Program & Abstracts

Monday, September 30, 2024	**School (live on Youtube)**
09:00 - 09:20	Coffee and welcome
09:20 - 09:30	Welcome speech and organization of the school
09:30 - 11:00	**Philippe Drobinski and Laurent Dubus** Introduction to energy transition and its relationship with the climate 1
11:00 - 12:30	**Philippe Drobinski and Laurent Dubus** Introduction to energy transition and its relationship with the climate 2
12:30 - 14:00	Lunch
14:00 - 15:30	**Anna Creti and René Aid** Economic modeling of the energy system 1
15:30 - 15:50	Formation of discussion groups for cross-disciplinary discussions by participants
15:50 - 16:15	Coffee Break

Tuesday, October 1st, 2024	**School (live on Zoom)**
09:00 - 10:30	**Nadia Maïzi** Bottom-up modeling of the energy system
10:30 - 10:50	Coffee break
10:50 - 12:20	**Anna Creti and René Aid** Economic modeling of the energy system 2
12:20 - 14:00	Lunch
14:00 - 15:30	**Rémy Doudard** Integrated modeling of the energy system
15:30 - 15:50	Coffee break
15:50 - 17:20	**Jean Marc Janin** Presentation of the ANTARES model
17:20 - 17:45	Group meetings for cross-disciplinary discussions

Wednesday, October 2nd, 2024	**School (live on Youtube)**
09:00 - 10:30	**Laurent Dubus, Bastien Cozian, Corentin Herbert, and Amaury Lancelin** Extremes and the energy system 1
10:30 - 10:50	Coffee break
10:50 - 12:20	**Riwal Plougonven** Forecasting for the energy system 1
12:20 - 14:00	Lunch
14:00 - 15:30	**Riwal Plougonven** Forecasting for the energy system 2
15:30 - 15:50	Coffee break
15:50 - 17:20	**Laurent Dubus, Bastien Cozian, Corentin Herbert, and Amaury Lancelin** Extremes and the energy system 2
17:20 - 18:00	Presentations by groups of their joint discussion

Thursday October 3rd, 2024	**Workshop (live on Youtube)**
09:00 - 10:30	**Daniel Crow (IEA)** IEA Modelling and Scenarios
10:30 - 11:00	Coffee break
11:00 - 11:45	**Frédéric Wurz (Grenoble INP)** From an Observatory approach to modeling and optimization paradigms for a socio-technical approach for the Energy Transition
11:45 - 12:30	**Olivier David Zerbib (ENSAE)** Can Investors Curb Greenwashing?
12:30 - 14:00	Lunch
14:00 - 14:45	**Sylvain Cros (LMD)** Intraday solar power forecasting: methods and applications
14:45 - 15:30	**George Kariniotakis (Mines Paris)** Renewable energy forecasting: State of the art and latest tendencies of research
15:30 - 16:00	Coffee break
16:00 - 16:45	**Marc Bocquet (ENPC)** Artificial intelligence, data assimilation and data-driven surrogate models for the climate

Friday October 4, 2024	**Workshop (live on Youtube)**
09:00 - 09:45	**Philippe Quirion (CIRED)** Eoles, an open-source model for studying the electricity balance of low-carbon scenarios - An application to the negaWatt scenario
09:45 - 10:15	**Alicia Bassière (CentraleSupelec)** A mean-field game model of electricity market dynamics
10:15 - 10:45	Coffee break
10:45 - 11:30	**Benteng Zou (University of Luxembourg)** Strategic Considerations of Critical Mineral Depletion, Recycling, and Substitution
11:30 - 12:15	**Anna Creti (Université Paris-Dauphine)** The new emission trading system (ETS2) in the European policy mix
12:15 - 14:00	Lunch
14:00 - 14:45	**Freddy Bouchet (LMD/PSL/CNRS)** Observational constraints on extremes for estimating the warmest events by the end of the century
14:45 - 15:00	**Greta Cazzaniga (LSCE)** Presentation of the PowDev project
15:00 - 15:30	Coffee break

15:30-16:15 **Olivier Vidal (UGA)**

The energy-mineral resources nexus in a changing world

Workshop - List of Abstracts

Daniel Crow : IEA Modelling and Scenarios

I will discuss the International Energy Agency's Global Energy and Climate Model and the IEA's approach to energy scenario modelling in the annual World Energy Outlook publication

Frédéric Wurz: From an Observatory approach to modeling and optimization paradigms for a socio-technical approach for the Energy Transition

In the context of the current climate and environmental crisis, energy production, distribution and consumption activities have a major impact. Thus the international energy agency attributes more than 70% of carbon impacts on a global scale to them, and all institutional actors (ADEME, AIE, RTE, etc.), as well as the IPCC, agree on the need to mobilize, in addition to technological levers such as decarbonization and technical efficiency, socio-technical levers such as energy sufficiency or flexibility of energy consumption. In this context we propose a talk with the following outline:
- A reminder of this climatic, environmental and energy context
- A definition of the notions of energy sufficiency and flexibilities in their social and technological dimensions and the way in which the importance of these levers was revealed and imposed during the 2022 and 2023 energy crisis, notably with the risk criticism of load shedding or even blackout
- How these socio-technical issues call for the definition of an inter-disciplinary modeling and optimization approach at the interfaces of human sciences, economics, environmental sciences, systems sciences and energy technology. We will try to characterize this science by detailing:
o The deployment of new concepts that it mobilizes:
Firstly for the definition and assembly of socio-technical energy systems and their characterization through new experimental devices and protocols, mobilizing the concepts of Living-Lab, and field studies thanks to an “observatory approach”: these allow to collect data and information about the nature of technical systems, but also elements relating to the acting between stakeholders or the potential for energy sufficiency or flexibility at the interface of technical issues and practices, behaviors and uses, all of which is carried out by participatory and inclusive science
Then the modeling paradigms mobilized which will range from dynamic simulation, optimization, agent modeling or even energy transition stories and scenarios

The points covered will give an overview of scientific and operational approaches to make the connection between macroscopic data and scenarios and observations, levers or obstacles from individual and local scales to collective and more global scales for studying energy transition.

Olivier David Zerbib : Can Investors Curb Greenwashing?

We show how investors with pro-environmental preferences and who penalize revelations of past environmental controversies impact corporate greenwashing practices. Through a dynamic equilibrium model with information asymmetry, we characterize firms' optimal environmental

communication, emissions reduction, and greenwashing policies, and we explain the forces driving them. Notably, under a condition that we explicitly characterize, companies greenwash to inflate their environmental score above their fundamental environmental value, with an effort and impact increasing with investors' pro-environmental preferences. However, investment decisions that penalize greenwashing, policies increasing transparency, and environment-related technological innovation contribute to mitigating corporate greenwashing. We provide empirical support for our results.

Sylvain Cros: Intraday solar power forecasting: methods and applications

Due to the Earth's rotation and cloud passage, photovoltaic (PV) power generation is inherently variable and stochastic, limiting its predictability. Grid operators typically curtail PV power when it exceeds grid demand, resulting in energy losses. Maintaining grid stability requires instantaneous balance between electricity consumption and production, posing significant challenges for PV integration. Solar power forecasting plays a crucial role in optimizing PV grid integration by enabling strategies such as energy compensation, storage sizing, demand-side management, and electricity trading. However, for intraday time horizons, accurate solar irradiance forecasting remains a complex task due to the challenges of modeling cloud dynamics and life cycles in traditional meteorological models. In recent years, alternative techniques leveraging geostationary satellite and all-sky camera observations have shown promise in providing more accurate intraday forecast, addressing the needs of emerging grid configurations, including microgrids self consumption optimisation, and aggregator portfolios valorisation for intradays markets.

Georges Kariniotakis: Renewable energy forecasting: State of the art and latest tendencies of research

In the context of the energy transition, electricity grids are integrating massive amounts of weather-dependent renewable generation (mainly wind and solar), the volatility and uncertainty of which bring unprecedented challenges to the grid operation. Short-term forecasts of renewable (RES) production at horizons ranging from a few minutes to a few days ahead, are widely used by the involved actors (grid operators, aggregators, traders…) to make decisions regarding the safe and economic operation of the electricity grid. Research and development in RES forecasting dates back to the '80s and has evolved into a very active area of research today. The aim is always to improve accuracy and better estimate uncertainties, as large errors can have considerable technical and financial consequences. Operational forecasting systems have been in use since the early '90s. By that time, AI came on board in the field of renewable energies, with neural network models applied for the first time to wind power forecasting. 30 years later, AI-based approaches are widely used in energy forecasting. In this talk we will present the state of the art in RES forecasting, highlight the main contributions in the literature and how forecasts are used in applications. We will present some disruptive approaches developed in the frame of the H2020 EU project Smart4RES for forecasting and optimal use of forecasts for power systems management and energy trading. These include AI-based approaches that enhance energy forecasting with properties beyond classical accuracy, such as resilience, simplicity, interpretability and value maximization. Finally, we will present advances on joint forecasting and optimization (prescriptive analytics) that permit to simplify model chains, collaborative forecasting supported by privacy-preserving data sharing.

Marc Bocquet: Artificial intelligence, data assimilation and data-driven surrogate models for the climate

Artificial intelligence, and particularly deep learning, revolutionised numerical weather prediction (NWP) in 2023. Several teams from giant tech companies have proposed surrogate models for high-resolution global atmospheric dynamics. These models achieve the performance levels of the deterministic IFS of the European Centre for Medium-Range Weather Forecasts, as well as its ensemble prediction variant. In this presentation, I will discuss the techniques used to construct these models, their scope and limitations, and illustrate the concepts with our own models and results, in NWP and sea-ice models for climate. I will also discuss the integration of such surrogate models with data assimilation for the improvement of NWP, as well as some more fundamental issues related to the end-to-end approaches to data assimilation.

Philippe Quirion : Eoles, an open-source model for studying the electricity balance of low-carbon scenarios - An application to the negaWatt scenario

We present the latest version of the energy system optimisation model Eoles and utilise it to study whether the energy mix of the négaWatt 2022 scenario manages to meet demand for 2050 in France, for 19 meteorological years. We find that even without recourse to interconnections, electricity demand only exceeds production for 3 to 4 hours a year on average, which does not exceed the fault criteria set out in the French Energy Code. To eliminate any hour of failure, an additional 13.2~GW of dispatchable technologies is required, which corresponds to a 37\% increase compared to the négaWatt scenario. We then study the addition of three disptachable technologies: methane turbines, hydrogen turbines and batteries, that are all close in terms of total system cost. In addition, electricity balance can be achieved even if the photovoltaic capacity is reduced compared with the negaWatt scenario. The associated gain (€5.5~bn./year) is significantly higher than the additional cost of the dispatchable capacity mentioned above (around €1~bn./year).

Alicia Bassière : A mean-field game model of electricity market dynamics

The global electricity sector's environmental transition has led to significant growth in wind and solar capacity and a decline in coal-based generation. However, this shift has also caused lower baseload electricity prices, impacting the profitability of conventional producers, and increased peakload price volatility, making the system more reliant on natural gas. This paper proposes a long-term model using a mean-field game (MFG) approach to describe the electricity industry's dynamics, focusing on gas as a substitute for coal. This paper extends the recent contribution [Aïd, Dumitrescu, and Tankov, 2021] in several ways, making the model much more realistic, especially for describing the medium-term impacts of energy transition on electricity markets. We also present a central planner counterpart using mean-field control (MFC) and demonstrate their equivalence. A case study calibrated on German data examines the impact of environmental policies.

Our results show that without policies, gas power plants meet rising demand, leading to higher gas and electricity prices. A carbon tax eliminates coal plants by 2030 and encourages renewables, though it raises long-term electricity prices. Renewable subsidies promote wind power initially but are less effective beyond a certain threshold.

Benteng Zou : Strategic Considerations of Critical Mineral Depletion, Recycling, and Substitution

Moving towards cleaner technologies to combat resource depletion and environmental issues, understanding the supply and recycling of critical minerals, and their substitution are essential. The uneven distribution of these minerals creates major challenges, including dependency on certain sources and the risk of running out. This study looks into how these minerals are used andrecycled, furthermore, when their substitution should be introduced. We focus on the strategic decisions made by countries that export these resources and those that import them.
We explore several key points: (1) Resource Options: Our findings show that markets can rely on new (virgin) minerals, recycled materials, or a mix of both to meet demand. Especially, the virgin resource and its substitutions may co-exist for a long time. (2) Exporting Strategies: When extracting new minerals becomes too costly, exporters might stop supplying them and rely entirely on recycling, especially as recycled materials become scarce. (3) Substitution: Surprisingly, the moment when the substitution should start to supply the market and the optimal supply are clear; while that is not the case of recycling who crucially depends on the virgin supply.
This research sheds light on the complex dynamics of mineral supply, recycling, and substitution, offering insights that can guide policy discussions on sustainable resource management.

Anna Creti : Optimal dispatching: how to account for renewable integration and carbon pricing.

Optimal dispatching and merit order pricing with variable load will be explained in a normative perspective (first best and it's implementation). The joint effect of renewables and carbon pricing as different drivers that may change generation costs and thus optimal dispatching will be added to the analytical model and illustrated by several examples.

Yoann Robin : Observational constraints on extremes for estimating the warmest events by the end of the century

Olivier Vidal : The energy-mineral resources nexus in a changing world

Achieving global carbon neutrality requires the construction of new infrastructures for the production, storage, transport and use of energy. These new infrastructures consume large quantities of base and rare metals, the availability of which is a cause for concern. In addition, the production of raw materials requires large quantities of energy. Raw materials and energy issues are therefore

inextricably linked, and need to be addressed within a common framework. This framework should also address the demand for raw materials associated with growing global demand due to the rapid emergence of developing countries, increasing urbanization and the development of high technologies.
We will present and discuss the results of a dynamic model (DyMEMDS) linking expected metal demand for different GDP, population and energy scenarios with production capacity constrained by geological and technological parameters. The modeling results provide a better understanding of the coupling between reserves - mineral resource production - cost and price - energy and greenhouse gas emissions.

Greta Cazzaniga : Presentation of the PowDev project

PowDev is a France 2030 PEPR project aiming at the evaluation and optimization of electrical systems resilience amidst the massive integration of renewable energy sources (RES). This will involve developing a comprehensive set of decision-support tools that consider the effects of extreme weather events, the intrinsic complexity of the power grid, and different socio-economic scenarios. A key aspect of this project is to simulate and analyze blackout scenarios under the influence of RES and climate change projections. The objective is to better understand how complex chains of events unfold, and how different RES configurations can either mitigate or exacerbate the risk of blackouts. Another crucial part of the project is to establish a quantitative framework for optimizing resilience, which remains a loosely defined concept in the power systems field. By studying different phases of resilience—ranging from preparation to recovery—the project aims to propose remedial solutions both for system operation and design. This will include strategies for grid architecture, redundancy, backup supplies, and the use of flexible resources like energy storage. Ultimately, the project will provide tools and methodologies to support decision-making processes, enabling power systems to adapt and recover quickly from disruptions, ensuring reliability and stability despite the growing integration of renewable energy sources.