Next-Generation Modelling and Forecasting of Variable Renewable Generation for Large-scale Integration in Energy Systems and Markets

Data science for renewable energy prediction

Smart4RES

Smart4RES in brief

The **Smart4RES** project aims to bring **substantial performance improvements to the whole model and value chain** in **renewable energy (RES) forecasting**, with particular emphasis placed on optimizing **synergies with storage** and to **support power system operation** and **participation in electricity markets**. For that, it concentrates on a number of **disruptive proposals** to support ambitious objectives for the future of renewable energy forecasting. This is thought in a context of steady increase in the quantity of data being collected and computational capabilities. This comes in combination with recent advances in meteorological forecasting and data science.

Smart4RES concentrates on novel developments towards very high-resolution and dedicated weather forecasting solutions. It makes optimal use of varied and distributed sources of data e.g. remote sensing (sky imagers, satellites, etc), irradiance and meteorological measurements, as well as high-resolution weather forecasts, to yield high-quality and seamless approaches to renewable energy forecasting. The project accommodates the fact that all these sources of data are distributed geographically and in terms of ownership, so far with stakeholders' reluctance limiting their sharing. Novel alternative approaches are to be developed and evaluated to reach optimal forecast accuracy in that context, including distributed and privacy-preserving learning and forecasting methods, as well as the advent of platform-enabled data-markets, with associated pricing strategies. Smart4RES places a strong emphasis on maximizing the value from the use of forecasts in applications through advanced decision making and optimization approaches. This also goes through approaches to streamline the definition of new forecasting products balancing the complexity of forecast information and the need of forecast users. Focus is on developing models for applications involving storage, the provision of ancillary services, as well as market participation.

The Smart4RES multidisciplinary team

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Vision

Smart4RES proposes a holistic approach that covers the whole model and value chain related to RES forecasting from weather forecasting to end-user applications. To this end, disruptive research ideas are explored to reach breakthrough rather than incremental improvements.

The **digitalisation of the energy sector** has led to the emergence of a **wealth of data**. Exploiting these data (in combination with current computational and data storage capabilities), through **new adapted modelling tools,** is the key to change the game in **RES forecasting** but also for the **decision-making tools** that use these forecasts in end-use applications.

The knowledge created will be the foundation for the **next generation of modelling and short-term forecasting tools of weather-dependent RES power production** and **related decision making**. The **expectations** from such next generation tools include:

- **Outstanding level of accuracy** to reduce the impacts of RES intermittency under large-scale integration in power systems and electricity markets.
- **Ability to maximise the value** that the tools bring to applications where RES forecasts are used as input and mitigate risks associated with residual uncertainty.
- Ability to exploit jointly existing and **new sources of data** (weather and RES power measurements, remote sensing, etc.) compared to current models, which have a high dependability on data sources.
- Coverage of all **weather-dependant renewable sources** with the highest expected market share in the next decades (e.g. wind power, photovoltaic (PV), solar thermal, run-of-the-river hydro, combinations).
- Ability to cover the full spectrum of **temporal scales**, i.e. very short term (minutes to next hours), short term (hourly to 2-3 days), longer term (up to 10 days and more), and **spatial scales**, i.e. RES plant level up to aggregations, regional or national.

The overarching goal of Smart4RES as a Research and Innovation Action as specified in the Call LC-SC3-ES-6-2019 is to **develop and validate the next generation tools** that jointly enable:

1) an **increase of 10 to 20% in RES forecasting** performance and,
2) enhanced value in applications thanks to a holistic approach that considers the whole model and value chain of RES electricity production forecasting.

This overarching goal is compliant with all of the above-mentioned expectations of a next generation tool in RES forecasting. It is accompanied by the ambition to have a major impact on the state of the art and to contribute to Europe's international leadership in the field. Europe is facing hard competition today in the renewable energy industry. However, by combining excellence, there is an opportunity to develop next-generation tools and make noteworthy progress in the field of services related to RES generation.

Research gaps addressed

Weather Prediction Models, RES forecasting models and decision making

The **model and value-chain** of RES forecasting is described in the diagram below. First, Numerical Weather Prediction (NWP) models operated by meteorological institutes and satellite- and sky imager-based methods, generate **forecasts of weather variables** (i.e. wind speed, solar irradiation, cloud coverage, etc.) for horizons up to 7 days ahead with updates every 6 hours, and spatial resolution down to 1 km with a temporal resolution of 1-3 hours. NWP models assimilate a wealth of directly measured or remotely sensed data. These forecasts together with measurements from RES plants are then used as input to dedicated **RES forecasting models** to predict the power output of these plants. If the horizon is very short (up to 6 hours), forecasts can be based only on on-site measurements, satellite and all sky imager data. Forecasts are delivered as a service or through on-site software at end-user premises. Weather and RES forecasts are then delivered to end-users though **services and data platforms**. End-users use them to make predictive decisions in various applications. This **decision-aid** step rely either on a human expert making a decision, or an automated software tool involving optimisation functions.

End-user applications

Examples of end-users can be TSOs, DSOs, microgrid operators, market operators, aggregators, RES operators, energy traders, smart-home/community energy managers. They use them to perform functions for the **predictive management of the grid and the RES plants** with applications like cross-border exchange, dynamic line or transformers rating, reserves estimation, congestion management, scheduling and dispatching, **market participation** e.g. of virtual power plants (VPPs), microgrid management, predictive maintenance of RES plants, operation of storage devices at different configurations (i.e. smart -homes, grid connected to provide flexibility, in hybrid plants combined with RES).

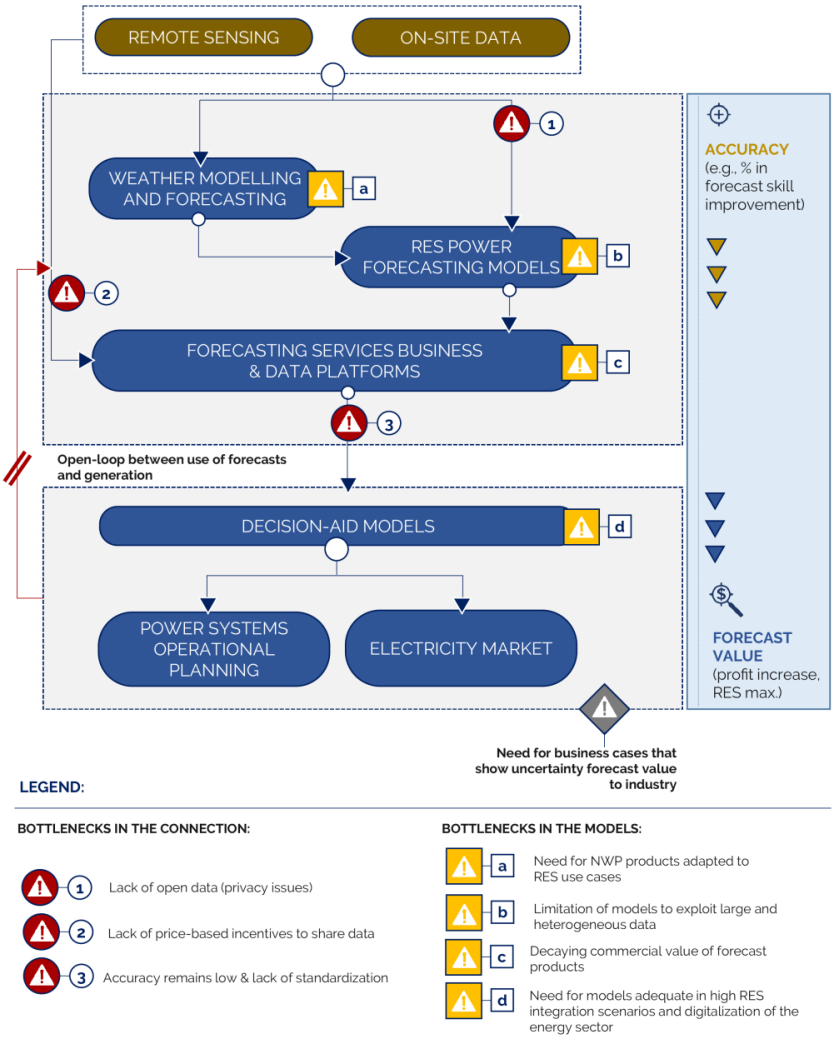

Diagram: Overview of the model and value chain of today's RES forecasting technology and related technology gaps.

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Research gaps addressed

This model and value chain present **several gaps and bottlenecks at different levels**, synthesised below.

Forecast accuracy, multiple data sources and models

First, the existing RES forecasting models present a **high dependability on the type of input data**. In the case of solar forecasting NWP data is usually complemented by satellite derived forecasts to improve the accuracy for the first 6 hours. Also all-sky imagers are generally used at multi-MW power plants to further improve the forecasts for the next minutes. This means that in order to cover multiple time horizons, several models are needed. Models able to exploit multiple sources of large amount of heterogeneous data including new types of data are currently lacking and needed.

Economic, contractual and technical feasibility of data sharing

Data are often constrained by **confidentiality or privacy issues**. Data owners should be provided solutions that incite them sharing data for the benefit of forecasting accuracy, while respecting these constraints. Shared data has to be distributed and made available for interested parties as easily as possible. For this purpose, adequate concepts and technical platforms are required. **Business models related to data exchange and usage must be rethought**, for instance based on scalable and dedicated platforms allowing for exchange at minimum cost.

Specificity of the RES forecast applications

Models for weather forecasting are oriented to cover all industrial applications (i.e. aviation, agriculture, flood prevention). Specific products issued from NWP models that are adapted to RES use cases are needed. Also it is necessary to increase the frequency of updates, while optimally using regularly collected data, and spatial and temporal resolutions to be more adapted to RES-related applications. Despite the fact that RES forecasts products are requested by numerous applications, there is a **lack of standardisation** of these products.

Decision-aid tools integrating uncertainties

At the end of the forecasting model chain, the **accuracy still remains at levels which are inadequate** for systems with high penetration resulting to over-dimensioning of costly remedies. When it comes to the applications, the **decision-aid models** that use RES forecasts as input in business practices **are mainly deterministic** even though the academic state of the art already proposes probabilistic approaches. For future energy systems with high penetration it is necessary to develop appropriate models able to account for the uncertainties and opportunities offered by the wealth of data provided by digitalised energy systems.

Capturing the full value of forecast services

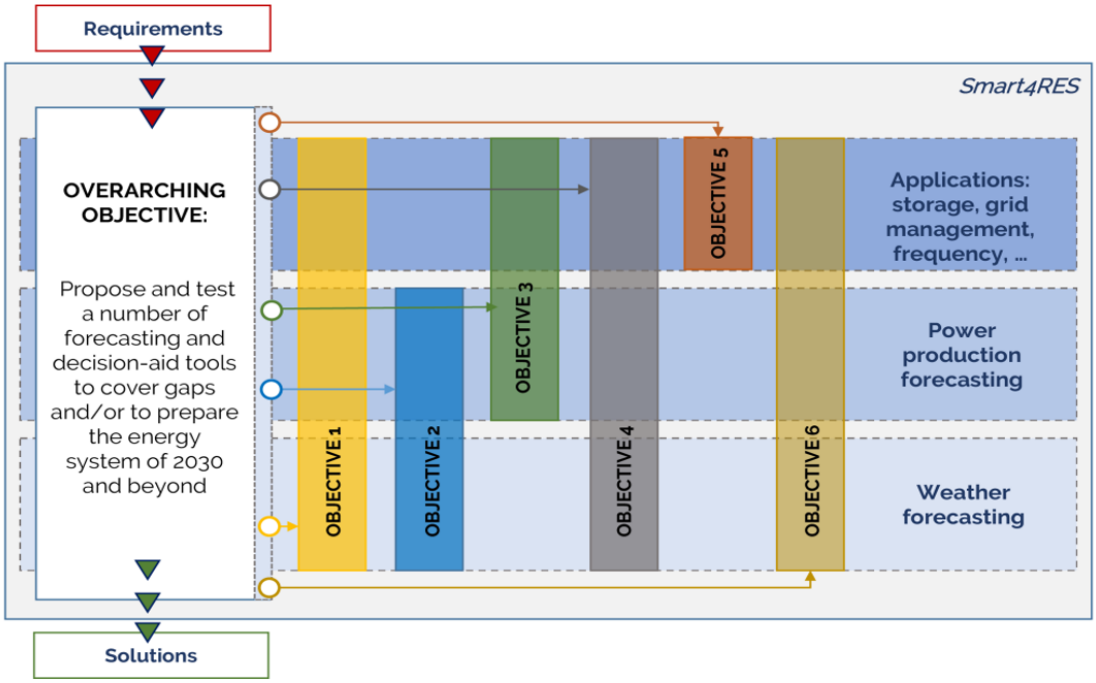
It is however needed to **develop business cases that show the value of probabilistic approaches** to the industry and lead to an easier adoption path of these approaches. Today there are **limited incentives to improve RES predictability** due to various reasons that can be existing overcapacity of conventional power plants, low RES penetration, RES plants still subject to feed-in tariffs. Although each RES plant is a source of data, even increasing in the future through the "digital twin" concept[1], there exists no incentive or business model permitting to fully extract the value from these data including for purposes like increasing RES predictability. Finally the **backward loop from application to forecasting is today open**. RES forecasting models are **optimised for their accuracy** (i.e. in terms of RMSE[2] or probabilistic scores). However, the optimisation could take more into account the way the forecasts are used in the application and the value they generate.

The next pages present the **high-level objectives** of the project that permit to address these gaps.

1 ETIP SNET, "*Digitalisation of the Electricity System and Customer Participation*", Technical Position Paper WG4, Sep. 2018. https://goo.gl/LGTr2C
2 RMSE: Root Mean Square Error

Research gaps addressed

The overarching goal of Smart4RES encompasses the research, development and validation of **a next generation of tools for modelling and forecasting energy production from variable renewables and decision aid for a number of use cases**. This goal is decomposed into **eight objectives** from which six technical (O1 to O6) objectives depicted below.



More specifically the 6 objectives splitting the Overarching Goal of the project are:

Objective 1: To define requirements for forecasting technologies to enable near 100% RES penetration by 2030 and beyond

Objective 2: To develop a RES-dedicated view of weather forecasting, leading to improvements in forecasting of the relevant weather variables in the order of 10-15% using various sources of data (satellite, all-sky imagers, NWPs), and the development of very high-resolution forecasting approaches

Objective 3: To develop a new generation of RES forecasting tools that are able to improve RES power production forecasting by at least 15%.

Objective 4: To streamline the process of getting optimal value from data and forecasts, through new forecasting products and data marketplaces, and novel business models.

Objective 5: To develop new data-driven optimisation and decision-aid tools for enabling the large-scale penetration of renewable energy, combined with storage, into the electricity market as well as to provide system services towards TSOs and DSOs.

Objective 6: Validation of new models in living labs and assessment of forecasting value vs remedies.

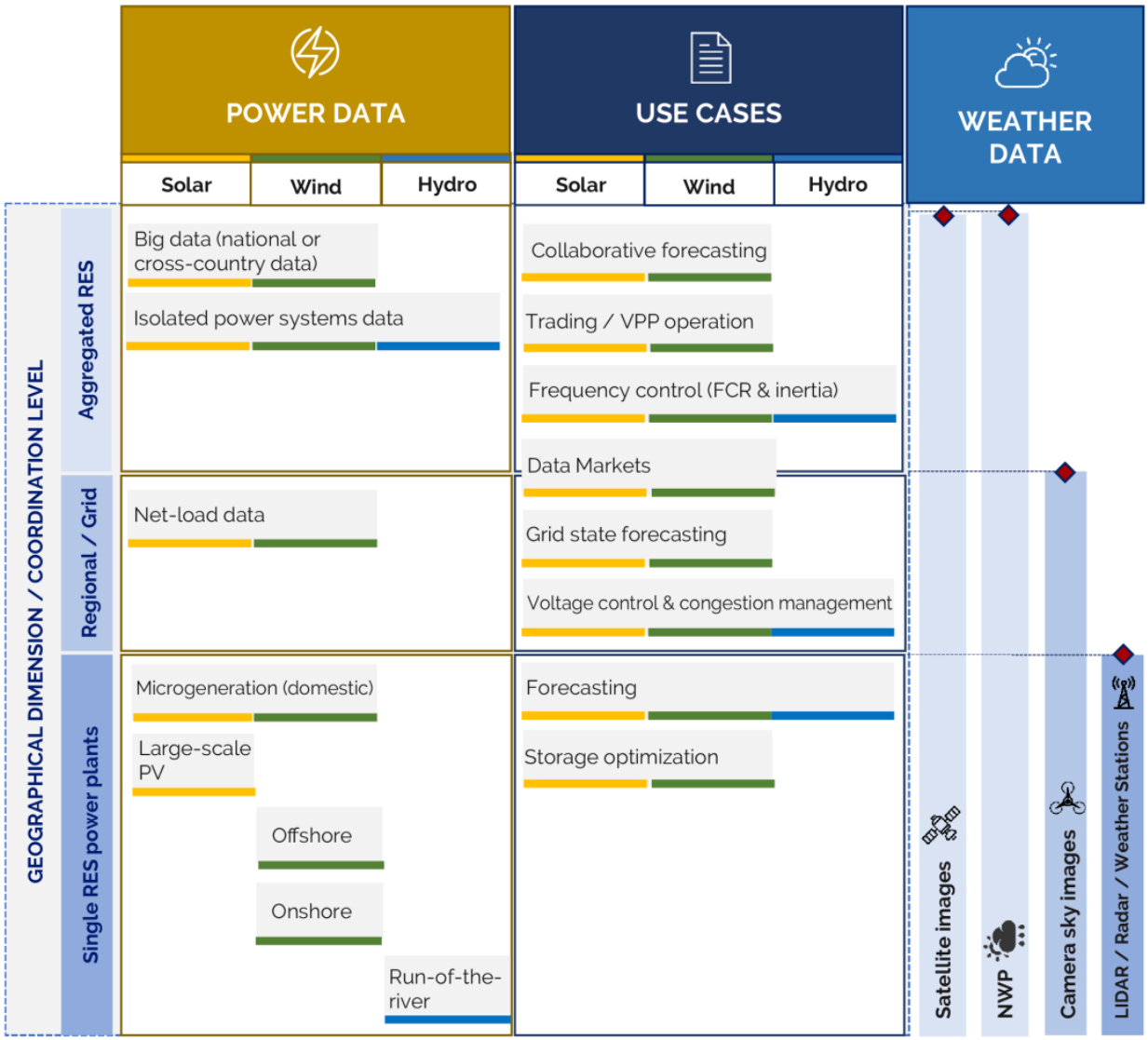
Concept and methodology

Smart4RES will develop and validate a set of tools for RES modelling & forecasting and decision-support by **integrating the perspective of end-users** through a number use cases. In this holistic approach, all the forecasting tools features are treated from the definition of RES forecasting requirements that correspond to configurations of various types of energy systems with high RES penetration, at different spatial scales (smart-home, microgrid, distribution grid, islands, regional/national level) and for various market designs. Despite the diversity of use cases, a key idea is to be as general as possible **to cover all configurations from the perspective of any Smart4RES user.**

Two families of use cases related to applications will be considered to define the requirements for the forecasting and decision-making tools that use these forecasts:

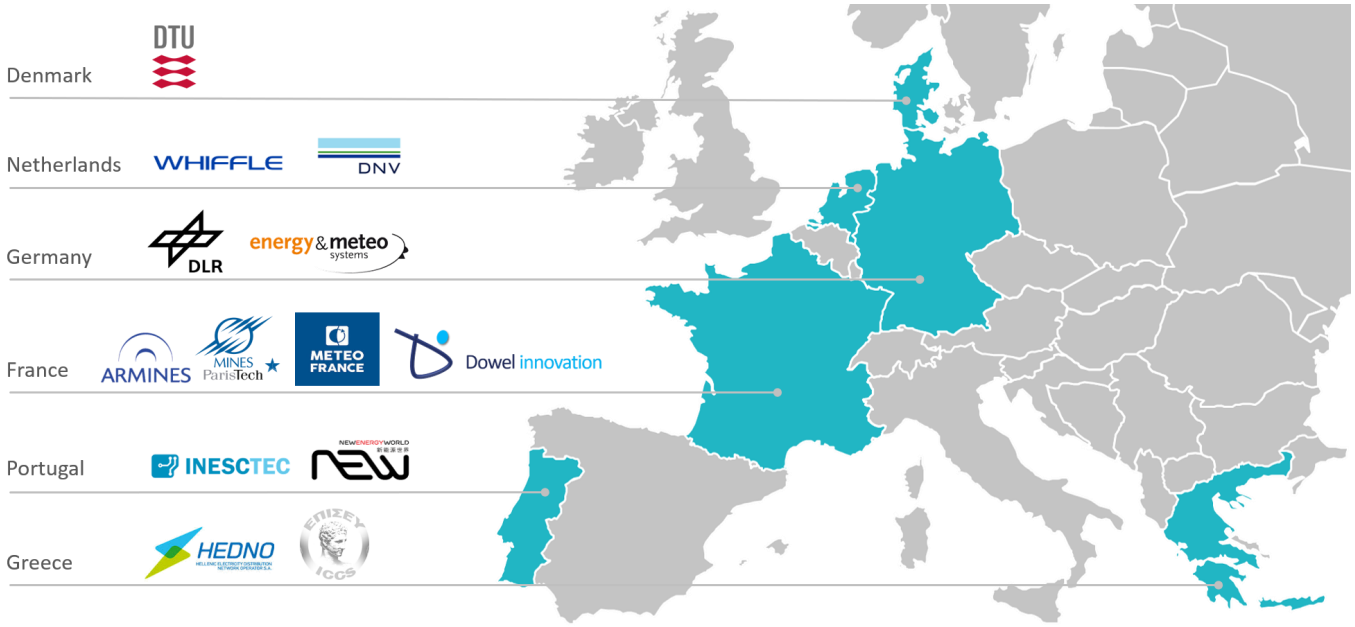
- Use cases related to the **predictive management of energy systems** with at near-100% RES integration.
- Use cases related to **electricity markets.**

The figure below shows a synthesis of use cases and geographical scales considered in the project.



Project partners

Led by ARMINES, Smart4RES gathers 12 partners from 6 European countries, with a recognised leadership along the modelling and forecasting ecosystem. The consortium is composed of 5 research centres, 4 private companies, the French national weather organization, 1 university and 1 DSO.



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