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R&D WHITE PAPER

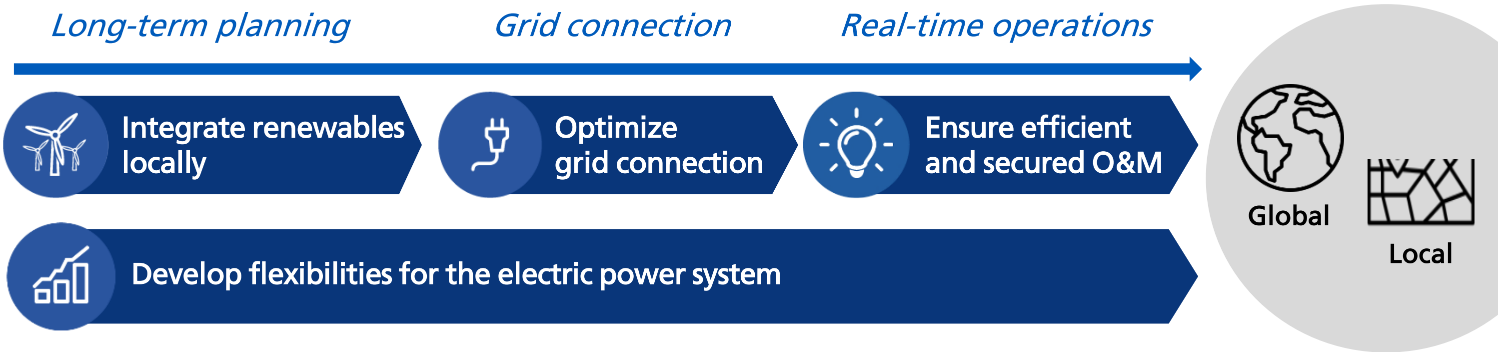
Integrating Renewable Energies
Challenges and Solutions

This White Paper published by **EDF R&D**, the Research and Development division of French utility EDF (Electricité de France), presents key **challenges induced by the development of renewable energy sources** and related **innovative solutions.**

Mainly aimed at **electric utilities across the world, grid operators, renewables producers, along with international financing institutions, industrials and public agencies** involved in the energy sector, this White Paper is designed to **share EDF R&D insights, experience and expertise** on this matter.

This document introduces four main challenges facing the industry integrating renewables into electric power systems, illustrated by recent EDF R&D works, solutions and references.

Four main challenges, at global and local scales



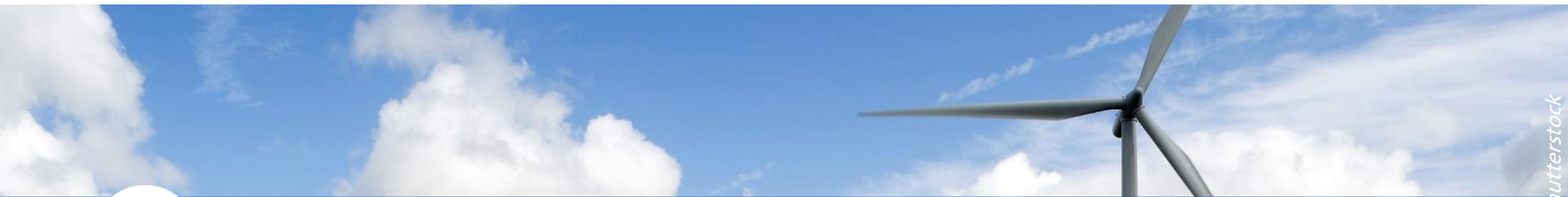
In a context of "energy transition" and decarbonation of the world economy, the development of intermittent **renewable energy sources** (RES), mainly wind and solar, induces **major challenges for utilities, grid operators and renewables producers.**

Renewable generation sources have different technical characteristics compared to centralized and conventional power plants (intermittency, size, location, interconnection…). Their increased penetration into power systems reinforces the need for new and efficient investments in grids and flexible solutions, along with increased supervision and control, enhanced renewables forecasting and ways to optimize generation fleets. These growing needs are indeed aligned with **ambitious objectives to increase the share of renewables in energy mixes all over the world.**

In parallel, **strong technological innovation brings new solutions** along to facilitate the integration of RES in electric power systems, while optimizing investments and ensuring reliable and secure power supply. Those solutions have been developed and tested by EDF through several demonstrators and operational projects.

EDF R&D believes that **sharing best practices and solutions becomes a key objective to foster renewables integration** in electric power systems (large and interconnected ones, or smaller systems like islands or microgrids). This White Paper intends then to contribute to a widespread knowledge in this key domain.

> *In a general way to address these challenges, a performing **utility should be able to operate in continuity over all timeframes,** from long-term planning to real-time operations. This broad coverage allows optimization of investments and anticipation of potential impacts on networks, generation and flexible assets. In the end, this comprehensive approach to challenges and solutions at various time scales and locations drives benefits to stakeholders and creation of social surplus.*



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Integrate Renewables Locally

#1

The main challenge is to **ensure the development of renewable resources**, at national, regional and local levels, contributing to a low-carbon society. Using modelling and forecasting tools, the objectives can be to **identify network investments** to ensure sufficient **hosting capacity** to connect renewables in a given region, to estimate the **RES potential** of an area for projected renewables development scenarios, or to assess **multi-energy approaches** aiming to meet decarbonation objectives set by public authorities.

Existing solutions

The development of RES is carried out within political frameworks and societal expectations towards energy transition, which can be achieved at global (supranational or national) and local levels. In order to plan transmission and/or distribution grids, utilities can elaborate energy **master plans**, relying on generation, T&D grids, and consumption data, using grid planning tools. Those take into account technical rules related for instance to grid voltage, capacity sizing of power grid components and power system security.

Additional tools and methods can be used by utilities to **estimate the RES potential of a given area over the next 5 to 20 years**, based on data cross-analysis (meteorological, land spaces, power and energy by type of generation, grid aspects…).

Once RES potential is estimated, it becomes possible to project the long-term evolution of the energy mix, by **comparing multi-energy solutions** (electrical, thermal…) **to decarbonize a given area (region, city…)**. Leveraging performance of new simulation tools, outputs and KPIs like energy consumption, CO_2 emissions, share of RES and associated investments can be estimated for several scenarios.

Such tools and methodologies can help regions, cities or islanded power systems define energy transition strategies meeting their overall decarbonation objectives.

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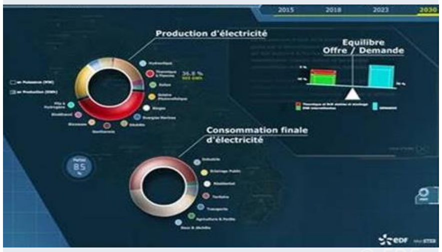
The above analysis helps utilities and grid operators assessing grid hosting capacity (capacity of the grid to accommodate RES at a given location, without assets upgrades or impact on power quality) and find grid nodes most adapted to host RES.

Regional energy studies
EDF R&D recently carried out a comprehensive study performed for a French region assessing the **decarbonation potential in transportation and energy sectors** by 2035 (renewables, electric mobility, electrification of economic sectors…).



EDF R&D energy mix /
RES potential assessment tool

Estimation of the RES potential in Mongolia and its integration in regional markets.

An EDF Grid Engineering entity and R&D study financed by the Asian Development Bank showed strong solar and wind potential in Mongolia and assessed several possibilities to export electricity to neighboring countries through transmission grids.

Optimize Grid Connection

#2

The challenge is to **optimize costs and time** required for connecting new RES to the grid, therefore facilitating their integration in the most efficient and cost-effective way, while meeting power system security requirements. Utilities and grid operators need to be prepared to a significant and growing increase of grid connection requests. To do so, **new technical and contractual solutions** have emerged, aiming to ensure high reliability and security of power systems integrating large shares of renewables.

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Existing solutions

These new solutions consist in making the best use of existing networks by increasing their hosting capacity, while preventing network constraints induced by new RES connections. Indeed, those shall comply with existing requirements and rules related to grid connection (grid codes).

More precisely, the objective of these solutions could be to modulate the network voltage at the renewables grid connection points, or even their power injection under specific conditions. These solutions can limit connection costs for grid users while ensuring safe network operations.

Regarding voltage management, several options allowing cost effective and faster connections have been experimented (local or centralized voltage management).

Depending on the regulation, another possible solution may consist in **temporarily modulating the active power** of a renewable installation to prevent network constraints, in exchange for reduced grid connection costs. Such solution allows renewables to be connected to existing grid feeders, thus avoiding reinforcement investments for RES producers. Renewables integration also depends on existing grid codes, defining main technical prescriptions for connection and operations of new installations (frequency and voltage controls, fault ride-through capabilities, anti-islanding protections…).

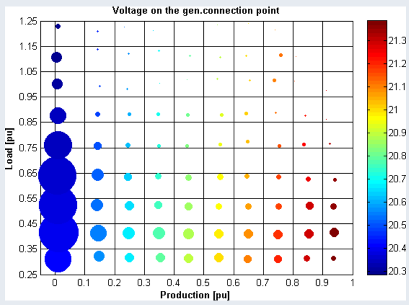
Indeed, RES integration may also impact electric grid stability and security, requiring specific studies to ensure stability and safety conditions under high RES shares, also assessing power system behavior in case of large voltage or frequency deviations.

All of these solutions rely on **innovative modeling and forecasting tools**. Indeed, those are required to statistically estimate the potential impacts of new connections on the grid, assess needs for investments and network upgrades, and help determine the best connection solutions (including use of new technical and contract-based solutions detailed above).

Before and until real-time operations, additional tools are necessary to simulate the state of the network and ensure smooth network operations. Those may include **operational planning tools** or **digital DER interfaces**, to exchange information with generation installations.

EDF has developed innovative solutions within "Smart Grid Vendée" and "VENTEEA" demonstrators supported by ADEME. Combined with operational planning tools, these solutions facilitate RES interconnection and integration (local or centralized voltage management, non-firm / "smart" grid connection offers, battery storage with multi-actor/multi-service approach…).

Non-firm / "smart" grid connection offers: process relying on innovative algorithms and sets of simulations using probabilistic approaches (generation / consumption scenario over 30 years, generation / consumption forecasts) and real-time tools (operational planning / optimal power flow, digital DER interfaces).



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Ensure Efficient and Secured O&M

#3 The challenge is to ensure the **efficiency of grid operations & maintenance processes** in a context of significant RES penetration. It includes the effective operation of protection systems, secured and reliable real-time communications between renewables installations and control centers, performance monitoring, as well as collection and analysis of associated data.

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Existing solutions

Two major types of solutions benefiting from **digital innovations** can be considered:

- **Telecom, software and hardware equipment / infrastructures**, to ensure bidirectional communications with RES with the highest reliability and quality of service,
- **Storage and analysis of the exchanged data** through the creation of a **data lake**.

Among the solutions to ensure communication with RES installations, **digital DER interface** can be deployed to exchange information (grid measurements, maintenance data…) and to send real-time orders such as emergency curtailment or flexibility activation. HV and MV substations may also be equipped with "**smart Remote Terminal Units (RTU)**" to collect more data with a higher level of accuracy, combined with secured, resilient, and cost-efficient **telecom network and equipment**.

With an increasingly growing number of connected devices and equipment, and the exponential volume / number of data being generated, the need for strengthening cybersecurity becomes crucial.

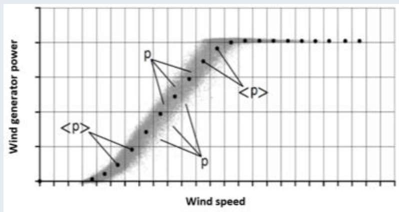
To reinforce the protection and surveillance of both telecom networks and assets and mitigate possible failures or attacks, **solutions based on hardware components, software applications, and standardized protocols** can be deployed on legacy or new infrastructures.

These solutions pave the way for a stronger cooperation between renewable producers and electric utilities and grid operators. Use cases include optimized works placement to maximize renewable generation (widening technical availability). The creation of a **data lake**, combined with IoT, data analytics, or artificial intelligence, can facilitate RES operations and maintenance, with use cases such as performance assessment, predictive maintenance, generation optimization, or down time reduction.

To ensure secure and evolving data exchanges, the application of **communication standards** is becoming crucial. Standards help ensure interoperability and homogenize data exchanges in increasingly digital grids. One of the most relevant standard for smart grid and RES integration is IEC 61850, on which EDF is now building up most of its smart grid architectures and solutions.

Data analysis and structuration for assisting the energy transition and digital transformation (types of data to collect, associated structure, monitoring solutions…).

Processing RES operational data



Generic Systems solutions is a set of software and protocol solutions (Device Management System, Device Configuration System, smart RTU, SCADA…) allowing renewables assets supervision and maintenance, system administration, system configuration…

'Cybersecurity box' designed and developed by EDF R&D for RTU and DER

© EDF – Alexandre Michon

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Develop Flexibilities for the Electric Power System

#4

The challenge is to **contribute to the development of "flexibilities"**, which can be defined as abilities to adapt the electric power system to generation and consumption variations at different timeframes. The objective is to **accommodate large shares of renewable energies in power systems** integrating conventional generation, while ensuring a high level of **power system** security and **creating value** for all its stakeholders.

Existing solutions

In the context of RES development, various utilities are moving beyond the traditional role of 'assets manager', to embrace a 'system operator' role. This implies not only managing power grids, but also leveraging new types of generation, loads and flexibilities connected to the network, in close cooperation with related stakeholders.

Depending on market designs, several types of flexibilities could be implemented and contracted at different timeframes, from network planning phase to real-time operations.

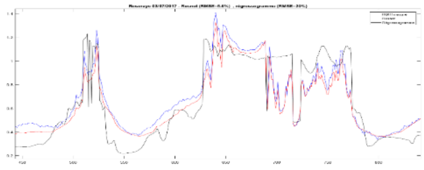
Flexibilities contracted during the grid connection phase consist in connecting a grid user with limited reinforcement costs, in exchange for an ability to modulate its active power upon network constraints. **Flexibilities** may also be **contracted during network planning phases** through a tendering process or an over-the-counter contract, in order to optimize grid investments. Those would typically be activated in near real-time to prevent grid constraints of various natures.

Another type of **flexibilities** is related to **real-time operations**, with an activation following a constraint detection or an outage to facilitate service restoration.

The use of RES flexibility can also constitute an opportunity for strengthening power systems resiliency, especially in islanded systems (or in local systems like remote microgrids). It can be particularly relevant when combined with **energy storage** (centralized or decentralized) to compensate for a sudden drop in solar or wind generation in real-time. **Smart charging of electric vehicles** (specifically if aggregated) will provide additional flexibility allowing to alleviate constraints while making better use of renewable generation.

EDF R&D recommends holistic approaches towards power system flexibility assessing flexibility requirements for several renewables scenarios, figuring out best combinations of solutions including energy storage and demand-response. This approach was developed in the recent EDF R&D study "Technical and economic analysis of the European electricity system with 60% renewables". [Web Link]

Renewables forecasting, is progressing thanks to innovation in weather forecasting and data at several time horizons and scales (from global to very local). Advances in modelling, data handling, analysis and fast computing also drive faster and accurate forecasts integrated in electric power system operations (optimization, risks mitigation)



EU-SysFlex project, supported by the European Union Horizon 2020 research and innovation program. New types of services will meet the needs of power systems with more than 50% of renewable energy resources.

Field testing within a French demonstrator coordinated by EDF R&D and focusing on a **multi-services & multi-resources approach** (from operational planning scheduler to local real-time control of storage, PV and wind farms).

EU-SysFlex

EDF R&D offers a **wide range of services and training courses** for international partners and clients, professionals or scientists.

Several areas of research are open to customers willing to **benefit from EDF R&D studies, expertise or lab testing.** EDF R&D services span across three major domains: **Smart Home, Smart City & Smart Business, and Low Carbon Generation.**

The **Institute for Technology Transfer (ITech)** is a training organization led by EDF R&D to share practices, expertise, and innovations based on EDF Research and Development activities.

Various training courses on renewable energies are available: grid integration, power system flexibility, smart grid solutions, solar / wind / marine technologies, control and communication technologies...).
Training is provided by EDF R&D leading experts in these key domains, in English or French.

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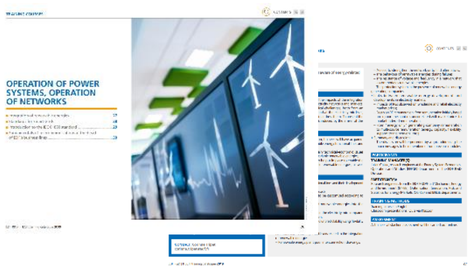

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EDF R&D carries out **research for all EDF Group entities**, helping them improve performance and prepare the future integrating innovative technologies and solutions.

EDF R&D has **three Labs in France and six abroad** (China, Germany, Italy, Singapore, UK, USA) and an office in Brussels.

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2. **STRENGTHENING THE PERFORMANCE OF GENERATION ASSETS**
3. **INVENTING TOMORROW'S ENERGY SYSTEMS**
4. **ACCELERATING DIGITAL TRANSFORMATION**

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