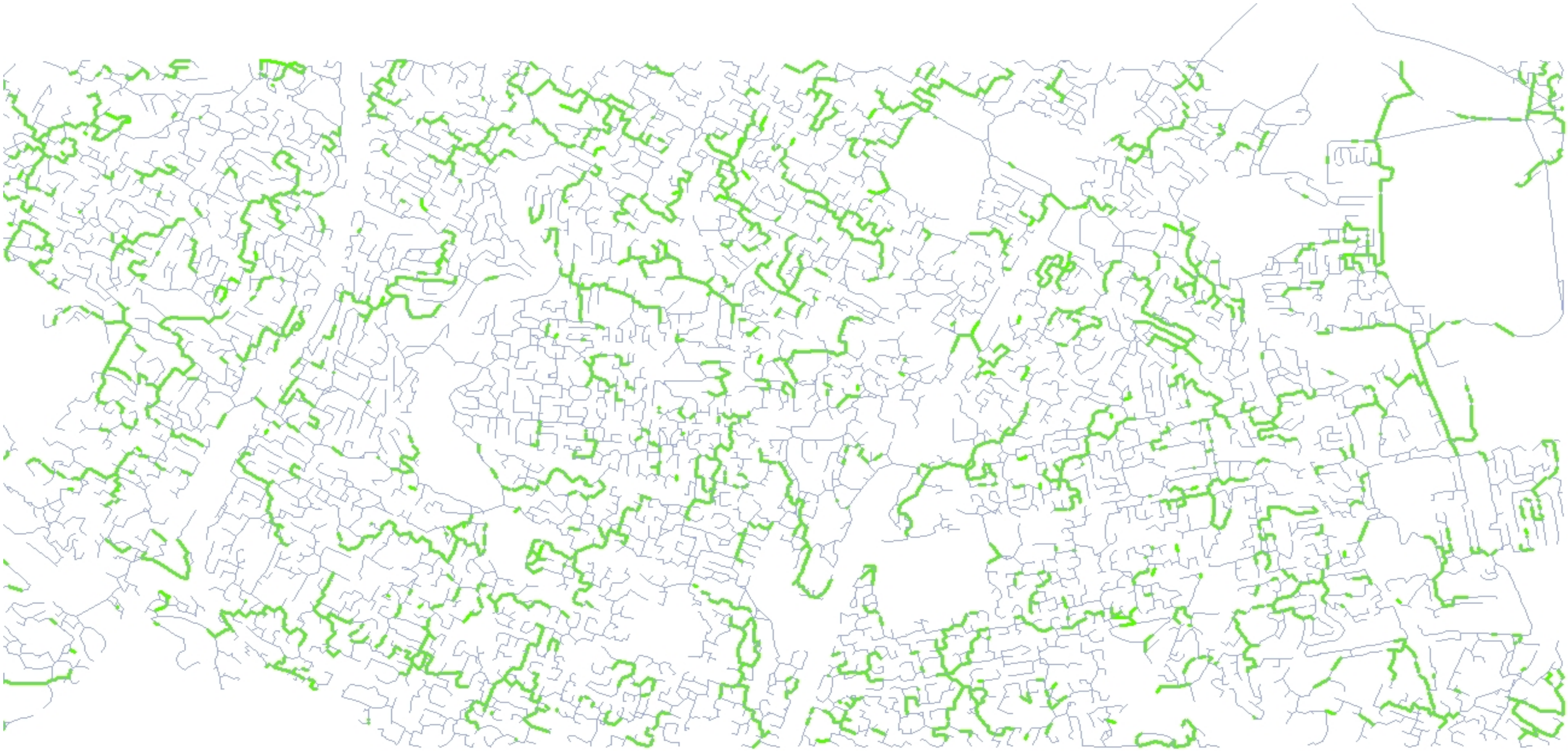




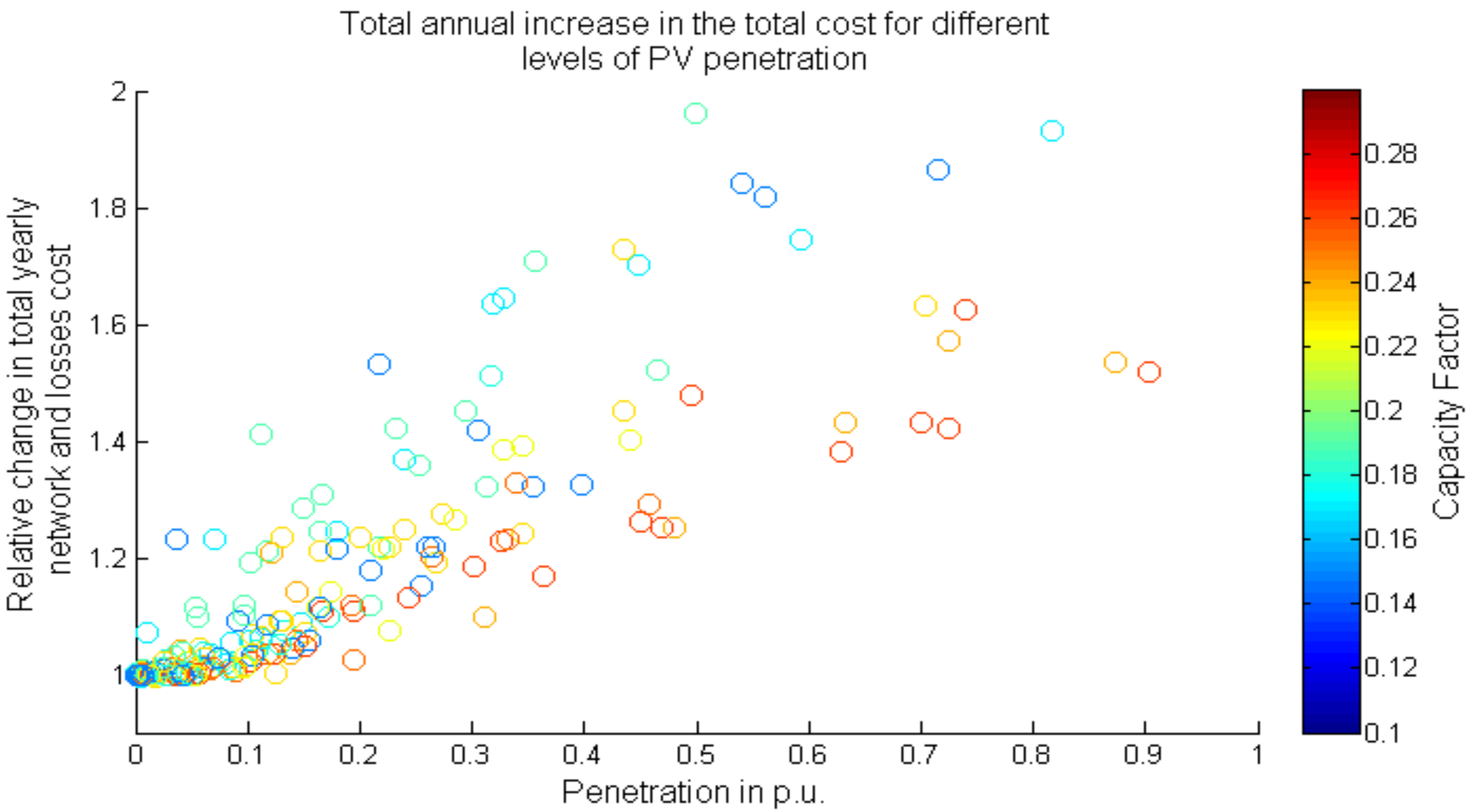






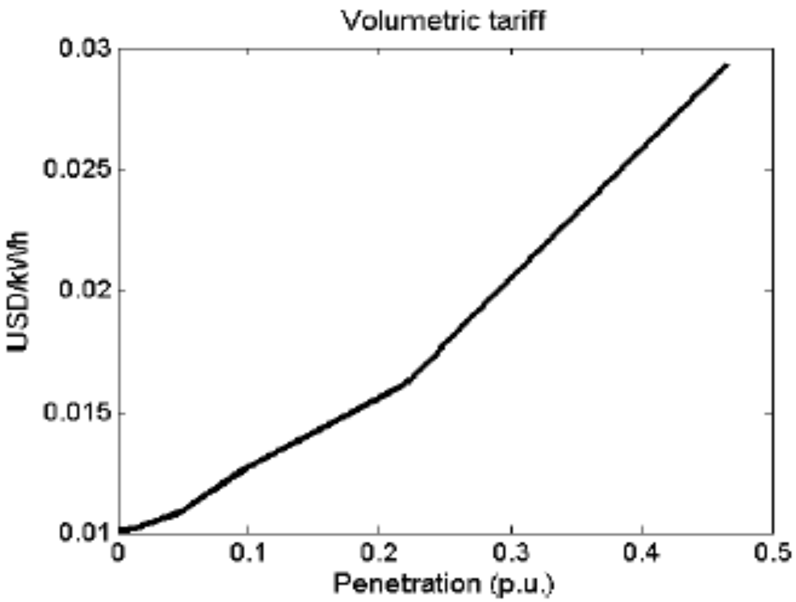


Results

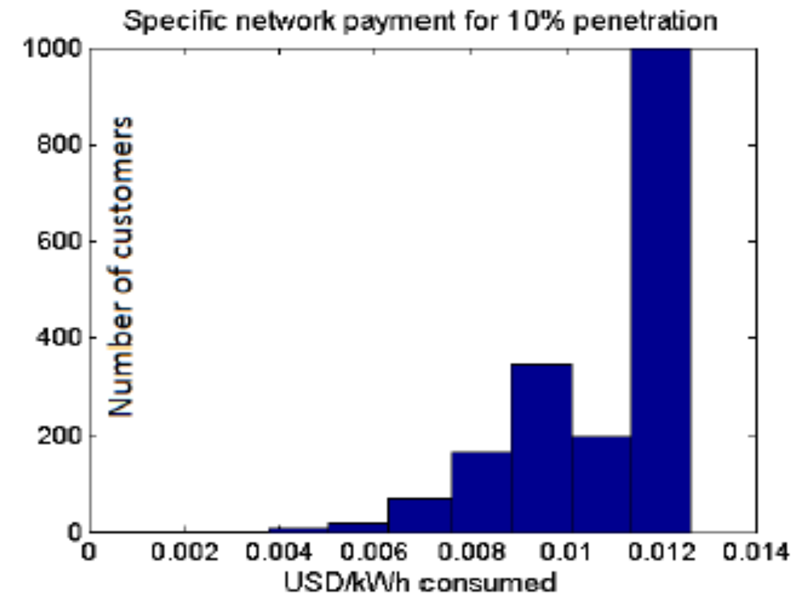


Total annual increase in the total cost for different levels of PV penetration
Relative change in total yearly network and losses cost
Penetration in p.u.
Capacity Factor
2
1.8
1.6
1.4
1.2
1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0.28
0.26
0.24
0.22
0.2
0.18
0.16
0.14
0.12
0.1

Net metering + volumetric network tariffs



(a) Changes in network charge



(b) Perceived network charge.

- Under **volumetric tariffs**, the network charge increases with penetration because larger costs have to be shared among fewer kWh.
- This increase is not perceived equally under **net-metering**: customers with distributed generation avoid part of the charge and are subsidized by others.

#4.B

Design of network charges

Ideas for a conceptual approach

(*) Related activities: THINK project of the Florence School of Regulation for the European Commission, led by Ignacio Pérez-Arriaga and "The utility of the future" (a COMITES project).

Redesigning distribution network tariffs

- Current network tariff design is **totally inadequate** for the future *(& also present)* network users
- Network charges should be **based on the actual cost drivers**
  - Minimum required **connection** assets
  - Contribution to **grid utilization peaks**
  - Aggregated contribution to **system losses**
  - Need for some ancillary services *(might be separately treated)*
- Once the amount of network charge has been computed, the **format of the charge** *(€/yr, €/kW or €/kWh)* is also important

Reference framework for the design of electricity distribution grid tariffs

	Allowed DSO revenue		
Cost drivers according to which total cost are allocated	Minimum required assets to just connect the agent (and all others)	Grid user's contribution to peaks	Grid user's aggregated contribution to losses
Format of respective tariff components	Calculated once for each agent, or all agents of a kind in a zone, on top of the strict shallow connection cost Charged in €/year	Calculated for "zones within the D system" and "types of agents"; updated regularly (e.g. monthly) Charged in €/kW	Depending on actual grid usage Charged in €/kWh
Example 1: Household with a typical consumption profile	Subscribes a contract for 4 kW withdrawal	Consumes most during peak hours Relatively high positive charge	Total consumption of 300 kWh per month
Example 2: Household with an advanced hourly meter, an EV, solar PV on the roof, energy storage and "smart" behavior	Subscribes contracts for 10 kW withdrawal and 75 kW injection	Consumes most during night (off-peak) and injects during morning and evening peak hours Negative charge	Total consumption of 600 kWh per month Total generation of 500 kWh per month (yearly average)

Source: THINK project report, Florence School of Regulation

Solar PV plus battery storage
The Boston Consulting Group, July, 13, 2013

Falling system costs are the primary reason for the improving economics. But there are other drivers, which vary by location. These include high retail energy prices, low compensation for surplus electricity fed into the grid, and, in at least one instance, direct government support for solar PV with battery storage. These factors have improved both the near-term economics and the system lifetime economics.

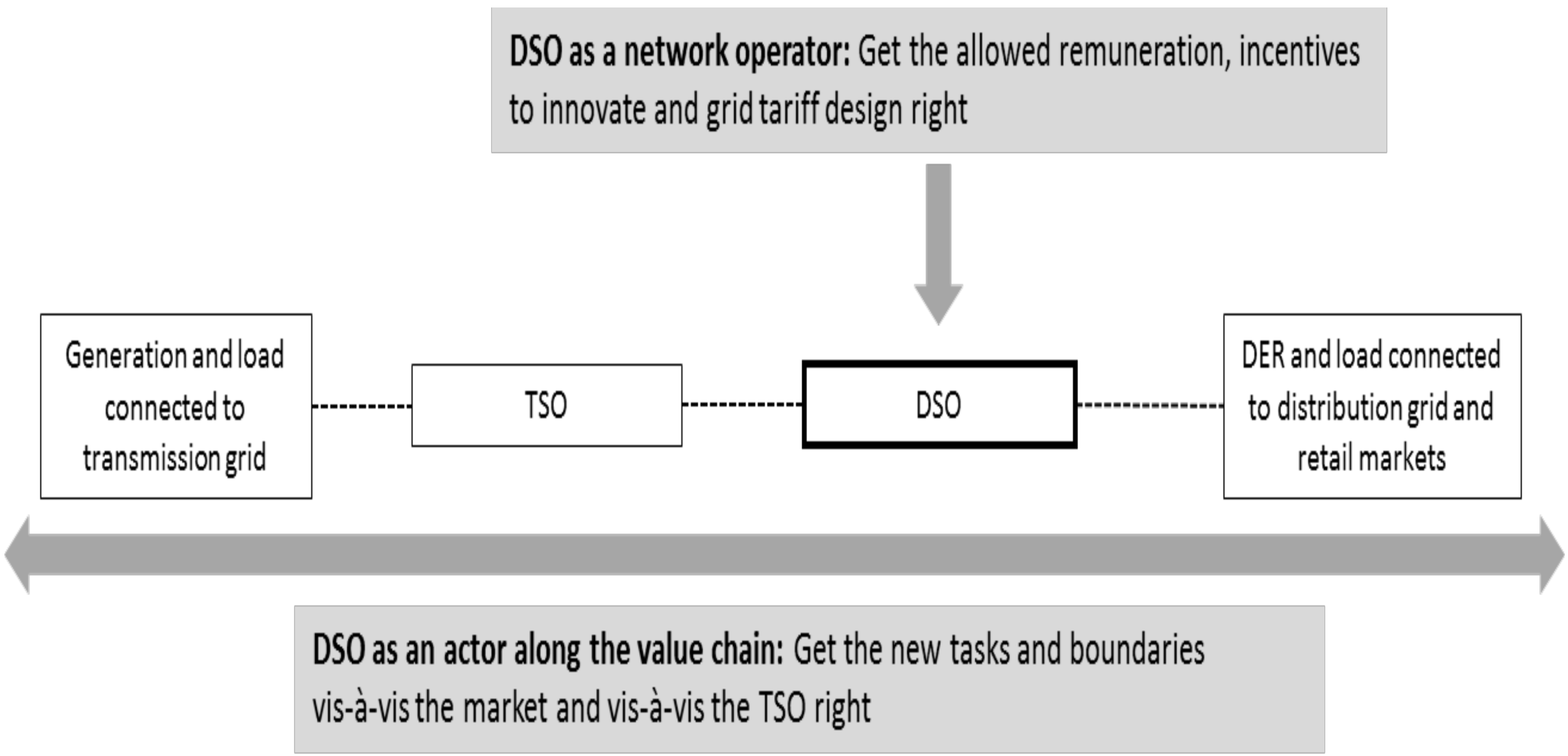
One can conclude that the economics of battery storage depends on the value of several subsidies & of a couple of regulatory flaws (low compensation for electricity fed to the grid & net metering with volumetric charges)

#4.B&C

The new role of the DSO & the interaction between DSOs/TSO

(*) Related activities: THINK project of the Florence School of Regulation for the European Commission, led by Ignacio Pérez-Arriaga and "The utility of the future" (a COMITES project).

The new role of the DSO



A taxonomy of system operators' tasks directly related to grid management

DSO	TSO
Long-term distribution grid planning and grid development (including the connection of load and DG and guaranteeing efficient access and use of the grid)	Long-term transmission grid planning and grid development (including the connection of bulk generation (and load) and guaranteeing efficient access and use of the grid)
Grid operation, in particular: • Voltage control • Load/DG curtailment in case of emergencies	Grid operation, in particular • Frequency containment • Frequency restoration • Replacement of generation

Major services which DER can provide to TSO and/or DSO

Service	Type of DER able to offer the service	System operator procuring such services
System balancing services	All types of DER	TSO
Frequency control	All types of DER	TSO
Voltage control	All types of DER	DSO
Blackstart	Larger-scale DS and DG	TSO and DSO
Short-term security congestion management	DG, DS, DR, (EV)	TSO and DSO

A global perspective

Questions

- What are **plausible futures** of the electric power system assuming that various combinations of the viable BMs emerge under specific regulations?
- What are the **implications** for new & existing market actors & end users?
- What might be a **plausible balance** between the **decentralized & centralized** paradigms?

Expected outputs

- Generation & assessment of **scenarios of potential visions** of the electric utilities of the future.

... and the way to go...

(for utilities & everybody else)

Edison Electric Institute

Power by Association

Disruptive Challenges:

Financial Implications and Strategic Responses to a Changing Retail Electric Business

Prepared by: Peter Kind
Energy Infrastructure Advocates

Prepared for: Edison Electric Institute

January 2013

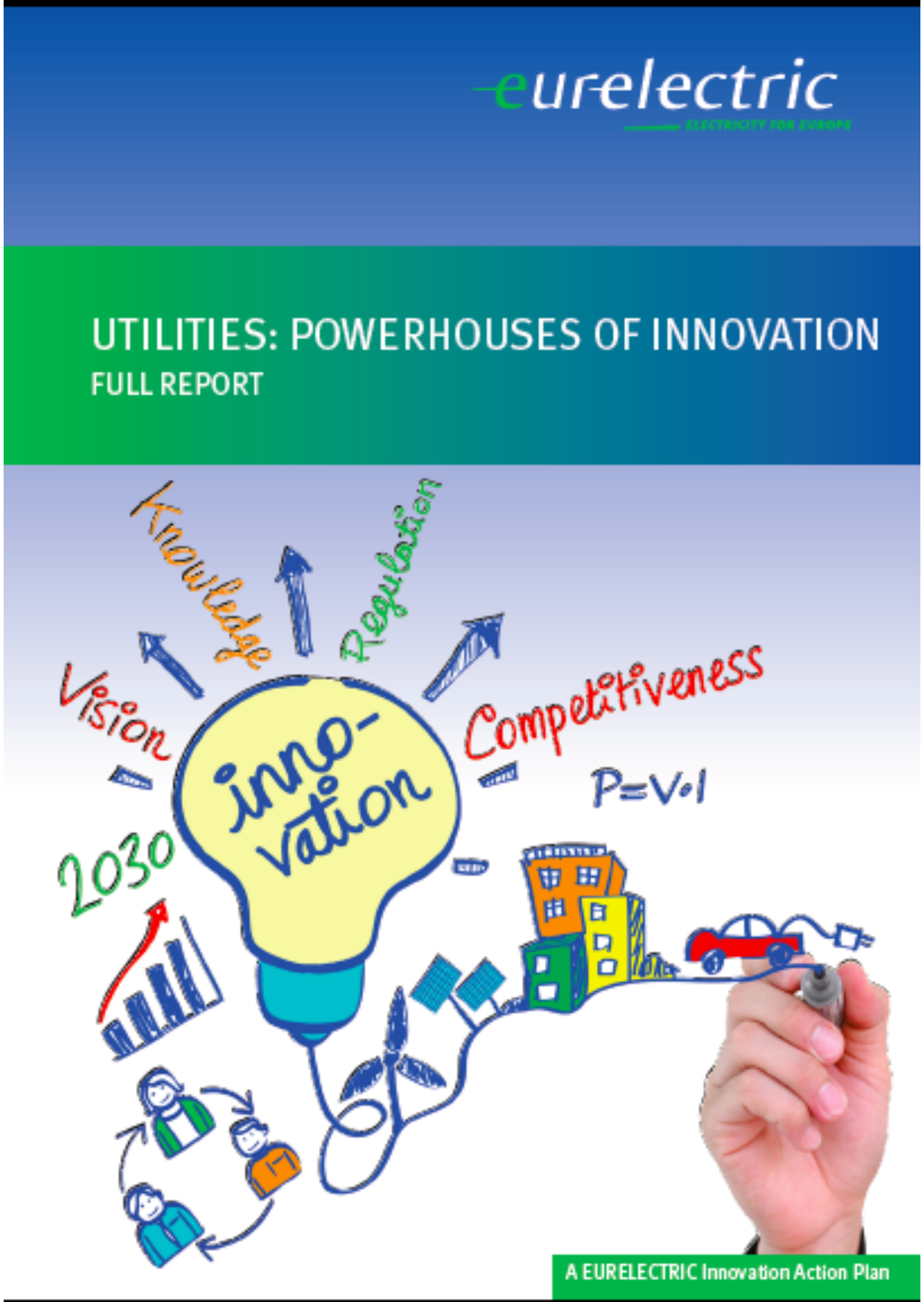
“Disruptive challenges”

(Edison Electric Institute, January 2013)

In a defensive mode…

“The **timing** of such transformative changes **is unclear**, but with the potential for forthcoming technological innovation becoming economically viable due to this confluence of forces, the industry and its stakeholders must **proactively assess the impacts and alternatives available** to address disruptive challenges in a timely manner.”

Source: Edison Electric Institute Report, January 2013, “Disruptive Challenges: Financial Implications and Strategic Responses to a Changing Retail Electric Business”



In a much more positive mindset

(as we shall see later)

"Utilities: Powerhouses of innovation"

(Eurelectric, May 2013)

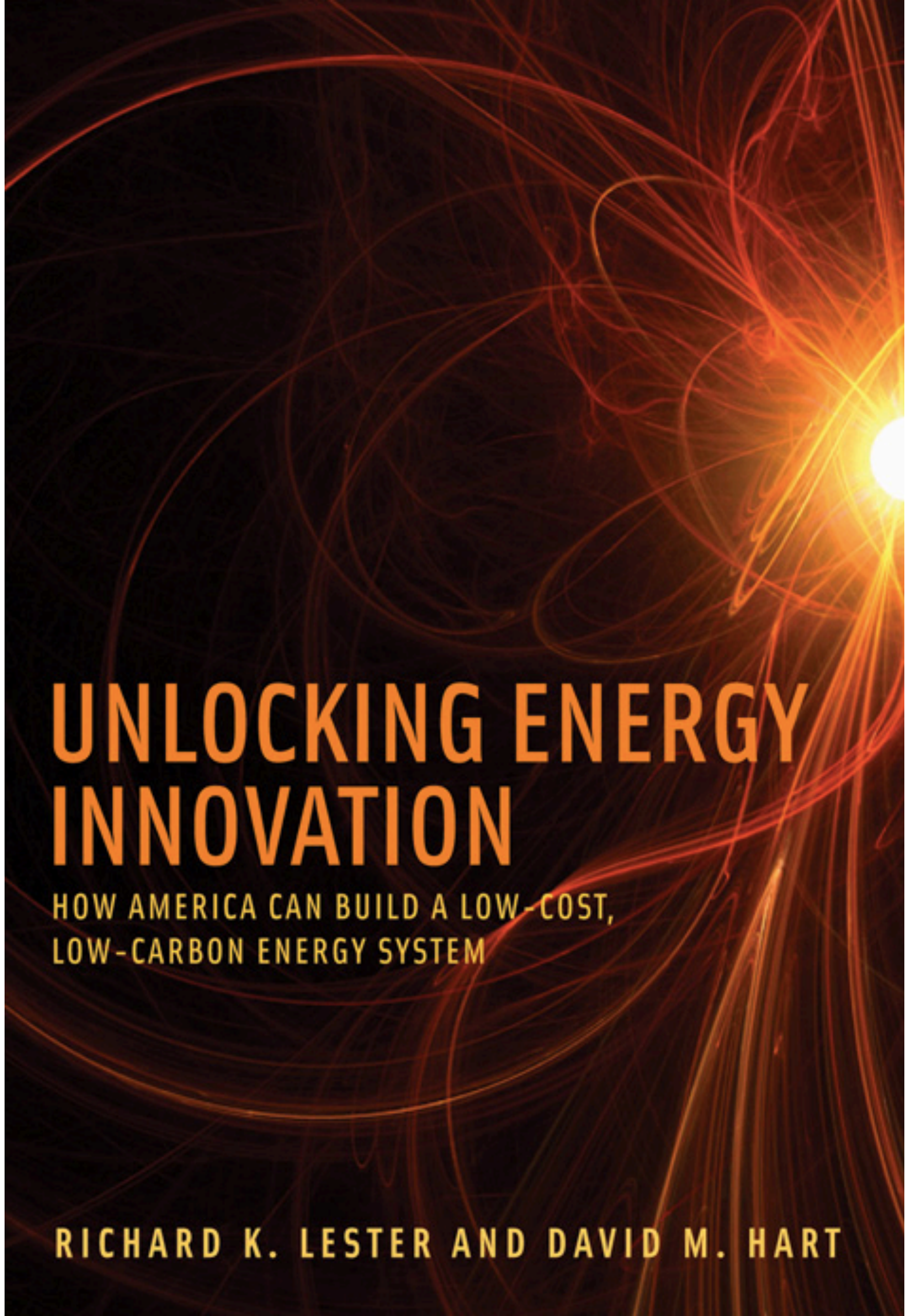
"**Energy services** (heating and lighting, but also mobility, etc.) **would be met not solely, or even primarily, through the supply of energy** – but through a range of channels including decentralized generation technology, improved energy efficiency across a range of applications, and sophisticated control technologies. At the end of this journey, therefore, lies **a potentially dramatically different business model for serving customer needs**, defined not in terms of energy supplied, but directly in terms of the benefits that end-users perceive themselves to be deriving from various energy-consuming services."

Source: Eurelectric, May 2013, "Utilities: Powerhouses of innovation"

Eurelectric identifies several possible **new "downstream products and services**" which the evolving **utility of the future** may deliver:

- "… **distributed generation** creates business opportunities to provide, install, and maintain new equipment at customers' premises, as well as additional potential services, such as virtual power plant generation models.
- Continued **energy efficiency improvement** will create a market for a wide range of technical solutions and, equally importantly, new business models to unlock the potential value that energy-saving solutions entail.
- As part of providing system flexibility, the importance of **demand response aggregation** will grow. A market involving B2B [business to business] customers is already emerging and is likely to extend to the B2C segment through two-way digital communication enabled by smart grids and the increased penetration of smart appliances and home control technologies.
- Future adoption of **electric vehicles** will require e-mobility solutions for private and fleet customers, spanning the development of **charging infrastructure** (public charging stations and private charging boxes), **power supply**, and **automatic billing** and data management."

Source: Eurelectric, May 2013, "Utilities: Powerhouses of innovation"


UNLOCKING ENERGY INNOVATION
HOW AMERICA CAN BUILD A LOW-COST, LOW-CARBON ENERGY SYSTEM
RICHARD K. LESTER AND DAVID M. HART

“Unlocking energy innovation”

(Richard Lester & David Hart, MIT Press, 2012)

“We argue that **completing the restructuring** process can help to jump-start **innovation** in electricity generation, transmission, distribution and use.

Reformed and reinvented **‘smart integrator utilities’** will need to be **central players** across all three waves of innovation that we hope to see in the twenty-first century.

But to unlock the full innovative capacities of the (US) economy, these utilities will have to **share the stage** with the kinds of firms that they and their protectors in government crowded off in the past.”

We may agree or not with what a "Smart Integrator Utility" or a "Distributed Energy System" could be or how they could evolve,

but it sure is an intriguing question.

THANK YOU FOR YOUR ATTENTION