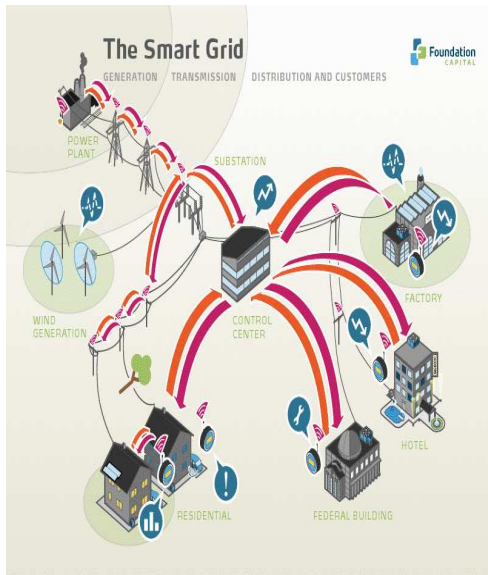


# Energy Systems the Optimization Challenge

Michel DE LARA  
Cermics, École des Ponts ParisTech, France

26 mars 2018

# Challenges ahead for optimization in energy



*Optimizing is  
obtaining the best  
compromise  
between needs and resources*

Marcel Boiteux  
(président d'honneur  
d'Électricité de France)

# Outline of the talk

- ▶ In 2000, the **Optimization and Systems** group was created at École des Ponts ParisTech and, since then, we have **trained PhD students** in stochastic optimization
- ▶ Since 2011, we witness a growing demand from energy firms for robust/stochastic/decentralized optimization, fueled by a **deep and fast transformation of energy systems**
- ▶ We will sketch **how we cooperate with the industry** on **micro-grid optimization** issues
- ▶ We cast a glow on snapshots highlighting **ongoing research**
  - ▶ subway station energy management
  - ▶ domestic district energy management
  - ▶ pumping station management

# Outline of the presentation

École des Ponts ParisTech–Cermics–Optimization and Systems

What is happening to energy systems?

How we cooperate between academy and industry

Snapshots on ongoing research

Conclusion

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# L'École nationale des ponts et chaussées



# Let's open the Russian dolls... one by one

- ▶ **École des Ponts ParisTech**  
is one of the world's oldest engineering institutes  
and hosts a substantial research activity
  - ▶ **CERMICS**  
is the applied mathematics and scientific computing research center
    - ▶ The **Optimization and Systems Group**  
is one of the three groups harbored by the Cermics

# Here is the flesh and blood of the Optimization and Systems Group

- ▶ **Senior researchers**

- ▶ Jean-Philippe CHANCELIER
- ▶ Michel DE LARA
- ▶ Vincent LECLÈRE
- ▶ Frédéric MEUNIER
- ▶ Axel PARMENTIER

- ▶ **Associated researcher**

- ▶ Pierre CARPENTIER (ENSTA ParisTech)

- ▶ **Students**

- ▶ engineering schools, master, PhD, post-doc



# The Optimization and Systems Group specializes in... optimization!

## ▶ Methods

### ▶ Multistage stochastic optimization

- ▶ Dynamic programming, SDDP, Stochastic programming
- ▶ Large-scale systems, decomposition methods
- ▶ Numerical methods
- ▶ Risk (risk measures, probability constraints)

### ▶ System control theory, viability and stochastic viability

- ▶ Discrete mathematics; combinatorial optimization; operations research; learning

## ▶ Applications

- ▶ **Optimized management** of **energy systems** under **uncertainty** (production scheduling, power grid operations, risk management)
- ▶ **Transport** modelling and management
- ▶ **Natural resources** management (fisheries, mining, epidemiology)

## ▶ Softwares

- ▶ Scicoslab, NSP
- ▶ Oadlibsim

# We teach at master and engineering levels

## ▶ Masters

- ▶ Master Parisien de Recherche Opérationnelle
- ▶ Économie du Développement Durable, de l'Environnement et de l'Énergie
- ▶ Renewable Energy Science and Technology Master ParisTech

## ▶ École des Ponts ParisTech

- ▶ Optimisation (F. MEUNIER)
- ▶ Introduction à la recherche opérationnelle (F. MEUNIER)
- ▶ Optimisation et contrôle (J.-P. CHANCELIER)
- ▶ Modéliser l'aléa (J.-P. CHANCELIER)
- ▶ Optimisation et énergie (V. LECLÈRE)

Our industrial contracts mostly deal with energy issues, whereas the public ones touch on biodiversity management

- ▶ Industrial contracts

- ▶ Électricité de France (EDF R&D)
- ▶ Conseil français de l'énergie (CFE)
- ▶ SETEC Energy Solutions
- ▶ Thales
- ▶ Institut français de l'énergie (IFE)
- ▶ Gaz de France (GDF)
- ▶ PSA

- ▶ Public contracts

- ▶ STIC-AmSud (CNRS-INRIA-Affaires étrangères)
- ▶ Centre d'étude des tunnels
- ▶ CNRS ACI Écologie quantitative
- ▶ RTP CNRS

Since 2011, our contacts in the energy sector have expanded

- ▶ with small companies
  - ▶ ARTELYS
  - ▶ SETEC Energy Solutions
  - ▶ SUN'R Smart Energy
- ▶ with large companies
  - ▶ French Energy Council (CFE), member of the World Energy Council
  - ▶ Institute for energy transition Efficacity

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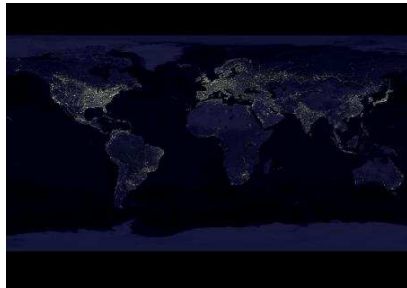
# Three key drivers are remolding power systems



- ▶ Environment / Penetration of renewable energies
- ▶ Expansion of markets
- ▶ Penetration of Information Technology



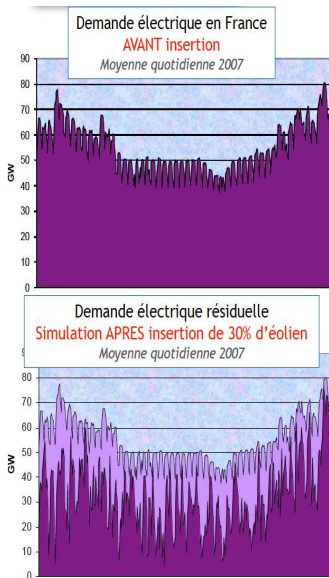
Multiple levels of integration – interoperability  
Distributed Generation   Renewable Generation   Storage   Demand Response



## Key driver: environmental concern

- ▶ The European Union climate and energy package materializes an environmental concern with three 20-20-20 objectives for 2020
  - ▶ a 20% improvement in the EU's **energy efficiency**
  - ▶ a 20% **reduction** in EU **greenhouse gas emissions** from 1990 levels
  - ▶ raising the **share** of EU energy consumption produced from **renewable resources to 20%**
- ▶ COP 21, Paris 2015

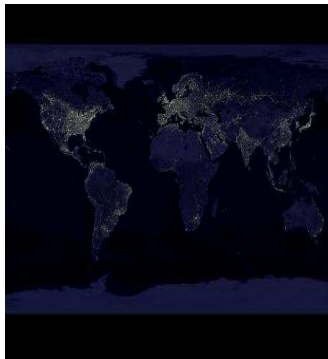
# Key driver: penetration of renewable energies



- ▶ Costs of wind and sun energies have dropped down
- ▶ Successfully **integrating renewable energy sources** has become critical
- ▶ But wind and sun energies are **unpredictable** and **highly variable**
- ▶ This triggers the use of local **storage**



# Key driver: economic deregulation



- ▶ A **power system**  
(generation/transmission/distribution)
  - ▶ **less and less vertical**  
(deregulation of energy markets)
  - ▶ hence with **many players**  
with their **own goals**
- ▶ with some **new players**
  - ▶ industry (electric vehicle)
  - ▶ **regional authorities**  
(autonomy, efficiency)
- ▶ with a **network in horizontal expansion**
- ▶ with more and more exchanges  
(trade of commodities)



A **change of paradigm for management**  
from **centralized to** more and more **decentralized**

# Key driver: telecommunication technology



Linky

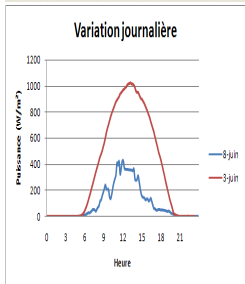
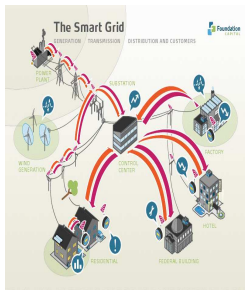
A power system with **more and more technology** due to evolutions in the fields of metering, computing and telecoms

- ▶ smart meters
- ▶ sensors
- ▶ controllers
- ▶ grid communication devices. . .



A **huge amount of data** which, one day, will be a new **potential for optimized management**

# The “smart grid”? An infrastructure project with promises to be fulfilled by a “smart power system”



- ▶ **Hardware** / infrastructures / smart technologies
  - ▶ Renewable energies technologies
  - ▶ Smart metering
  - ▶ Storage
- ▶ **Promises**
  - ▶ Quality, tariffs
  - ▶ More safety
  - ▶ More renewables (environmentally friendly)
- ▶ **Software** / smart management (energy supply being less flexible, make the demand more flexible)
  - ▶ smart management, smart operation, smart meter management, smart distributed generation, load management, advanced distribution management systems, active demand management, diffuse effacement, distribution management systems, storage management, smart home, demand side management. . .

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We cooperate with industry partners,  
looking for longlasting research relations  
through training and capacity building

- ▶ As academics, we cooperate with industry partners, looking for longlasting close relations
- ▶ We are not consultants working for clients, but focus en capacity building
- ▶ Our job consists mainly in
  - ▶ training Master and PhD students, working within the company and interacting with us, on subjects designed jointly
  - ▶ developing methods, algorithms
  - ▶ contributing to computer codes developed within the company
  - ▶ training professional engineers in the company

# Électricité de France R & D / Département OSIRIS

- ▶ **Électricité de France is the French electricity main producer**
  - ▶ 159 000 collaborateurs dans le monde
  - ▶ 37 millions de clients dans le monde
  - ▶ 65,2 milliards d'euros de chiffre d'affaire
  - ▶ 630,4 TWh produits dans le monde
- ▶ **Électricité de France Research & Development**
  - ▶ 486 millions d'euros de budget
  - ▶ 2 000 personnes
- ▶ Département **OSIRIS**  
Optimisation, simulation, risques et statistiques pour les marchés de l'énergie  
**Optimization, simulation, risks and statistics for the energy markets**
  - ▶ 145 salariés (dont 10 doctorants)
  - ▶ 25 millions d'euros de budget

# ARTELYS

- ▶ ARTELYS is a company specializing in optimization, decision-making and modeling
- ▶ Relying on their high level of expertise in quantitative methods, the consultants deliver efficient solutions to complex business problems
- ▶ They provide services to diversified industries: Energy and Environment, Logistics and Transportation, Telecommunications, Finance and Defense
- ▶ We have trained master and PhD students that now work for ARTELYS

# SETEC Energy Solutions

- ▶ Créée en 2011, **SETEC Energy Solutions** est la filiale du groupe SETEC spécialisée dans les domaines de la **production** et de la **maîtrise de l'énergie** en France et à l'étranger
- ▶ SETEC Energy Solutions apporte à ses clients la maîtrise des principaux process énergétiques pour la mise en œuvre de solutions innovantes depuis les phases initiales de définition d'un projet jusqu'à son exploitation
- ▶ We worked on the **optimization of a dam valley**, to assess the **opportunity to invest in a dam concession**



# The SUN'R Smart Energy company

- ▶ **SUN'R Smart Energy** is a Paris based company with
  - ▶ a focus on building smarter solutions for **distributed energy resources** in the context of emerging deregulated energy markets
  - ▶ and a solid political will towards the development of both **renewables** and energy **storage**
- ▶ In 2011, we started a collaboration that led us to be part of the **R & D SunHydrO project**

# What is the R & D SunHydrO project?



- ▶ R & D SunHydrO project (FUI, public and private funding)
  - ▶ design and build a pumping station for energy transfer (10–12 MW)
  - ▶ with profit-making business model
- ▶ ENSTA and ENPC are advisors for the optimization part
  - ▶ supervision of a post-doctorate recruited by SUN'R Smart Energy
  - ▶ in cooperation with an Operations Research specialist, especially recruited by SUN'R Smart Energy

# French Energy Council, member of the World Energy Council, contracted the Cermics in 2012 to report on Optimization methods for smart grids

- ▶ Formed in 1923, the **World Energy Council** (WEC) is the UN-accredited global energy body, representing the entire energy spectrum
- ▶ WEC informs global, regional and national energy strategies
- ▶ In 2012, the **French Energy Council** contracted the Optimization and Systems group to produce a report on **Optimization methods for smart grids**, freely available
  - ▶ Power Systems Undergo a Deep Remolding
  - ▶ Energy Actors Express Renewed Demands towards Optimization
  - ▶ Uncertainty in Decision-Making Can Be Handled in Many Ways
  - ▶ Displaying Stochastic Optimization Resolution Methods
  - ▶ Relating Ongoing Works and Practices

# We work with the institute for energy transition Efficacity

- ▶ Both France and Europe are committed to a 20% reduction in energy consumption and greenhouse gas (GHG) emissions by 2020
- ▶ If these targets are to be met, major efforts will be required from **cities** (housing, offices, shops, urban transport, etc.)
- ▶ To meet this challenge, the French government has decided to set up an **institute for urban energy transition, Efficacity** in 2014
- ▶ This research and development institute is of a new kind, based on an action research approach and bringing together France's cutting-edge skills from both public and private sector
- ▶ Michel De Lara is member of the **Efficacity scientific committee**
- ▶ The Optimization and Systems group **advises Efficacity** on **optimization** issues in **microgrid** management

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Domestic district energy management

Pumping station management

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# A context of increasing complexity



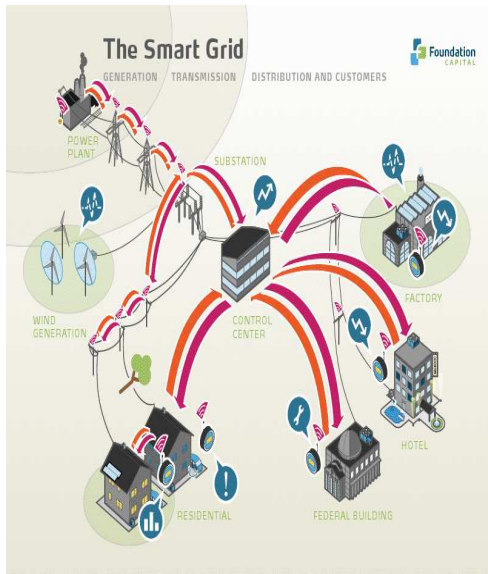
- ▶ Multiple energy resources: photovoltaic, solar heating, heatpumps, wind, hydraulic power, combined heat and power
- ▶ Spatially distributed energy resources (onshore and offshore windpower, solarfarms), producers, consumers
- ▶ Strongly variable production: wind, solar
- ▶ Intermittent demand: electrical vehicles
- ▶ Two-ways flows in the electrical network
- ▶ Environmental and risk constraints (CO<sub>2</sub>, nuclear risk, land use)



Multiple levels of integration - interoperability

● Distributed Generation ● Renewable Generation ● Storage ● Demand Response

# Challenges ahead for optimization



- ▶ large scale stochastic optimization
- ▶ various risk constraints
- ▶ decentralized and private information
- ▶ game theory, stochastic equilibrium, market design. . .