

How system operators can set up a roadmap to boost renewable hosting capacity with GETs



Summary

1. Artelys - General presentation
2. Introduction to GETs operation
 - a. Preventive planning
 - b. Real time operation
3. Roadmapping for better grid utilization with GETs
 - a. Methodology for road mapping (planning and benefits evaluation)
 - b. PowSyBl Metrix OPF Tool
4. Example of application (AST)
 - a. Hosting Capacity and benefits of GETs
 - b. Main recommendations



Artelys' presentation

Artelys in numbers

Artelys is an **independent company**, that has shown a **continuous growth** since its foundation in the year **2000**.

Today, the company **has offices all over the world**: France, Belgium, Canada, US, Italy and **Spain**.



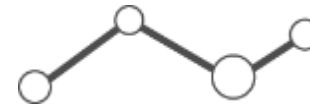
2000

CREATION Arnaud Renaud



15% per year

of sustained GROWTH



100 EXPERTS

Engineers PhDs



30% to 35%

of its activity dedicated to R&D



SOFTWARE DEVELOPMENT

Custom software, off-the-shelf software suites



SERVICES & CONSULTING

Optimization, Data science and business knowledge



STUDIES

Analysis and planning for an efficient Energy transition



Artelys, who are we?

We are a company specialized in **Artificial Intelligence, decision support and modeling**. Through a **high-level expertise in quantitative techniques**, our consultants design suitable solutions to the needs of our customers.



Recent clients in the energy sector

Public sector / NGOs



Infrastructure operators



Utilities

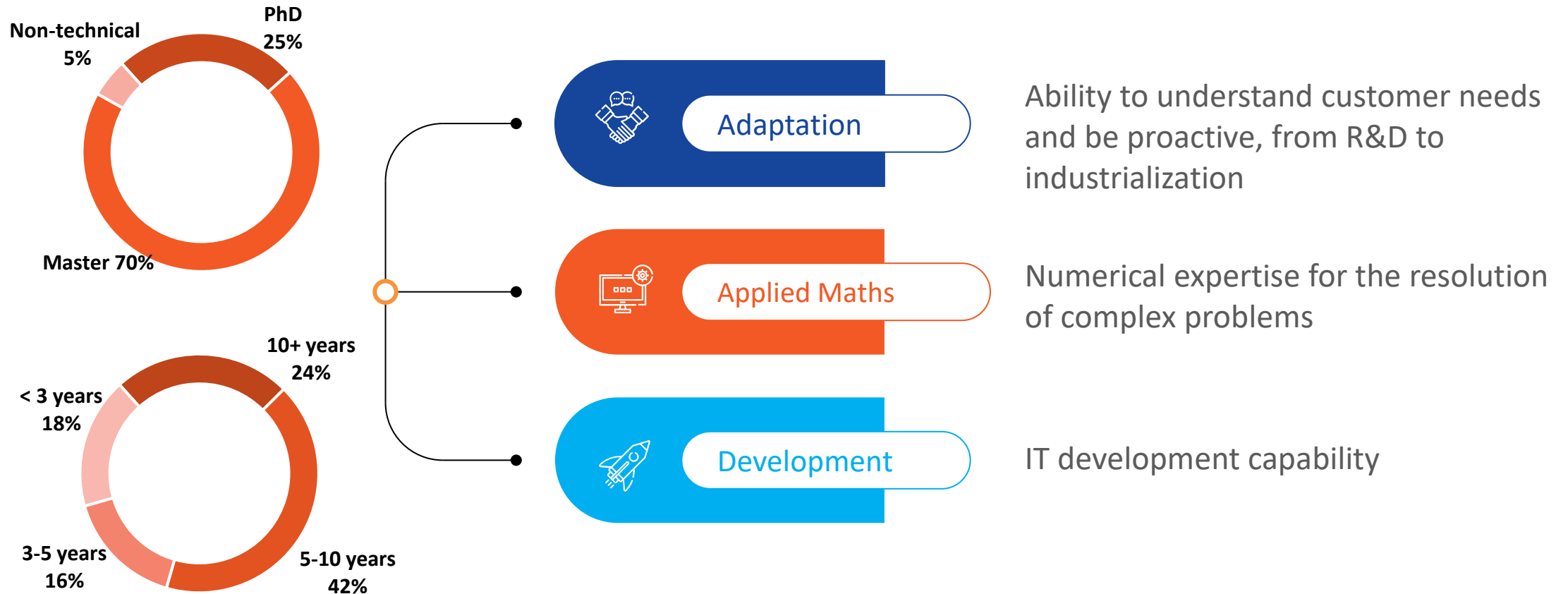


Markets



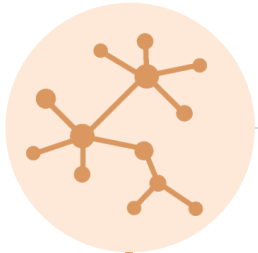
Technical expertise

Our **multidisciplinary teams** combine different knowledge angles and level of expertise around **operational research**, allowing us to provide a **very specialized practice around networks**



A set of skills in power systems domain

Expertise in network calculations



- Optimal distribution of flows (Optimal Power flows)
- With or without security constraints
- AC or DC
- Remedial Action Optimization



- Naza** - Support for the development of the zone automaton simulation platform
- Testing of optimization's algorithms to resolve congestions

A technological base available

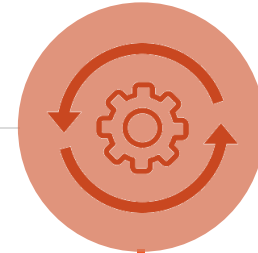


- Mastery of open-source tools
- PowSyBI (simulation load-flow)
- Metrix (Optimal Power Flow)
- Grid2Viz (Grids' visualization)
- Pypsa



- Development of a Reinforcement Learning analysis HMI
- Back End developments for the **imaGrid** project of the PowSyBI framework

Know-how in the development of operational tools



- Development and maintenance of high availability tools
- Automatic and secure data processing, imports/exports, performance guarantees



- CorNet** – computation engines for network simulation and analysis within CorNet's platform
- TSCNET** Services
- SWE** – specific features of CorNet platform for SWE region
- TERRE** – Market clearing module for reserve markets

An off-the-shelf tool for communication



- Educational communication solution on the themes of energy network management
- Internal or external communication
- Popularization of network issues



- Grid simulation tool for Tennet. **Simulator** accessible to the public



Introduction to GETs operation

The energy transition is stalling

1 Energy transition plans imply deploying a very large amount of renewable energy:

- Germany plans to install 55 GW of renewable before 2030 ([source](#)).
- U.S. interconnection queue, composed of generation projects waiting for approval to connect, has risen to 1350 GW in 2022 ([source](#)).



2 But the power grids are already heavily congested:

- German customers have spent EUR 4,25 billion on redispatching in 2022 ([source](#)).
- U.S. Customers are spending more than USD 6 billion per year on grid congestion charges ([source](#)).

3 And expanding the grid is a slow process

On average, 10 years to build a new line vs 5 years for grid connection ([source](#)).

⇒ Make the best of the existing grid to host more renewables:

- Curative curtailment (Post contingency)
- Dynamic Line Rating (DLR) or Ambient Adjusted Rating (AAR)
- Phase-Angle Regulator (PAR) / Phase-Shifting Transformer (PST)
- Topology optimization / Transmission switching
- Battery Energy Storage System (BESS)

No advanced technology completely replaces grid reinforcement. However, some technologies have a huge benefit to cost ratio.

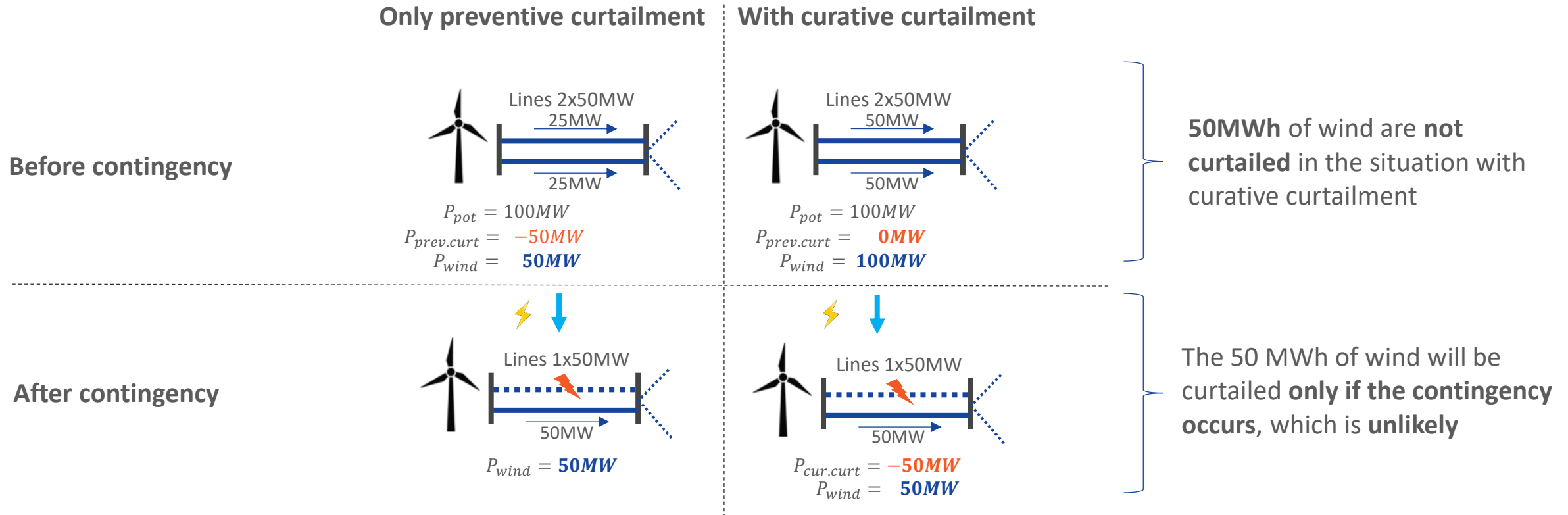
Preventive planning vs real-time operations

- These measures are usually implemented in the **Day Ahead Planification**.
- However, even more important gains could be expected from **the operations of GETs in real time**.

Day ahead planification	Real time operation
(-) The worst case is covered; therefore, the curtailment is too conservative most of the time.	(+) Less curtailment, lower costs (only happens if the contingency occurs, which is unlikely)
(-) The DLR process use the forecast, therefore is not use to its full potential	(+) DLR will use the actual data, reducing the need for margins.
	(+) Higher vRES capacity, without additional costs
(+) Easier to implement (already implemented in some planification processes)	(-) Complex to implement (need state estimation, automata, regulation, coordination)

→ As renewable forecasts improve closer to delivery time, vRES curtailment processes and/or topology optimization processes should aim to be implemented as close to real time as possible.

Preventive vs. curative curtailments in the operation of vRES



- Avoided hourly curtailment: ~ 50 MWh
- Huge gains in vRES hosting capacity and/or curtailment costs
- Limited reliance on grid reinforcements

NAZA project: real time curtailment automaton

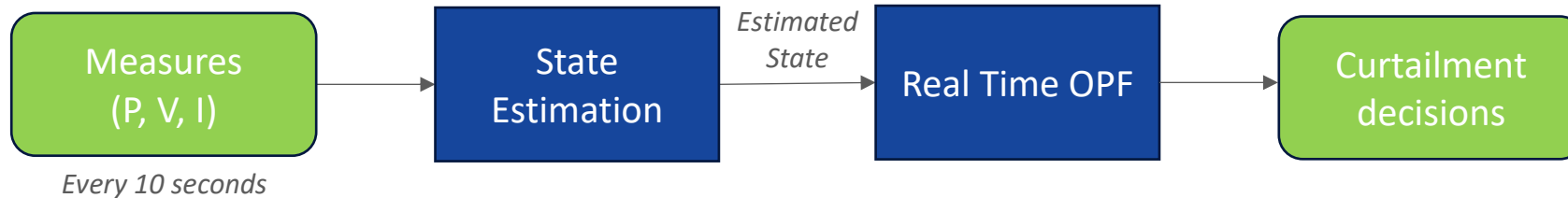
- The NAZA project (New Automata of Adaptative Zone) is a **numerical solution (100% software)**, developed by the French TSO RTE, in collaboration with French DSOs.
 - It is a **real time tool** that monitors the flows in the network and subsequently adjusts the production of electricity by RES units when the increase in production cannot be sustain by the network.
 - It avoids the curtailment of the RES units in the preventive timeframe (which often proves to be unnecessary as the contingencies rarely occurs).
 - As a result, it allows to increase the amount of RES in the system, while keeping the flexibility of the network, at low cost.
 - RTE estimates the investments avoided (avoided preventive curtailment + grid reinforcement) thanks to the automata to **700 M€/year over the next 10 years**.
- It is a **control tool to facilitate the management of RES** in the power system. The tool enables to **increase the RES penetration at lower costs**.

Real time digital twins

Optimal Power Flows (OPF) are the backbone of powerful tools for **optimizing the operation and planning** of electrical distribution grids, ensuring **efficiency**, **cost savings** and **grid reliability**. They can be used as **digital twins for real-time grid congestion management**.

Problem: A steady-state estimation of the network is needed to make real-time automated decisions.

Solution: Combining state-of-the-art optimization knowledge and power system expertise to connect a State Estimation to the OPF.



State Estimation provides **consistent** and **up-to-date information** on the state variables of a power system. This minimizes the difference between **actual measurements** obtained from sensors throughout the grid and their expected value given a linearized grid model. The OPF is a digital twin makes decisions based on all the available information.

NAZA, an innovative solution

▴ More details on how NAZA works:

- | The automata is deployed on one zone. RTE has deployed it on several zones each of around 100 substations.
- | The automata is deployed at the sub-transmission level (i.e. for France 63-90kV).

▴ What are the advantages comparing existing systems:

- | Allows to overcome the difficulties with systems rule-based such as traditional SPS (Special Protection Scheme) that are **difficult to configure and maintain**. They are also **not coordinated** and can therefore produce unpredictable results. Moreover, they **cannot adapt to new grid situations** as all the rules must be configured in advance.

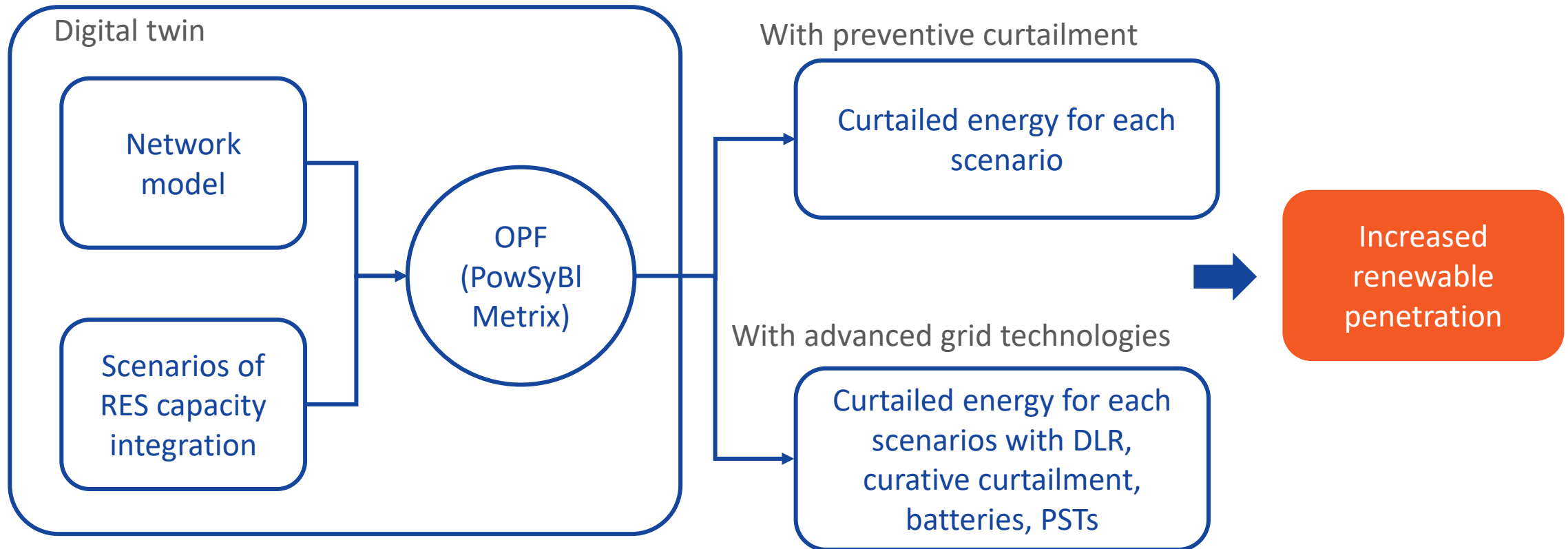
▴ NAZA is a centralized solution that coordinates all the actions within a zone, without the need to pre-configure the rules – its an adaptative solution!

A light gray world map is centered in the background of the slide. The text is overlaid on the left side of the map.

Road mapping using Innovative Grid Technologies

What is the best advanced technology for a given grid?

- Each grid situation is unique.
- Assessing the right technology to deploy on your grid is key to plan an efficient roll-out.
- Artelys has a proven methodology to assess the avoided curtailment thanks to available advanced technologies, in comparison with preventive curtailment only.



Detailed methodology (1/2)

Objectives

- | **Assess the hosting capacity** of vRES in the given transmission network
- | Evaluate the **benefits of GETs versus investments** in the integration of vRES

Grid simulations

- | Using **detailed grid representation** of the given transmission system, and operating points representative of demand and renewable generation integration. Various formats (CGMES, PSSE) can be supported.
- | **A Security Constrained Direct Current approximation Optimal Power Flow (SC DC OPF)** ensures that the generation dispatch is compatible with the secure operation of the network. It computes optimal preventive and curative remedial actions (e.g., redispatch actions or adapting setpoints of IGTs) to respect all network constraints in all N and N-k conditions. The tool is PowSyBl Metrix.
- | Simulations are performed at various vRES installed capacities and the curtailment of vRES is calculated for each simulation.

Detailed methodology (2/2)

- ▴ A base case without innovative measures and four innovative measures were implemented within this framework:
 - | Base case scenario, considering only preventive redispatch (before contingency)
 - | Curative redispatch (after contingency)
 - | Dynamic Line Rating (DLR)
 - | Equipment for increased power flow control (FACTS/PST)
 - | Battery energy storage systems (BESS)
- ▴ For each case, the hosting capacity is determined by identifying the vRES installed capacity for which the **marginal curtailment level reached 5%** of annual vRES energy generation.
- ▴ In term of cost-to-benefit ratio, the benefit of each technology is calculated based on the avoided curtailment allowed by the technology at the improved hosting capacity level, valued at, e.g., 50€/MWh.

PowSyBl: grid modelling and computation framework

4 **Metrix** is part of the open-source framework **PowSyBl** (“Power System Blocks”) dedicated to electrical grid modelling and simulation

| Governed by the **Linux Foundation Energy**

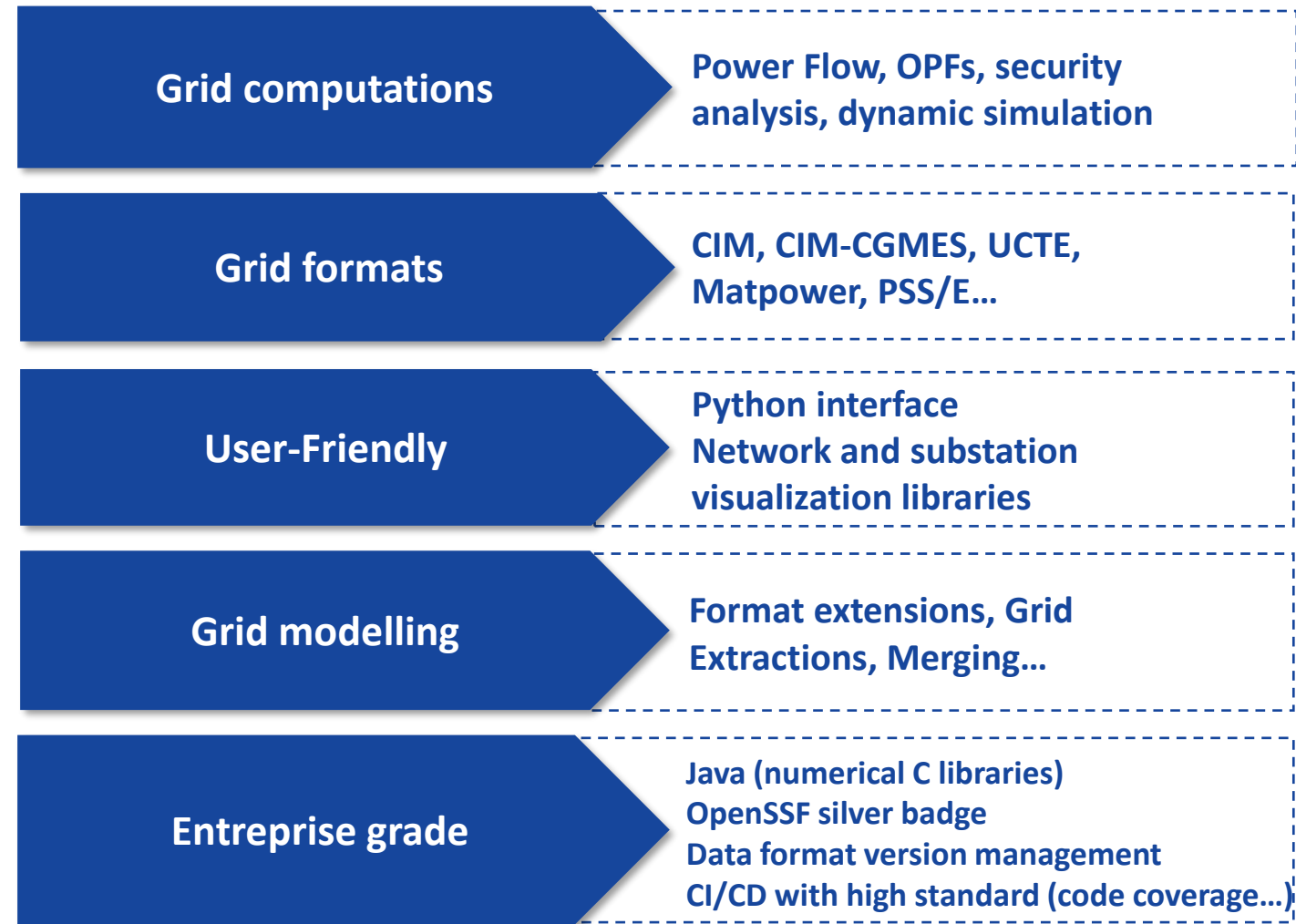
↳ Technical Steering Committee: RTE (French TSO), Artelys, AIA

↳ Commercial friendly license (weakly contaminating MPL v2)

| Community: 200+ users

↳ Operationally used by European Grid Operators

4 The open-source nature of the tool **enhances transparency**



A light gray world map is visible in the background of the slide. The map shows the continents and oceans, with a focus on the European region where the title is located.

Integration of renewable energy in the Latvian grid - AST

Main results

- 4 Innovative grid measures can **increase the hosting capacity of the Latvian grid**, by up to 40%. It can also provide **significant economic benefits** (benefit-to-cost ratio can reach 5 in some conditions).
- 4 **Curative redispatch** provides the highest increase in hosting capacity and benefit-to-costs ratio of the studied IGTs (DLR, Advanced power flow control and BESS). **Dynamic Line Rating** was deemed second best option. **Advanced power flow control equipment** can provide high value in congested corridors.

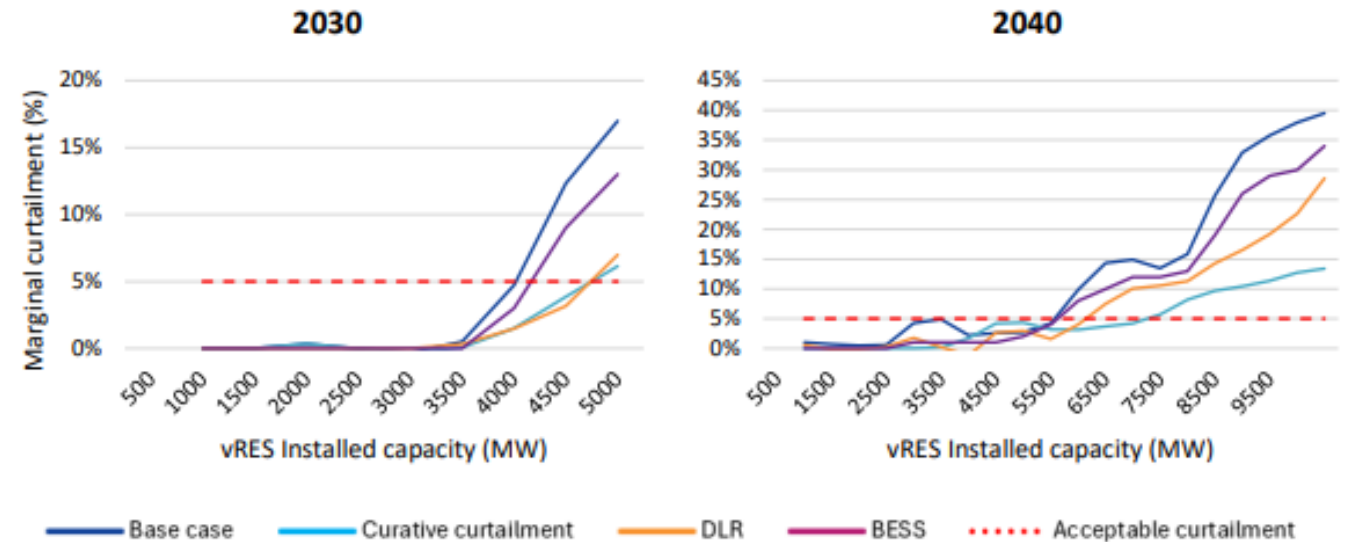


Figure 4 : Marginal preventive curtailment for 2030 (left) and 2040 (right) Min H2 scenarios, for the base case and three innovative grid measures

Main recommendations

1

Allow **efficient curtailment in the operation of the power system.**

Preventive curtailment is a requirement for more advanced technologies or operational processes

To be addressed by power systems operators to unlock barriers:

- Regulation
- Coordination between TSOs and DSOs
- Implementation of tools and processes as close to real-time as possible tools

2

Integration of GETs into **planning processes** as one of the **business-as-usual options to increase grid capacity**, being a complement to traditional grid reinforcement options.

3

Implement **advanced grid management solutions** as curative redispatch.

These technologies are complex and involves many stakeholders (TSO, DSO, vRES or BESS operators). Setting the ground for these technologies - through technical requirements and skills buildings - is highly important.

Take home messages

- ▴ Real time GETs implementation allows to leverage their full potential
- ▴ Artelys has developed a methodology to assess the benefits of GETs of RES hosting capacity
- ▴ Applied to the Latvian transmission grid, this methodologies showed that DLR first and then curative curtailment will maximize RES integration.

Contact

Nicolas OMONT,

Vice-President of Operations

nicolas.omont@artelys.com

+33 6 11 12 49 49

Artelys France

81 rue Saint-Lazare

75009 Paris

www.artelys.com

