The Role of Research Infrastructures in the Context of the Energy Transition on the Examples of the ERIGrid Projects

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Background and Motivation

- Challenges and drivers

- Climate change
- Deep decarbonisation
- Energy transition

- Industrial competitiveness
- Business Innovation
- Digitalisation

- Urban Transformation
- Infrastructure needs
- Societal changes

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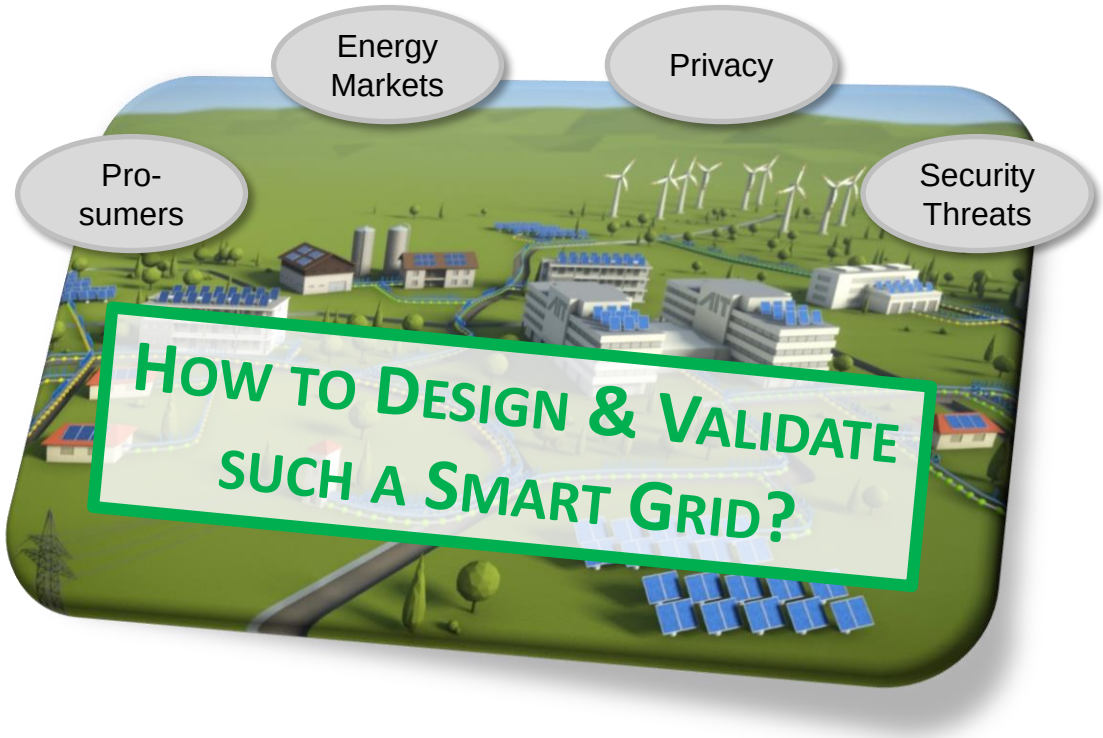
Background and Motivation

- Planning and operation of the energy infrastructure becomes more complex
  - Large-scale integration of renewable sources (PV, wind, etc.)
  - Controllable loads (batteries, electric vehicles, heat pumps, etc.)
- Trends and future directions
  - Digitalisation of power grids
  - Deeper involvement of consumers and market interaction
  - Linking electricity, gas, and heat grids for higher flexibility and resilience

→ *Smart Grid or Cyber-Physical Energy Systems*



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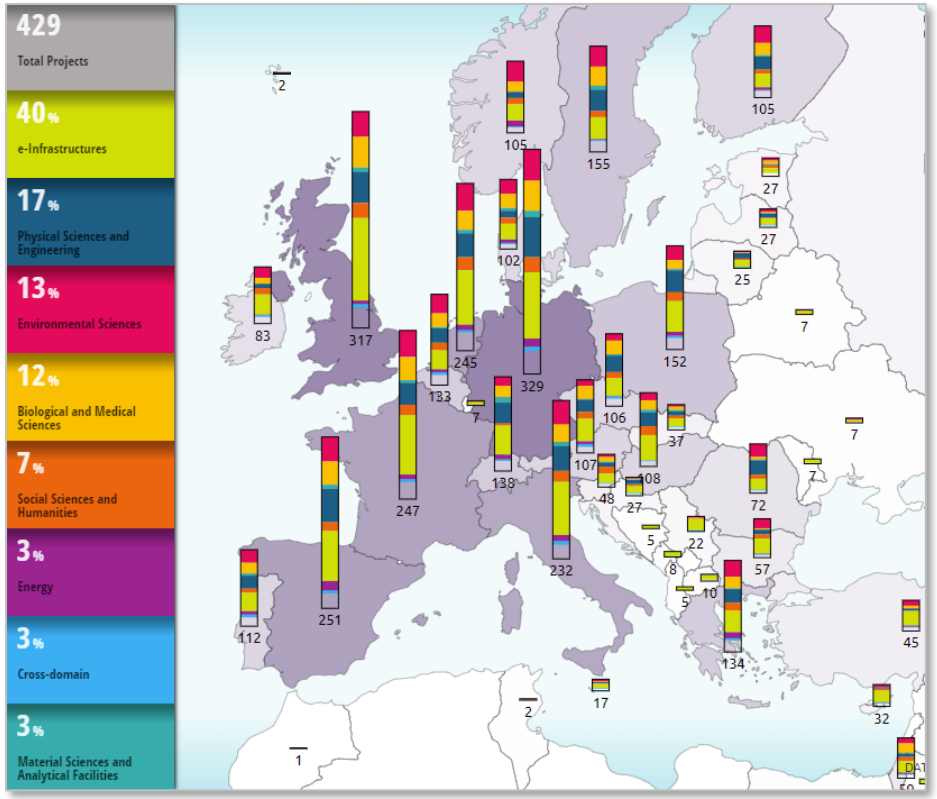
European Research Infrastructures (RI)

- Provide resources (major scientific equipment) and services to communities
- Conduct research and foster innovation
- Are strategic investments in scientific and technological excellence
- Act as knowledge and innovation hubs (collections, archives or scientific data)
- Essential pillar of the European Research Area (ERA)

→ ***Only a few cover energy-related topics***

→ ***Almost no one covers power system/smart grid topics***



Source: European Commission & RICH2020

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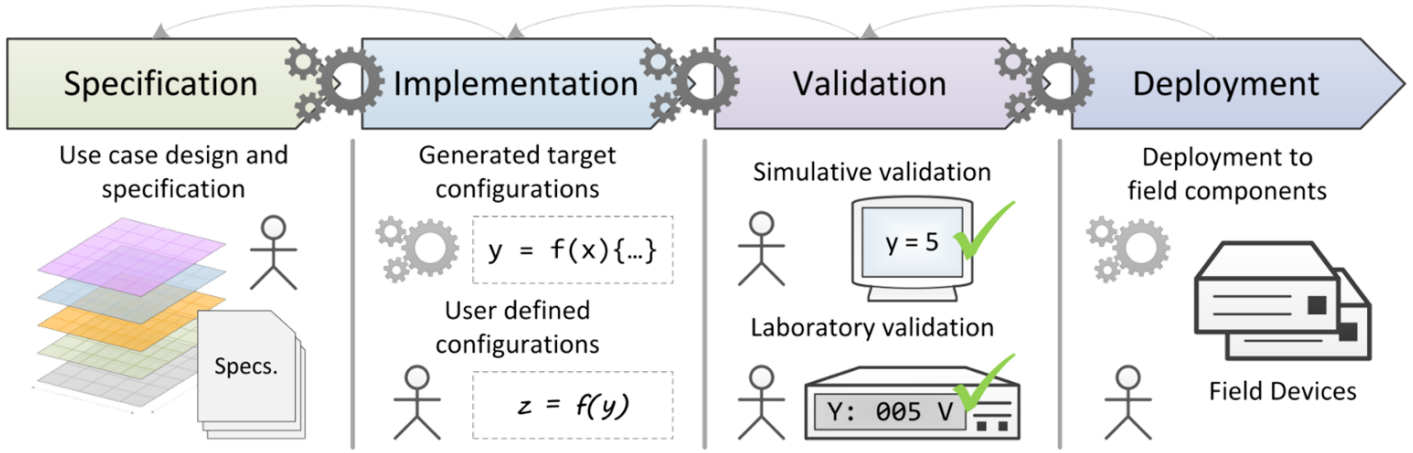
Vision and Research Directions

- Support for the integrated design, implementation, validation, and installation of smart grids and smart energy systems
  - Integrated system design
  - Validation and testing
  - Installation and roll out
- Future research needs
  - Improved development and testing services and tools
  - Extended and advanced research infrastructures and laboratories
  - Well educated researchers and engineers (“multi-domain understanding”)



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Integrated Smart Grid and Energy Systems RIs

- Long-term,
- Pan-European cooperation

2005

2024

DERlab
European Distributed Energy Resources Laboratories

- GA-ID 5189299
- FP6 NoE (11/2005-10/2011)
- 3 Mio EUR funding
- 12 partner
- Networking of DER labs, pre-standardization

DERri
Distributed Energy Resources Research Infrastructure

- GA-ID 228449
- FP7 RI IA (09/2009-12/2013)
- 5 Mio EUR funding
- 16 partner from 12 countries
- TNA to DER labs, pre-standardization
- ~800 access days for 100 user

ERIGRID
Connecting European Smart Grid Infrastructures

- GA-ID 654113
- H2020 RI IA (11/2015-04/2020)
- 10 Mio EUR funding
- 18 partner from 11 countries
- TNA to Smart Grid and DER labs, pre-standardization
- ~1050 access days for 175 user

ERIGRID 2.0
Connecting European Smart Grid Infrastructures

- GA-ID 870620
- H2020 RI IA (04/2020-09/2024)
- 10 Mio EUR funding
- 20 partner from 13 countries
- TNA & VA to Smart Grid , Smart Energy Systems and DER labs, pre-standardization
- ~1700 access days for 250 user

Legend:

DER … Distributed Energy Resource
RI … Research Infrastructure
TNA … Trans-national Access
VA … Virtual Access
NoE … Network of Excellence

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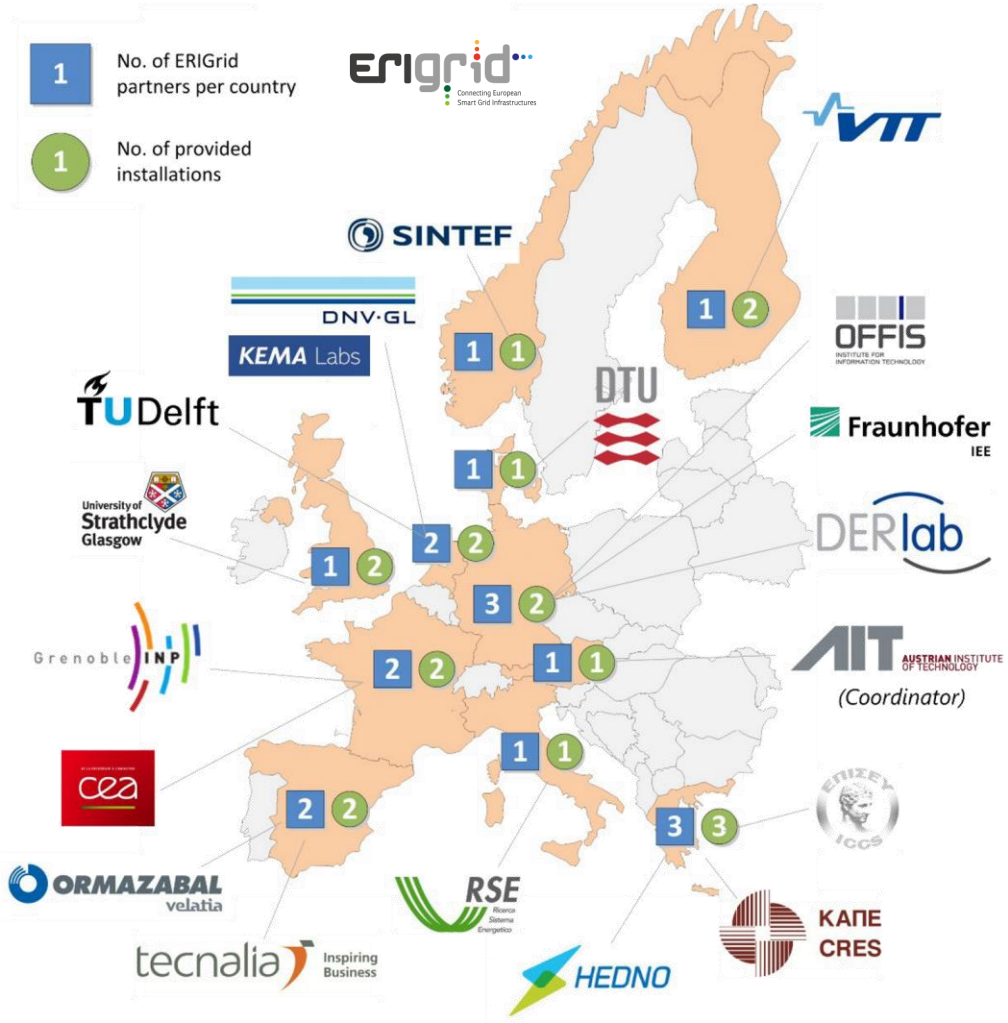
Smart Grid RI “ERIGrid” - Overview

- Applied research for validation of
  - Sustainable power and energy systems/smart grid systems
  - Distributed Energy Resources (DER)
- Tight collaboration of partners
  - 11 European countries involved
  - 18 Partners from research and industry
  - 19 top-class smart grid and DER labs



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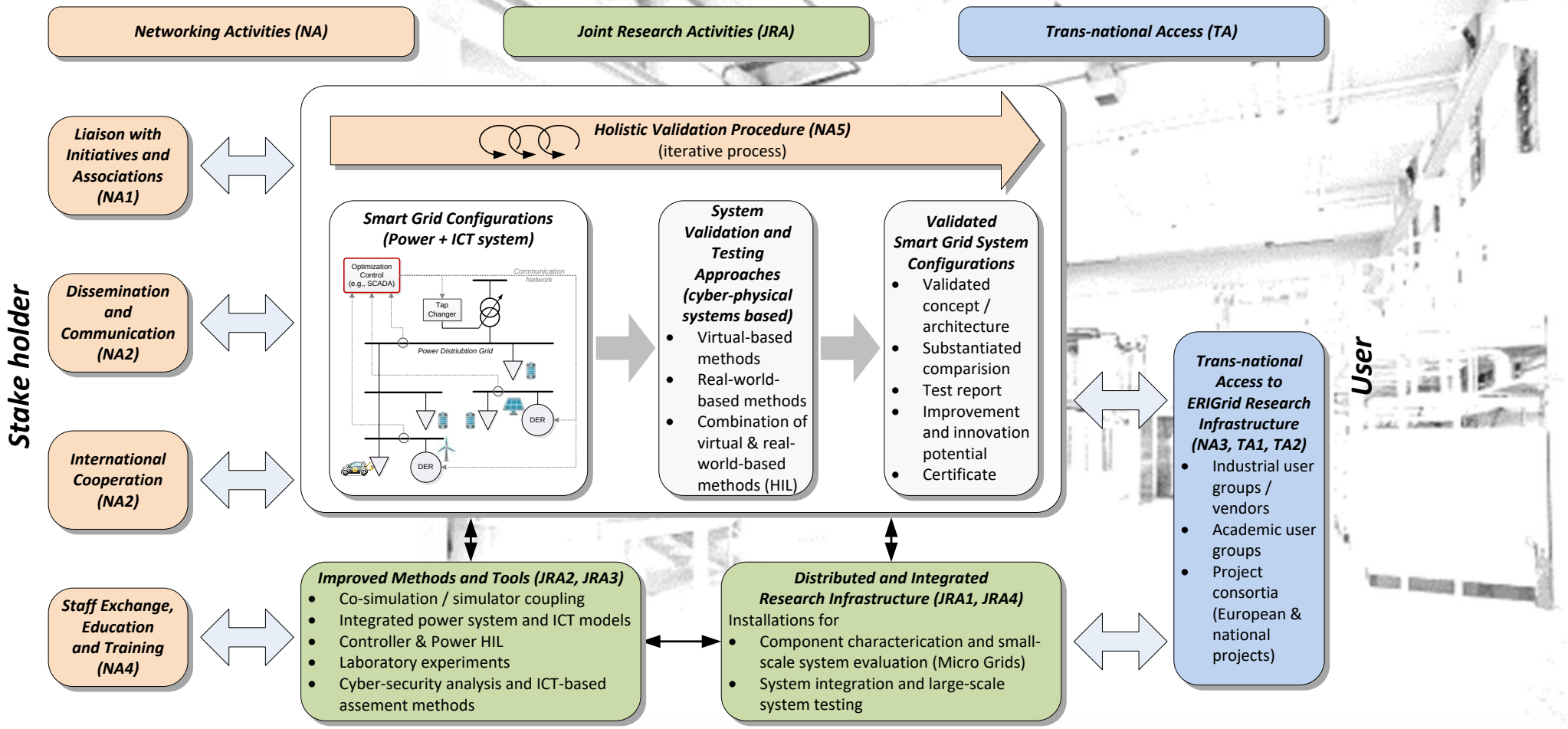
Smart Grid RI “ERIGrid” - Approach



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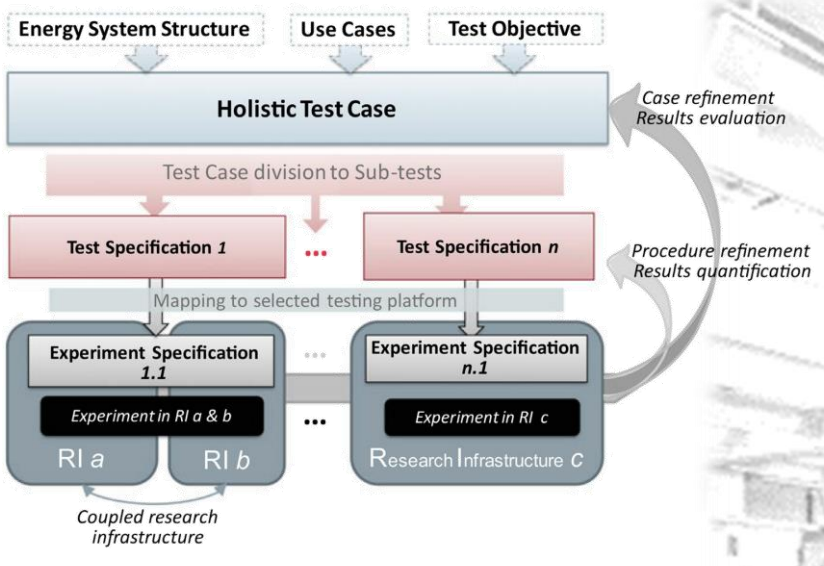
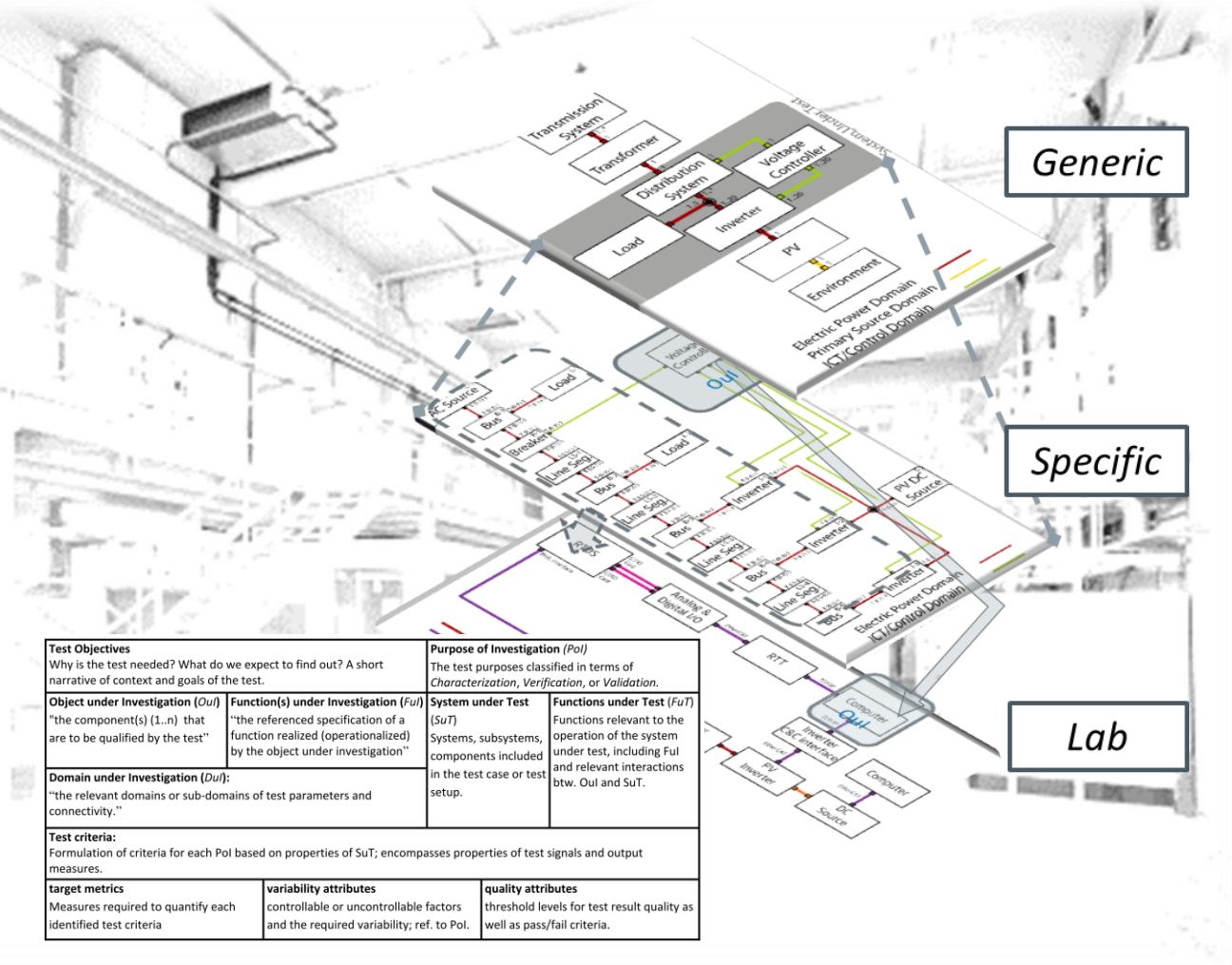
Smart Grid RI “ERIGrid” - Achievements



Advanced testing methods and tools

- Holistic validation approach (HTD) for smart grids
- Approach for specifying test cases, test specifications and experiments



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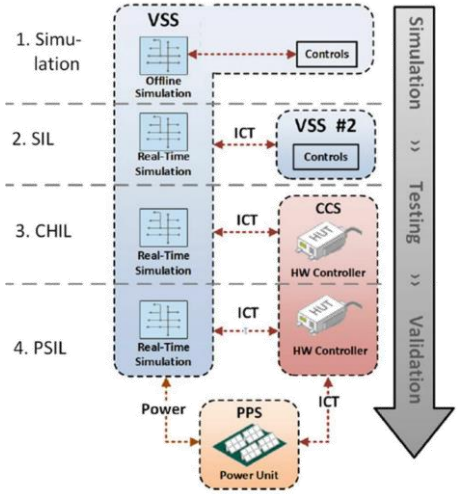
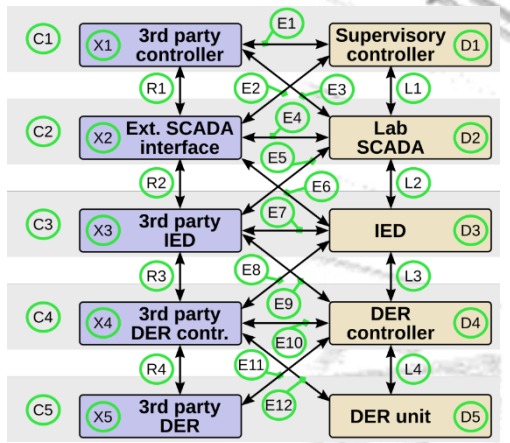
Smart Grid RI “ERIGrid” - Achievements





Advanced testing methods and tools

- Test chain approach
- Coupling approach for smart grid labs
- Virtual Pan-European Smart Grid RI

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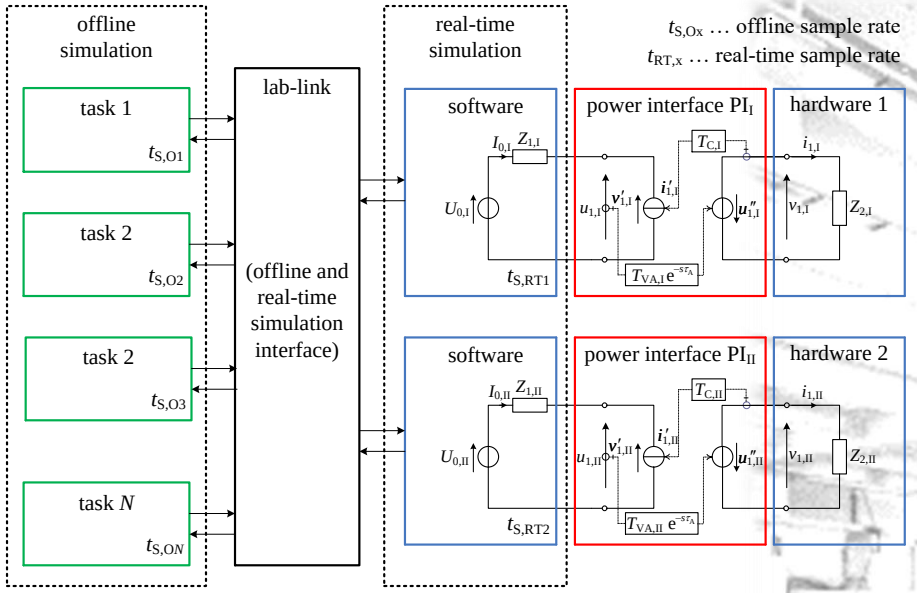
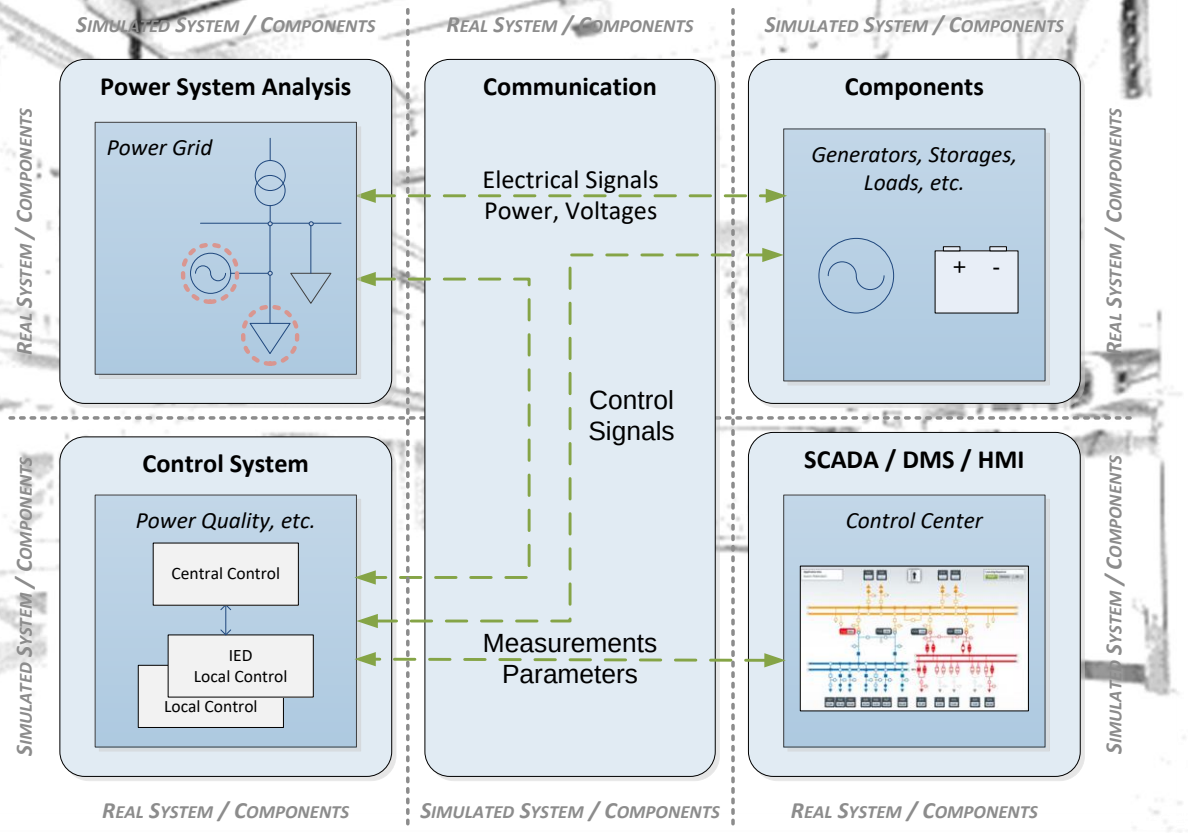
Smart Grid RI “ERIGrid” - Achievements





Advanced testing methods and tools

- Co-simulation and hardware-in-the-loop based system-level testing
- FMI-based simulation library

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Smart Grid RI “ERIGrid” - Achievements

73
user projects from all over the world gained lab access

175
engineers accessed best labs of Europe free of charge

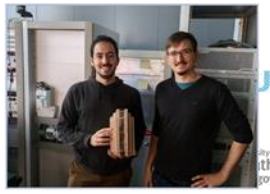
20
had companies involved

4
multi-side projects (involving more than one laboratory)

1,000
for over 1,000 days collectively ERIGrid labs were in use

14
projects came from outside Europe

14
projects were led by companies



7
projects were from ERIGrid partners (“internal TA”)

Free access for user groups to

- Power system,
- Smart grid and
- DER laboratories

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Smart Energy Systems RI “ERIGrid 2.0” - Approach

- Extended and applied research based on ERIGrid topics and achievements for
  - Smart grid and smart energy systems
  - Digitalization with lab interfacing and data exchange for physical/virtual access
- Tight collaboration of partners
  - 13 European countries involved
  - 20 Partners from research and industry
  - 21 top-class smart grid, energy systems, and DER labs
  - 10 virtual facilities

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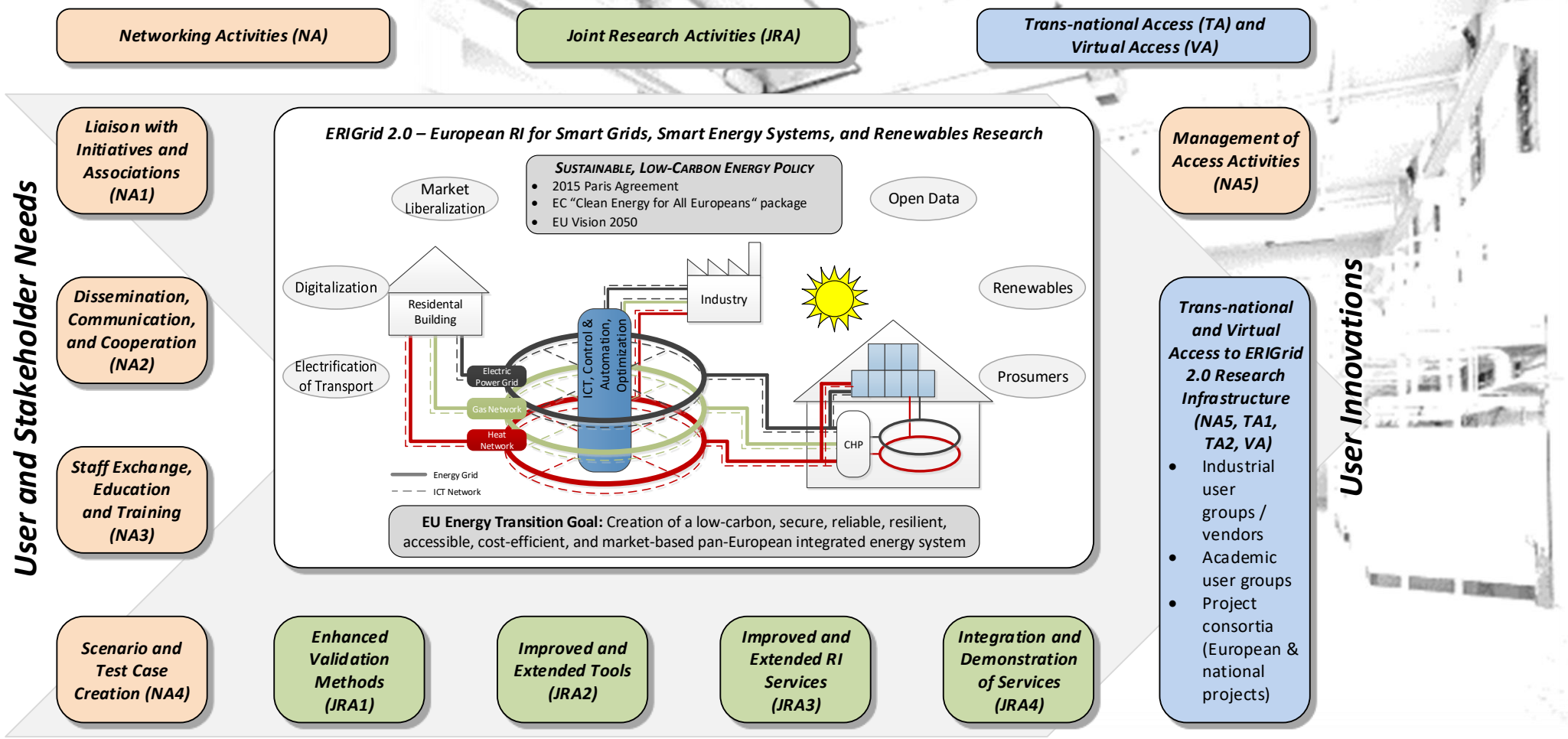
Smart Energy Systems RI “ERIGrid 2.0” - Approach



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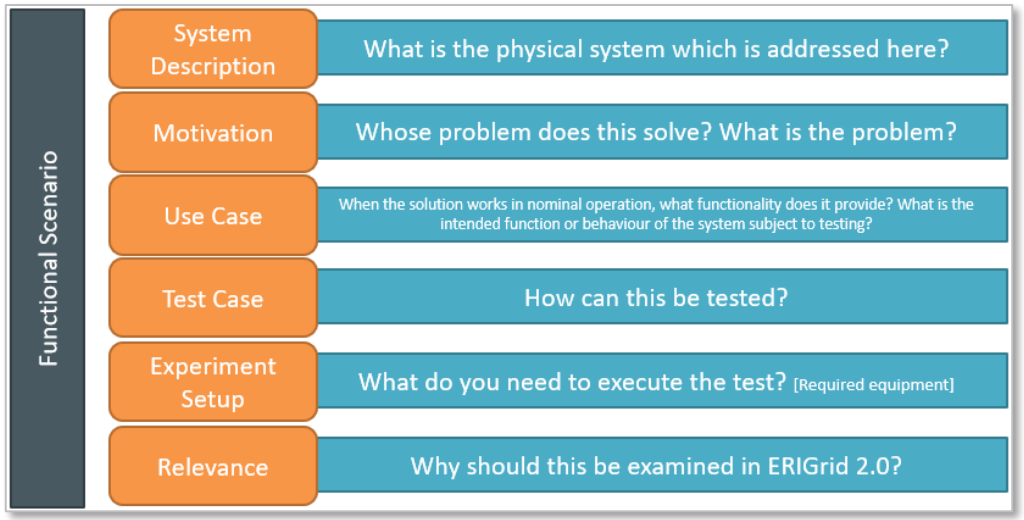
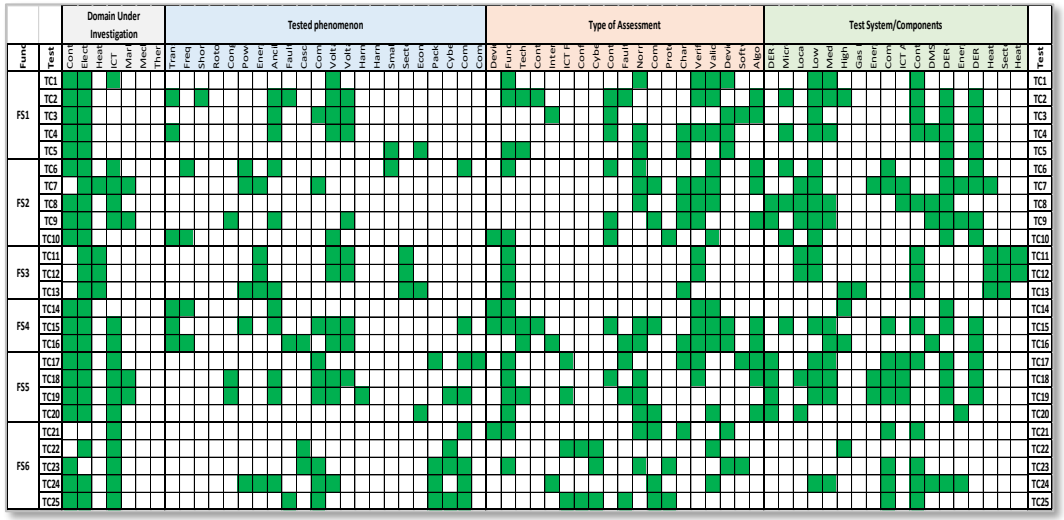
Smart Energy Systems RI “ERIGrid 2.0” - Achievements

- Identification of relevant scenarios (6) and test cases (25)
- Provision of functional scenarios with broad domain view
- HTD used to formulate test cases



- Each test case got keywords assigned
- Keywords help to
  - Define characteristics of technical areas
  - Select test cases



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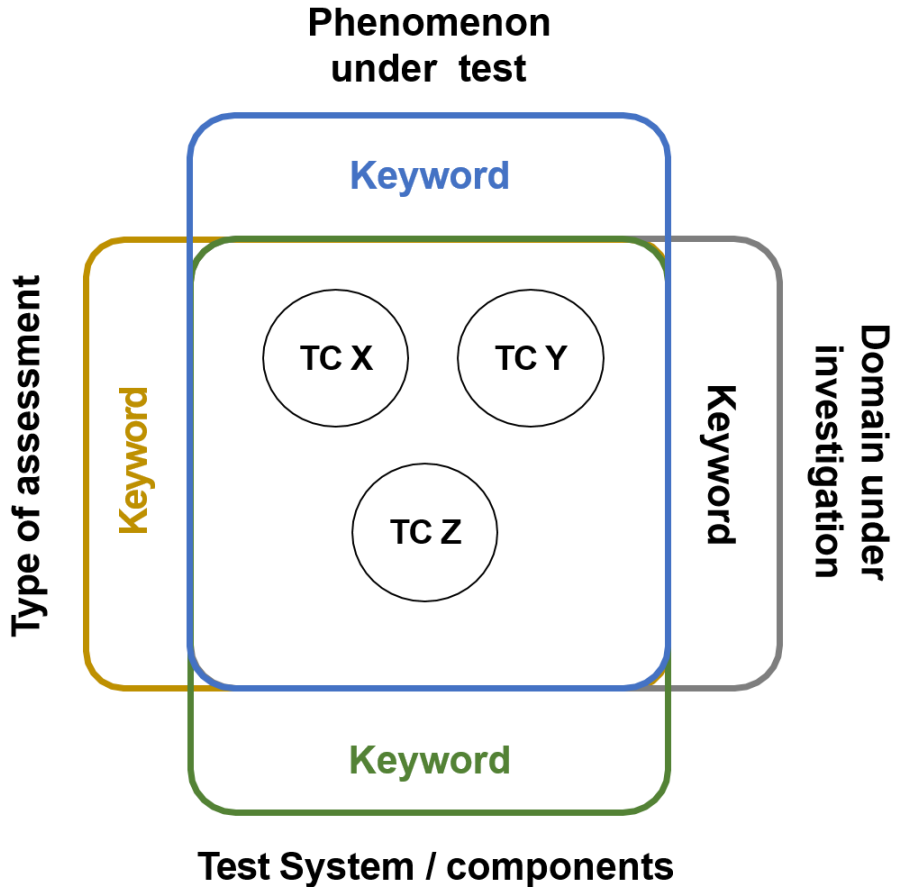
Smart Energy Systems RI “ERIGrid 2.0” - Achievements

- Derivation of Test Case Profiles (TPCs)
  - Collection of TCs that share similarities
  - Similarities in the context of application and testing facility properties
- Keywords focus on 4 dimensions
  1. Domain under investigation
  2. Phenomenon under test
  3. Type of assessment
  4. Test system



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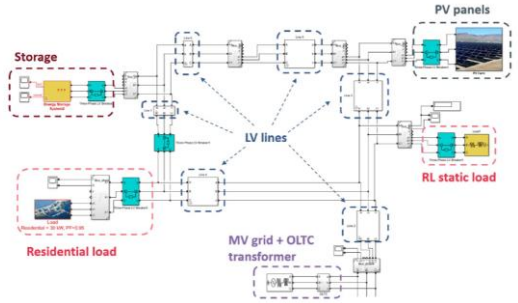
Smart Energy Systems RI “ERIGrid 2.0” - Achievements

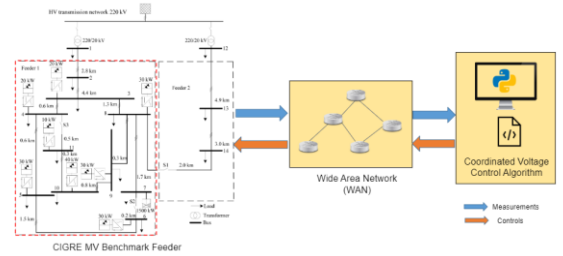
- Enhanced validation methods
  - Development of benchmark scenarios/ models for different testing setups
  - Developing guidelines for test reproducibility and representation of data and uncertainty
  - Developing methods for test upscaling and domain extension

Name	Domain	Simulation Environment
Electrical Network	Electrical	MathWorks MATLAB/Simulink
Multi-Energy Networks	Electrical, Thermal	pandapower, Modelica, Python
ICT-Enhanced Power Systems	Electrical, ICT	DIgSILENT PowerFactory, Mininet

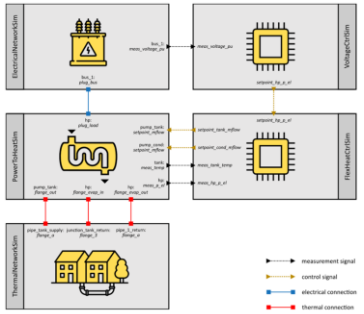
Electrical Network Benchmark



ICT-enhanced Power System Network Benchmark



Multi-Energy Network Benchmark



Documentation in GitHub

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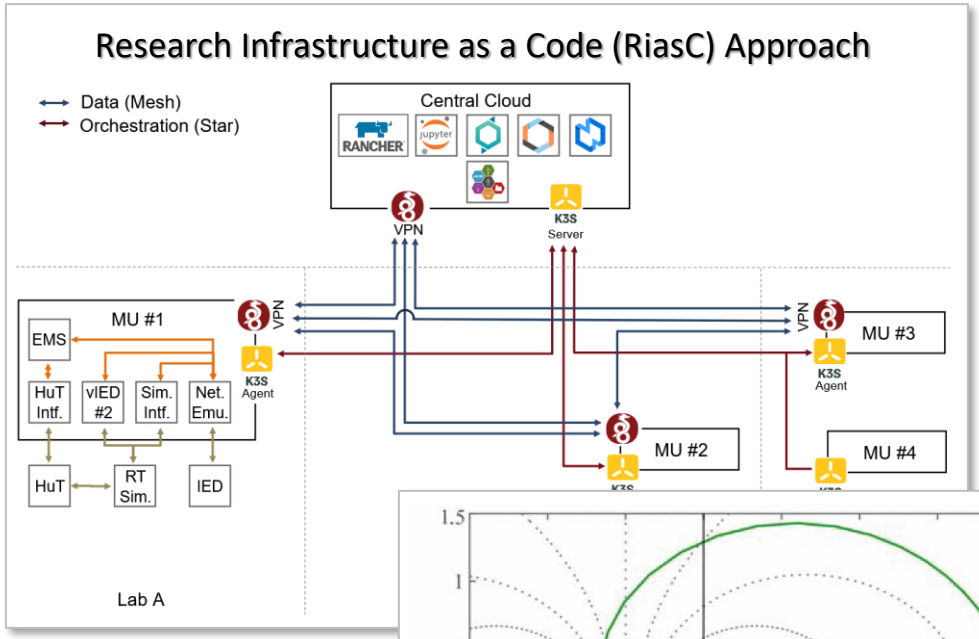
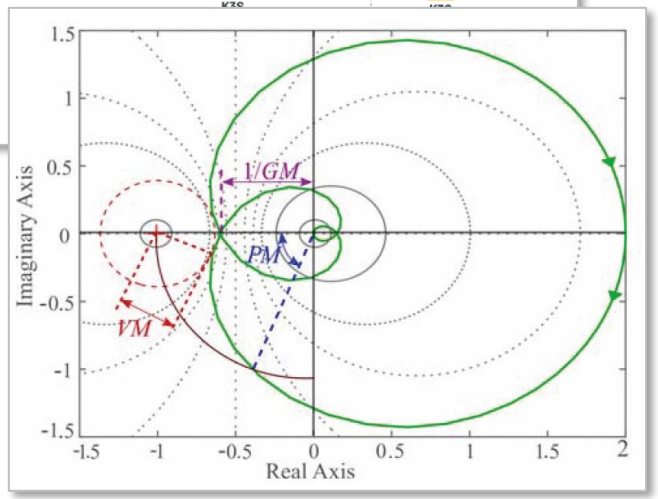
Smart Energy Systems RI “ERIGrid 2.0” - Achievements

- Improved and extended tools
  - Coupling multiple instances of non real-time simulators, real-time simulators, HIL components, and lab equipment (RiasC approach)
  - Demonstrate multi-domain co-simulation of physical infrastructures at multiple time scales
  - Develop and demonstrate methods for the coupling of real-time simulators with co-simulation and HIL
  - Sensitivity analysis of HIL experiments
  - Support distributed and remote experiments





G. Lauss et al., "A Framework for Sensitivity Analysis of Real-Time Power Hardware-in-the-Loop (PHIL) Systems," in IEEE Access, vol. 10, pp. 101305-101318, 2022, doi: 10.1109/ACCESS.2022.3206780.

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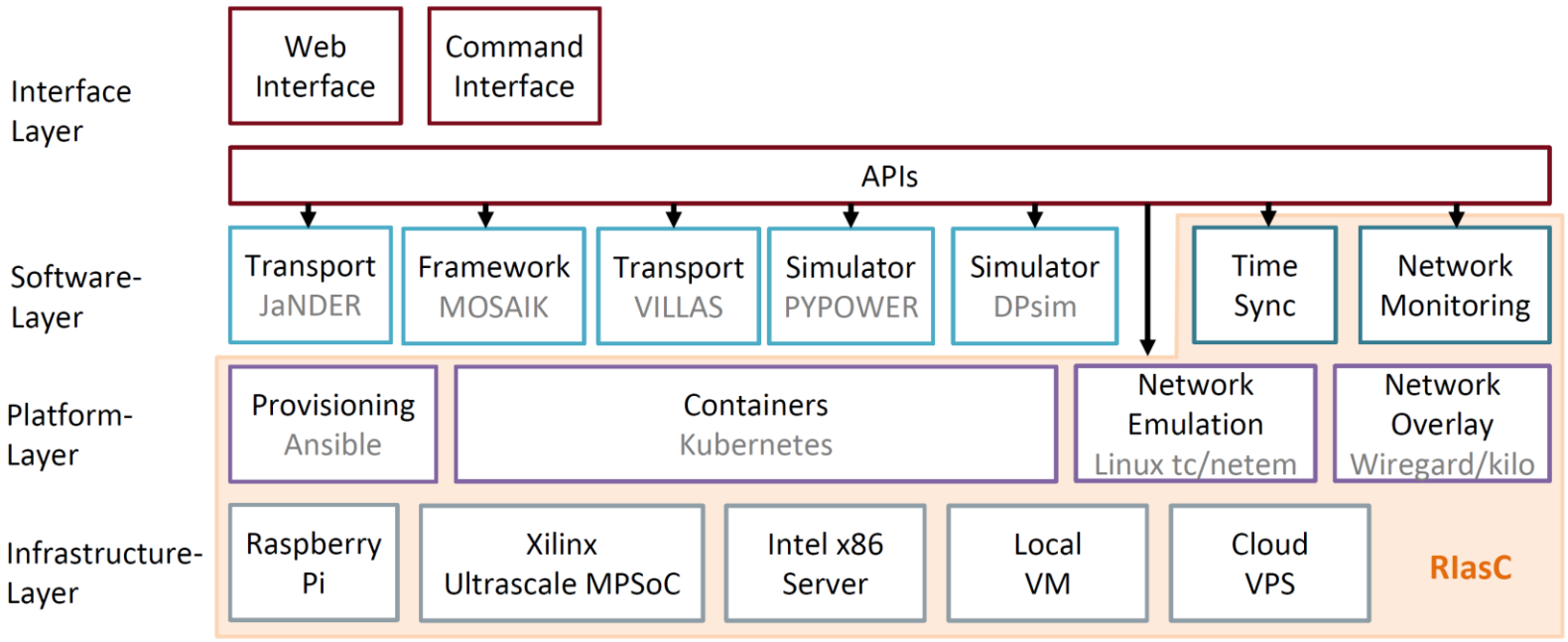
Smart Energy Systems RI “ERIGrid 2.0” - Achievements

- Improved and extended RI services
  - Improve and extend well-established frameworks for lab coupling and multi-RI experiments
  - Develop a set of extended services for seamless interconnection with various lab facilities/RIs
  - Demonstrate the application of services with an abstract prototype
  - Implement simulation specific services along with integration of automation services



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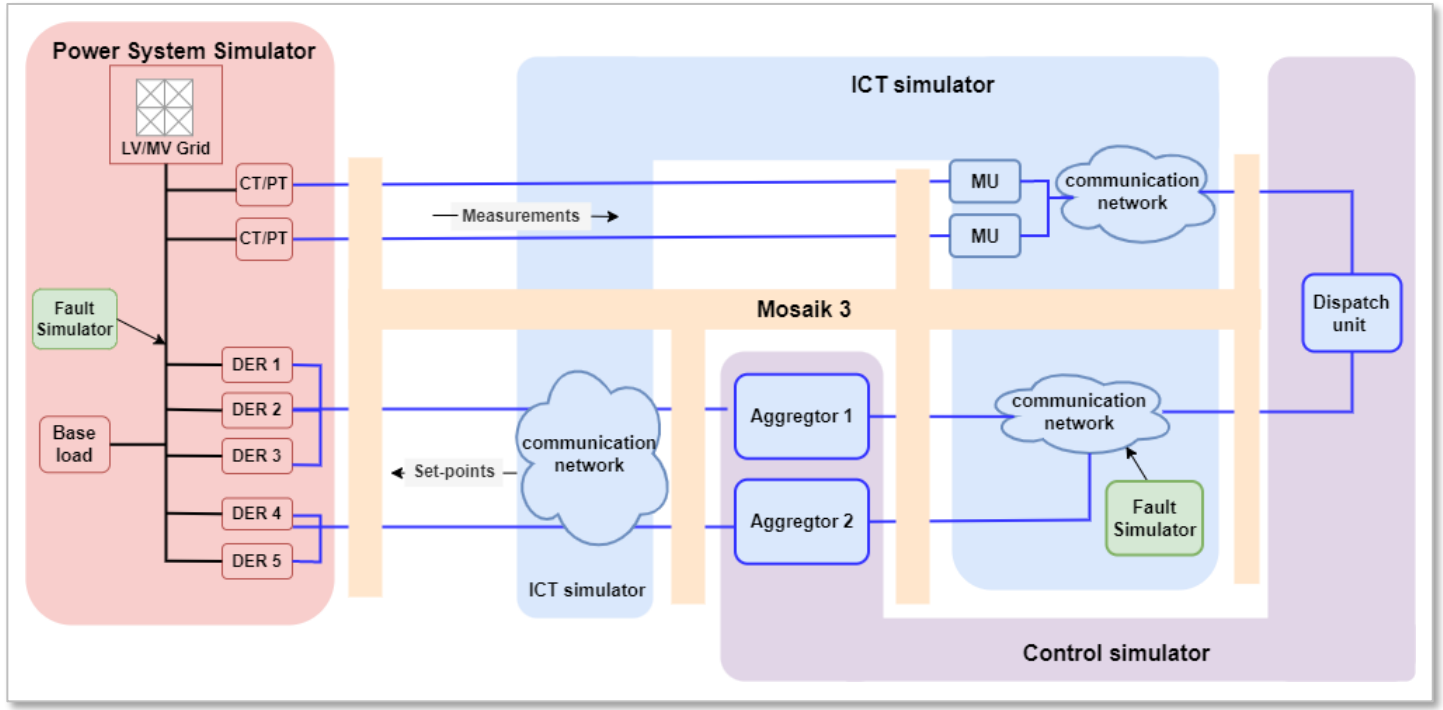
Smart Energy Systems RI “ERIGrid 2.0” - Achievements

- Integration and demonstration of RI services
  - Definition of useful integration and demonstration test cases based on the identified functional scenarios and test cases
  - Implementation of inter-connection methodologies and tools for the simulation, co-simulation, HIL, and distributed lab infrastructure
  - Demonstration of the services of the ERIGrid 2.0 extended RI



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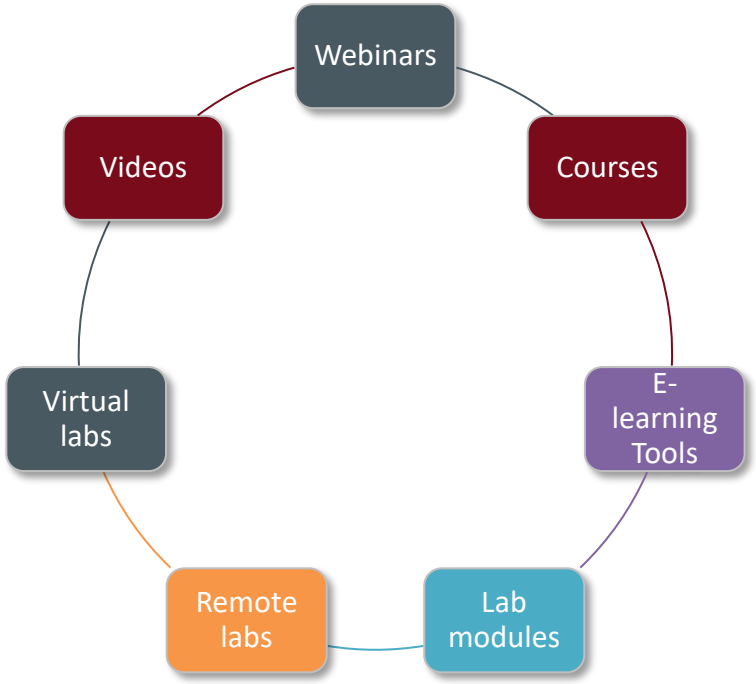
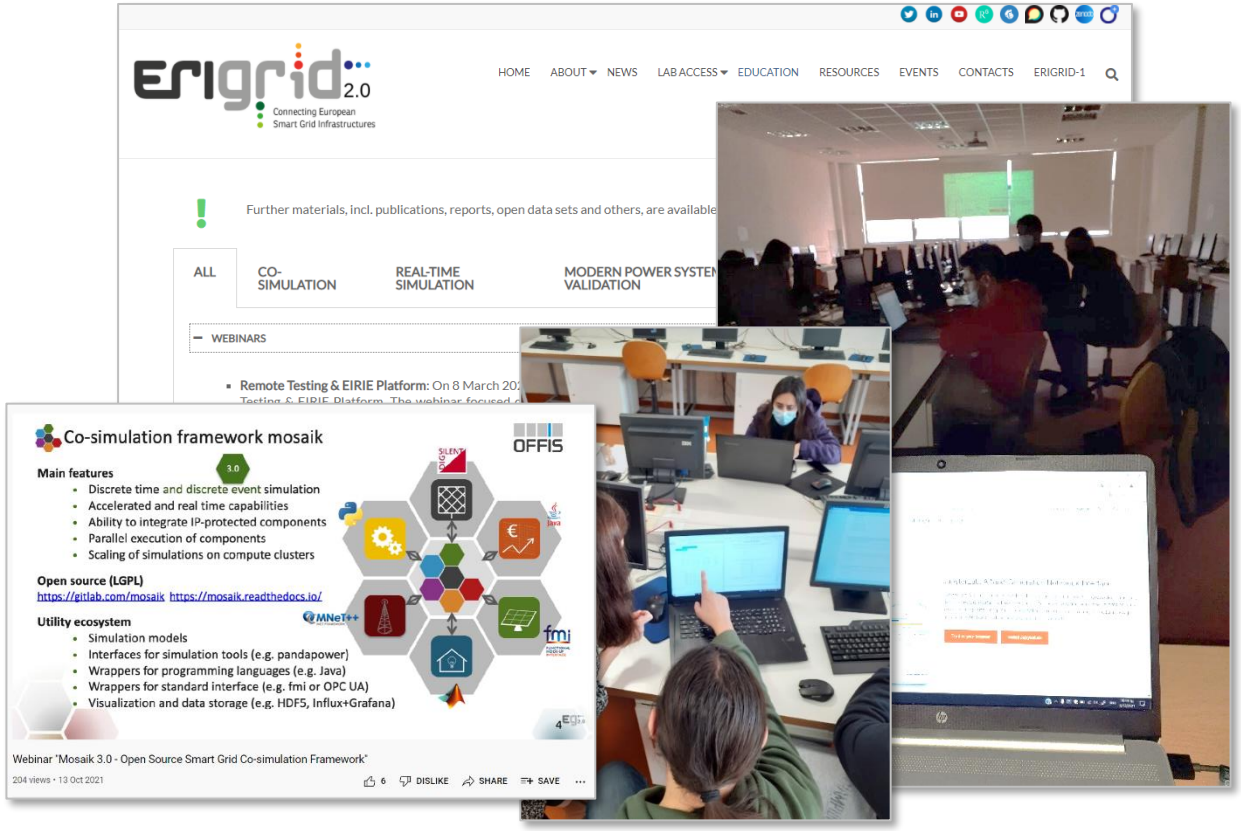
Smart Energy Systems RI “ERIGrid 2.0” - Achievements

- Education on smart grid and smart energy systems as well as related validation approaches
- Development and provision of training and education material



www.erigrid2.eu/education



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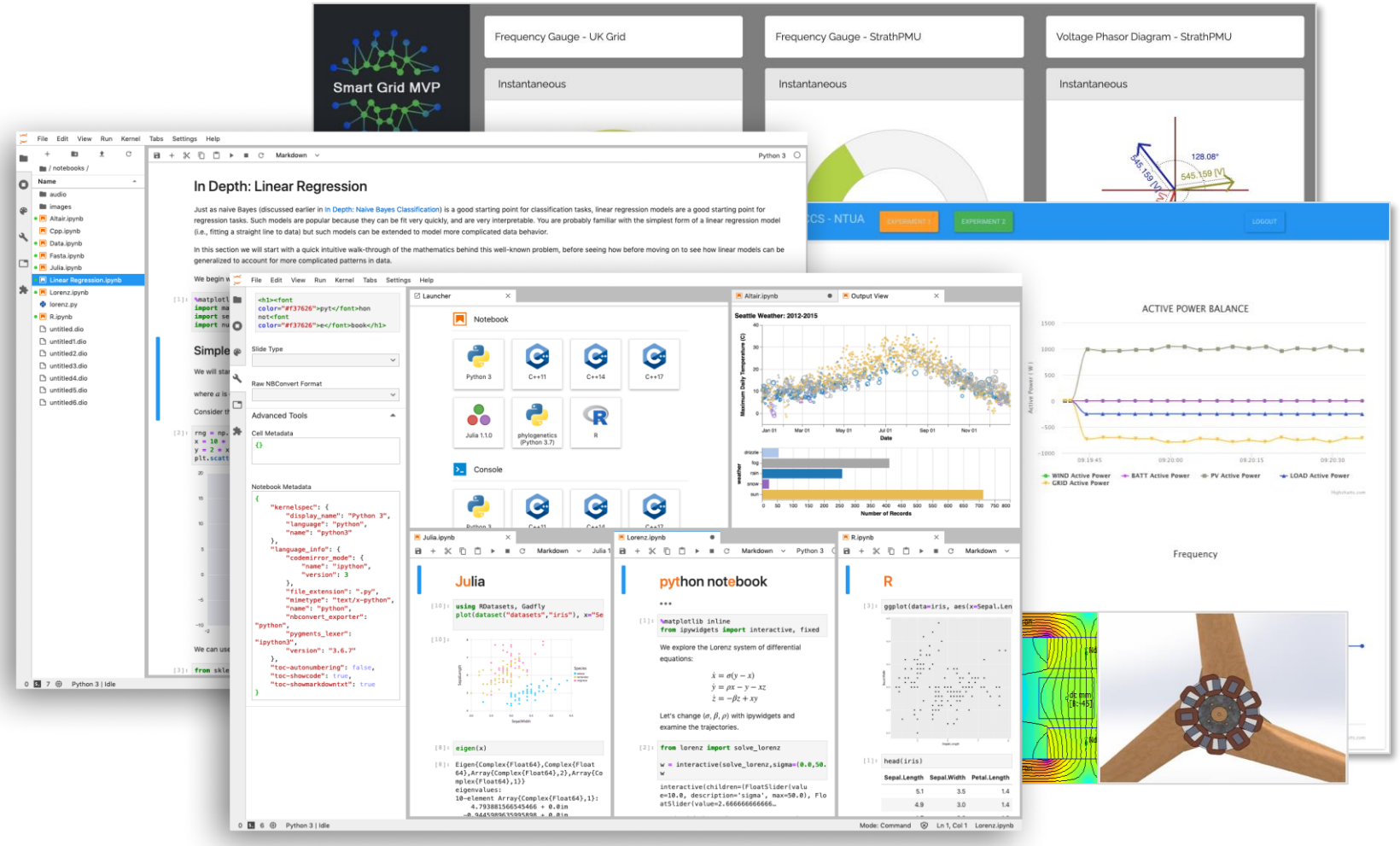
Smart Energy Systems “ERIGrid 2.0” - Virtual Services

- Focus on
  - Simulation-as--a-Service (SaaS)
  - Open data, Data-as-a-Service (DaaS)
  - Virtual labs



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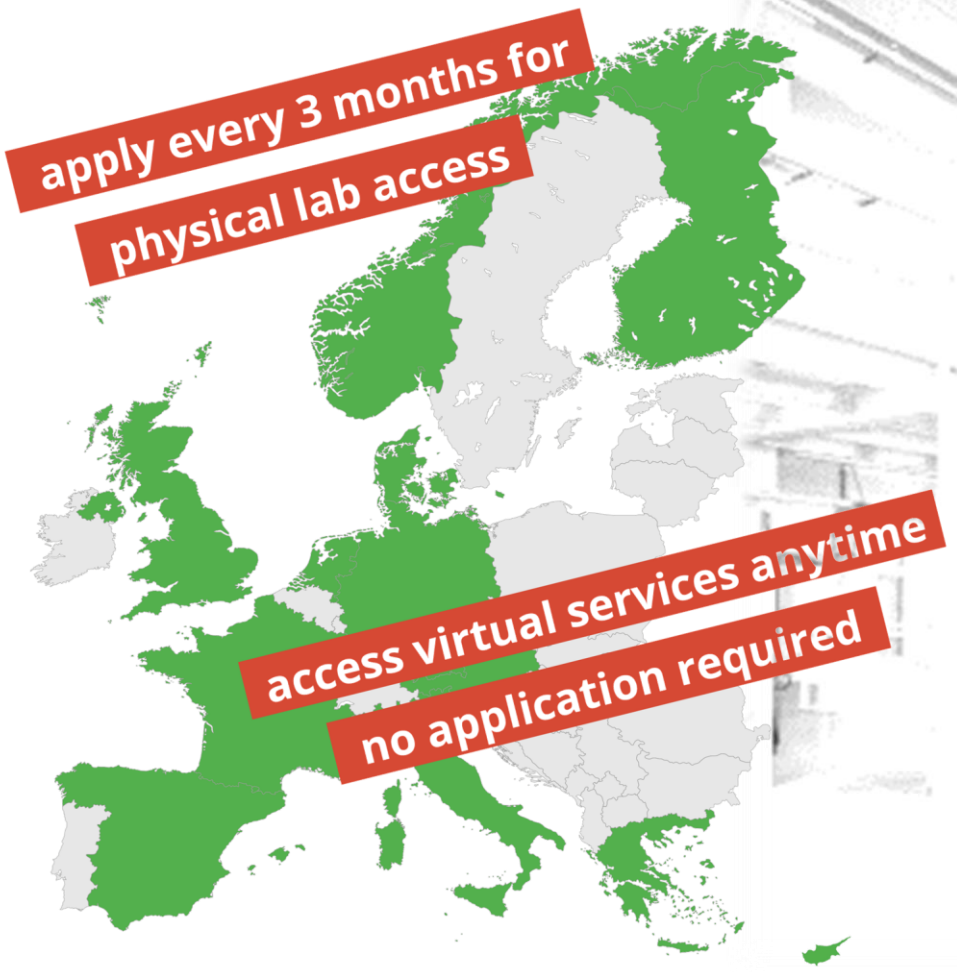
Smart Energy Systems “ERIGrid 2.0” - Lab Access



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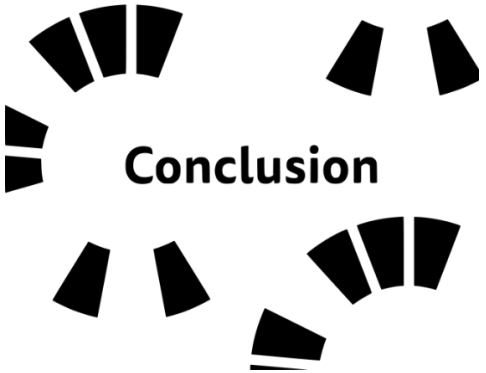
Conclusions and Lessons Learned

- A large-scale rollout of smart grid and energy solutions and technologies can be expected in the future
- New technologies, suitable concepts, methods and approaches are necessary to support system analysis, evaluation and testing issues of integrated approaches
- Flexible integration of simulation-based methods, hardware-in-the-loop approaches, and lab-based testing looks promising for overcoming shortcomings
- Development of system-level validation procedures and benchmark criteria is important
- Open research results (open access, open data, joint publications) contribute to innovation
- Lab-based RIs are essential for energy transition
- Multi-domain education and training essential
- Collaboration on international basis important and beneficial (IEA ISGAN/SIRFN, EERA SG, IEEE-SA – standardization, etc.)
- Great feedback from lab access users



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@ERIGrid 2.0 Project

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