Fostering Innovation with European Smart Grid Research Infrastructures

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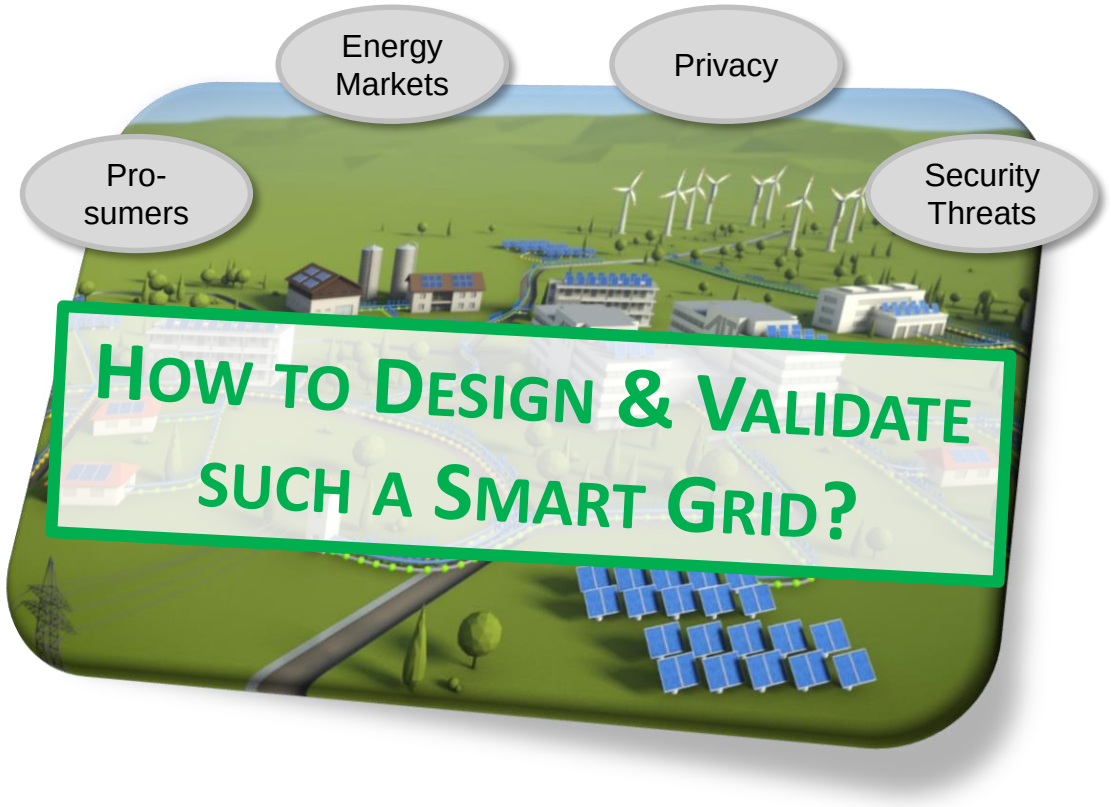
Background and Motivation

- Planning and operation of the energy infrastructure becomes more complex
  - Large-scale integration of renewable sources (Distributed Energy Res./DER – like PV, wind, etc.)
  - Controllable loads (battery storages, electric vehicles, heat pumps, etc.)
- Trends and future directions
  - Digitalisation of energy infrastructure
  - Deeper involvement of consumers and market interaction
  - Sector coupling (linking electricity, gas, and heat grids) for higher flexibility and resilience



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Needs and Requirements

- Separated design and validation of individual domains (power, ICT, heat, etc.) not sufficient anymore
- Integrated cyber-physical/multi-domain design and validation missing
- Reduction of manual steps necessary to handle complex system configurations
- Reduction of error sources due to manual steps required
- Improvement of application/software quality required
- Faster application development needed due to market behaviour and trends

	Req. & Basic Design Phase	***Detailed Design Phase***	***Implemen-tation and Prototyping***	***Deployment / Roll Out***
Software Simulation	+	++	o	-
Lab Experiments and Tests	-	-	++	+
Hardware-in-the-Loop (HIL)	-	-	++	++
Demonstrations / field tests, pilots	-	-	-	++

- … less suitable, o … suitable with limitations, + … suitable, ++ … best choice

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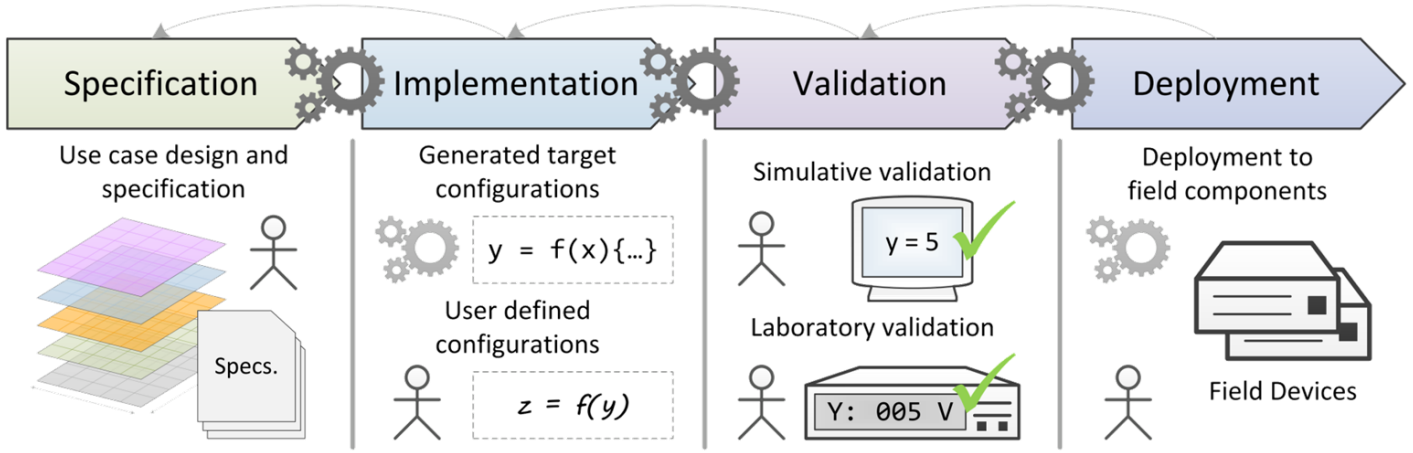
Vision and Research Directions

- 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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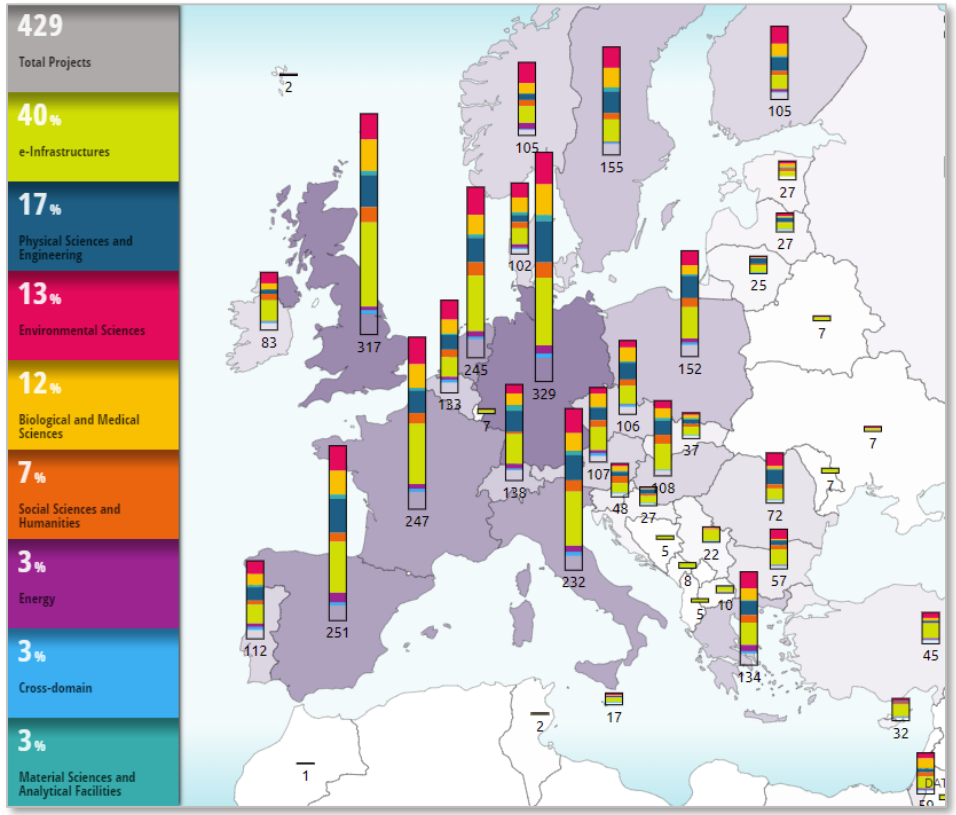
European Research Infrastructures (RI)

- 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 Science Area

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



Source: European Commission & RICH2020

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Integrated Smart Grid and Energy Systems RI's

- 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

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

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

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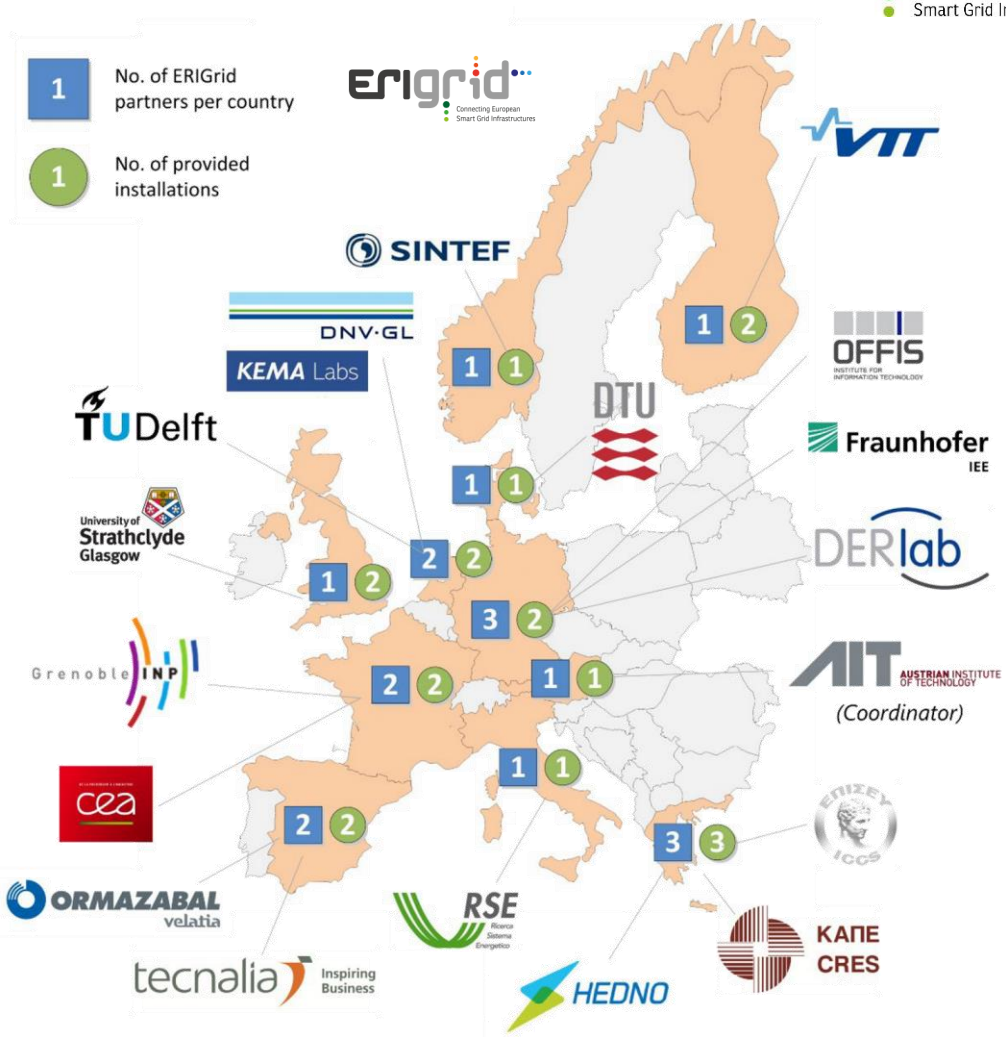
Smart Grid RI “ERIGrid” - Overview

- 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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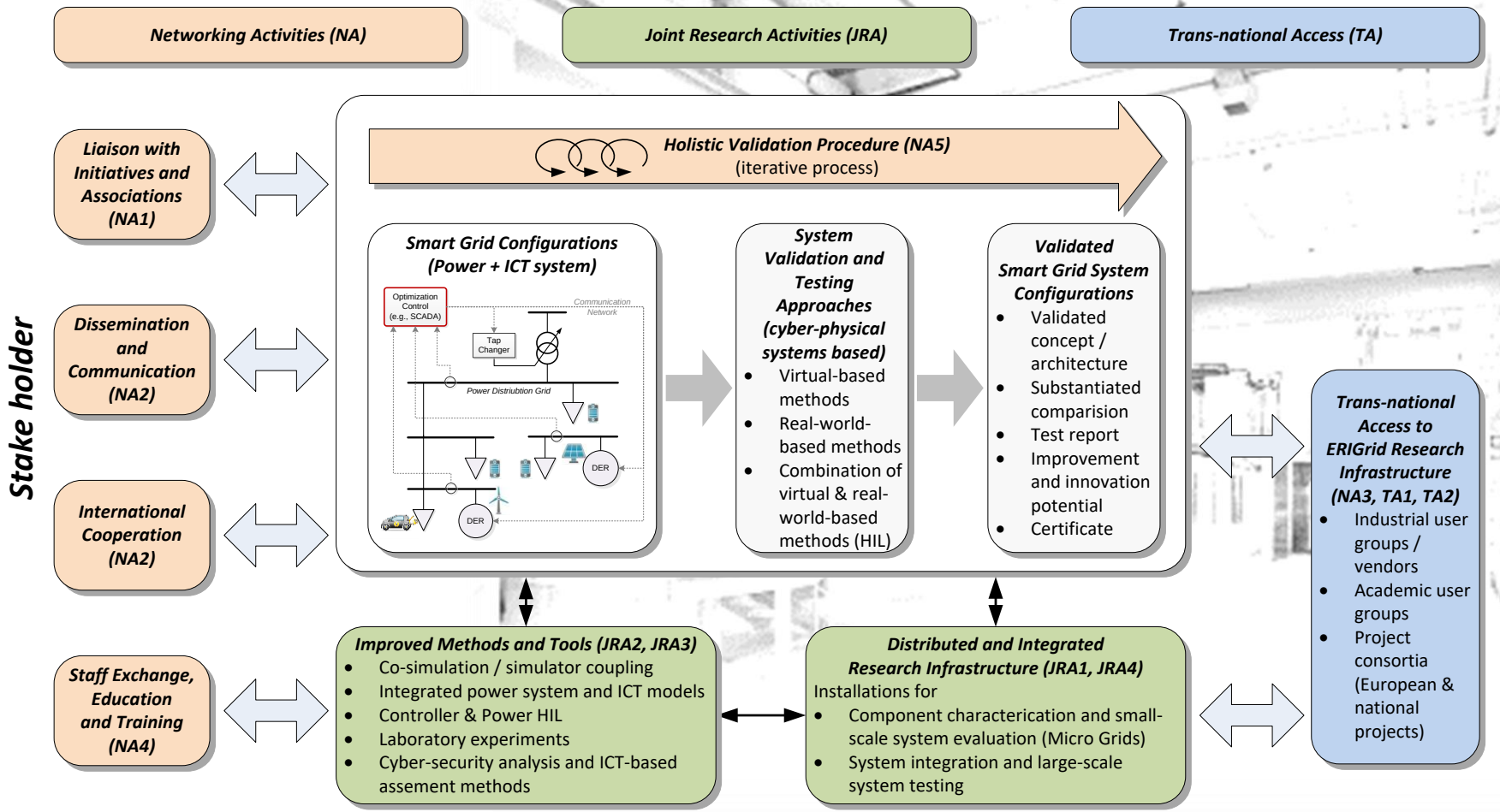
Smart Grid RI “ERIGrid” - Approach



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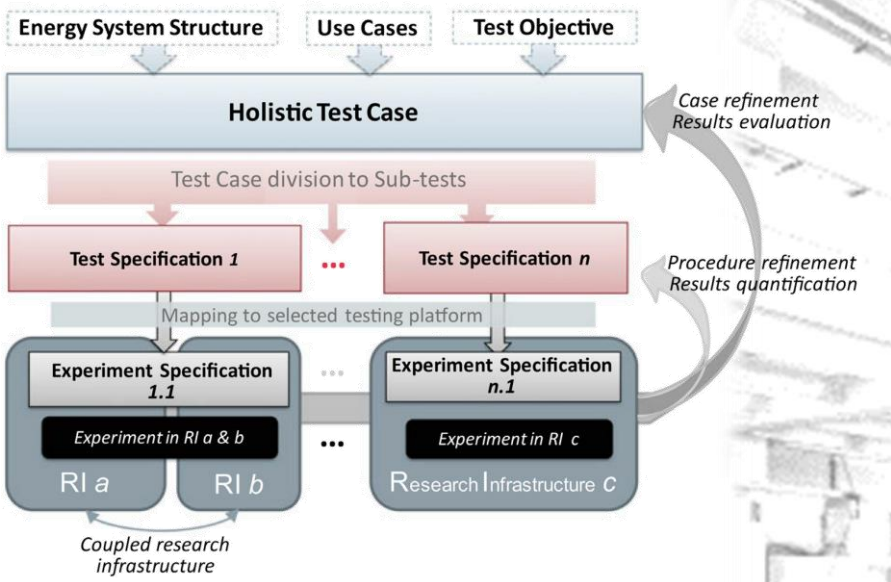
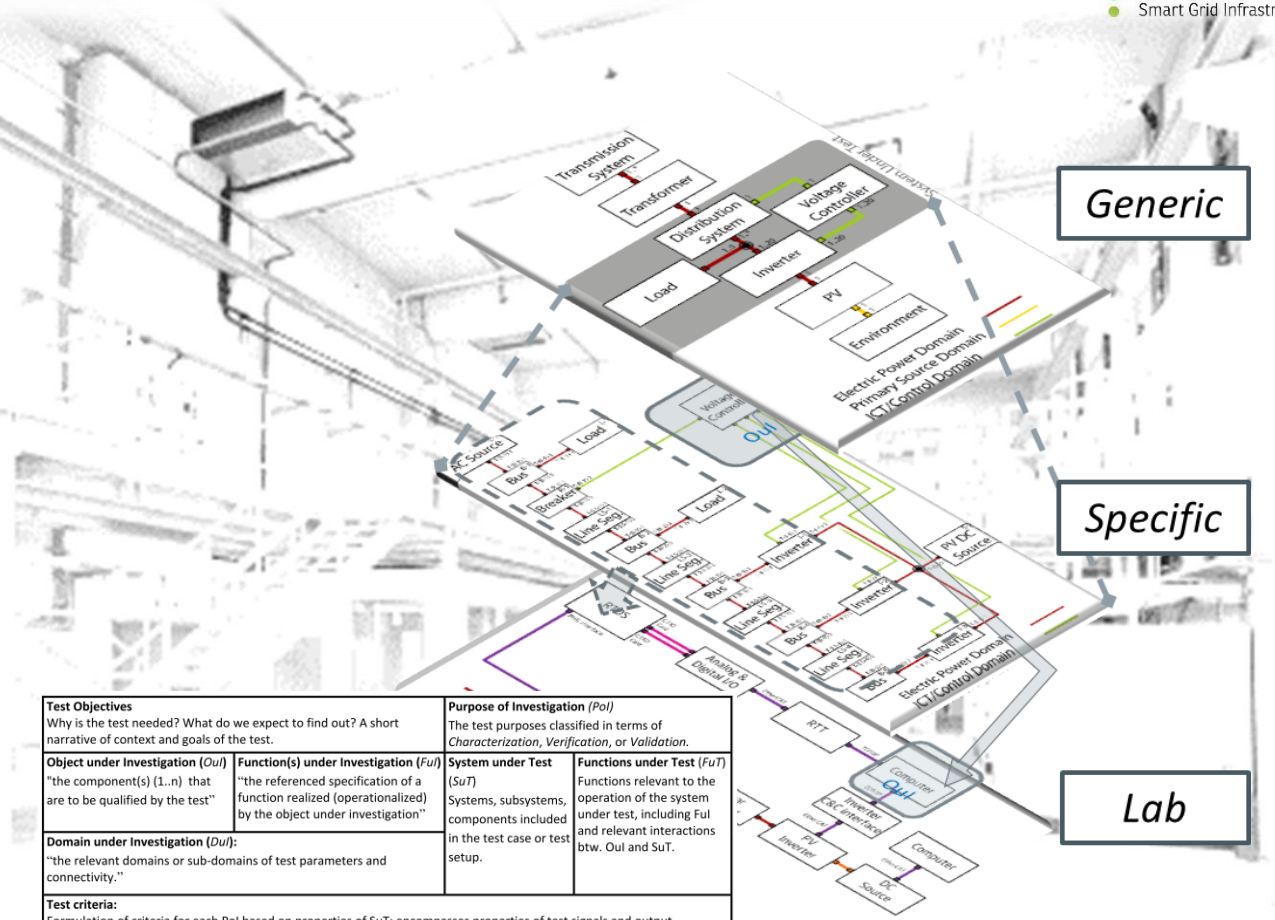
Smart Grid RI “ERIGrid” - Achievements





Advanced testing methods and tools

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

Test Objectives Why is the test needed? What do we expect to find out? A short narrative of context and goals of the test.		**Purpose of Investigation** *(PoI)* The test purposes classified in terms of *Characterization*, *Verification*, or *Validation*.	
Object under Investigation (*OuI*) "the component(s) (1..n) that are to be qualified by the test"	**Function(s) under Investigation** (*FuI*) "the referenced specification of a function realized (operationalized) by the object under investigation"	**System under Test** (*SuT*) Systems, subsystems, components included in the test case or test setup.	**Functions under Test** (*FuT*) Functions relevant to the operation of the system under test, including FuI and relevant interactions btw. OuI and SuT.
Domain under Investigation (*DuI*): "the relevant domains or sub-domains of test parameters and connectivity."			
Test criteria: Formulation of criteria for each PoI based on properties of SuT; encompasses properties of test signals and output measures.			
target metrics Measures required to quantify each identified test criteria	**variability attributes** controllable or uncontrollable factors and the required variability; ref. to PoI.	**quality attributes** threshold levels for test result quality as well as pass/fail criteria.	

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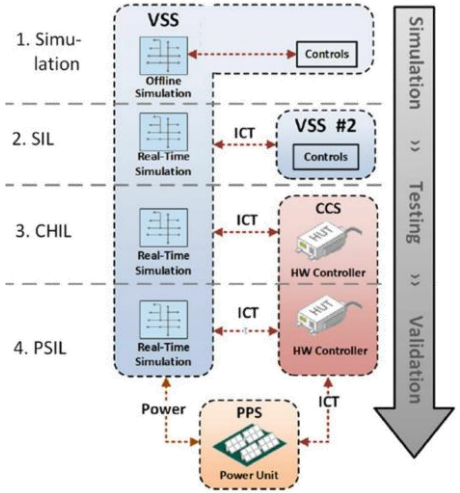

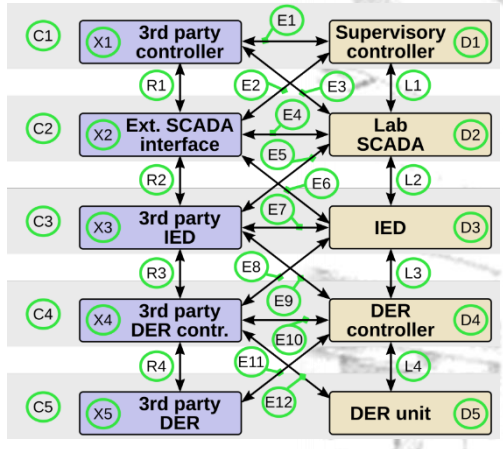

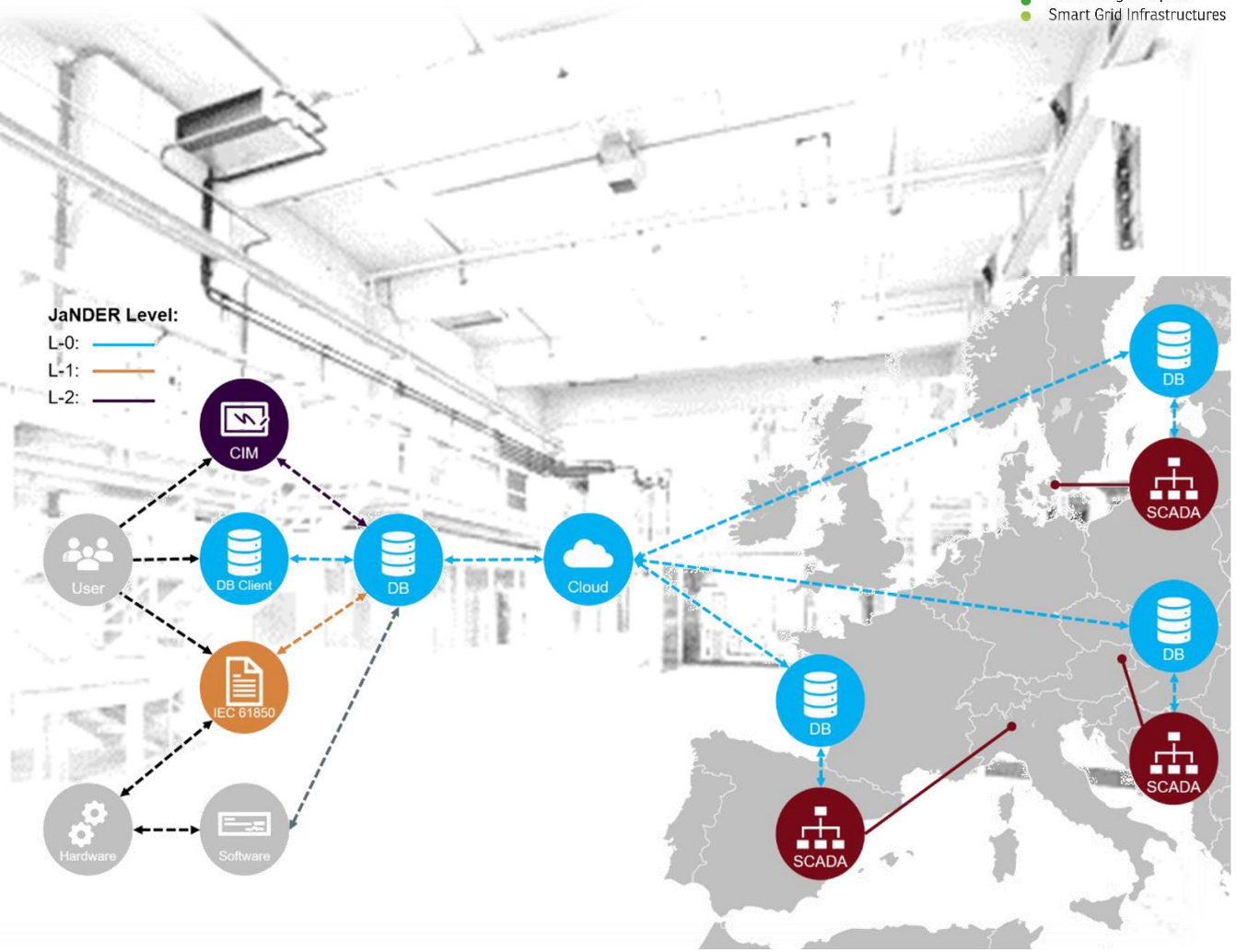

Advanced testing methods and tools

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

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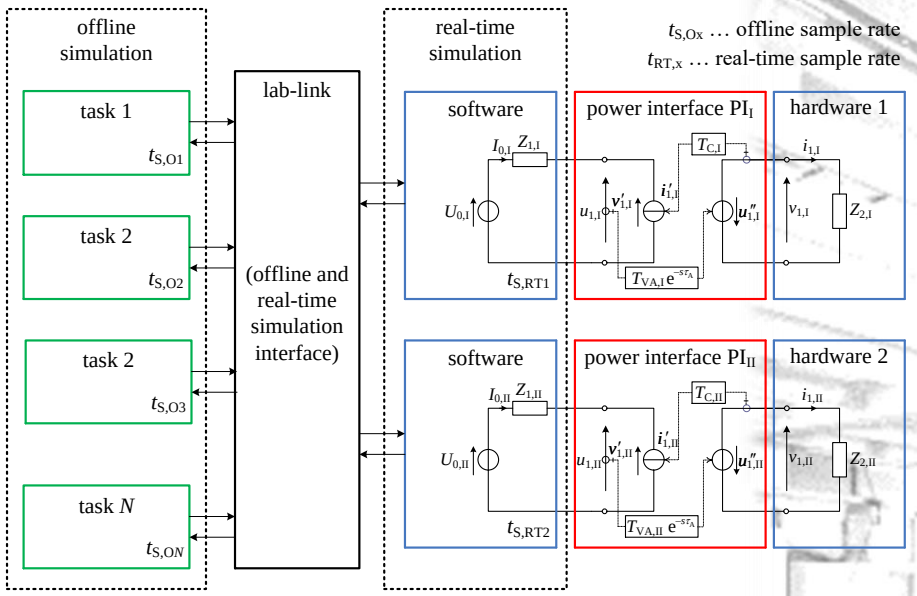

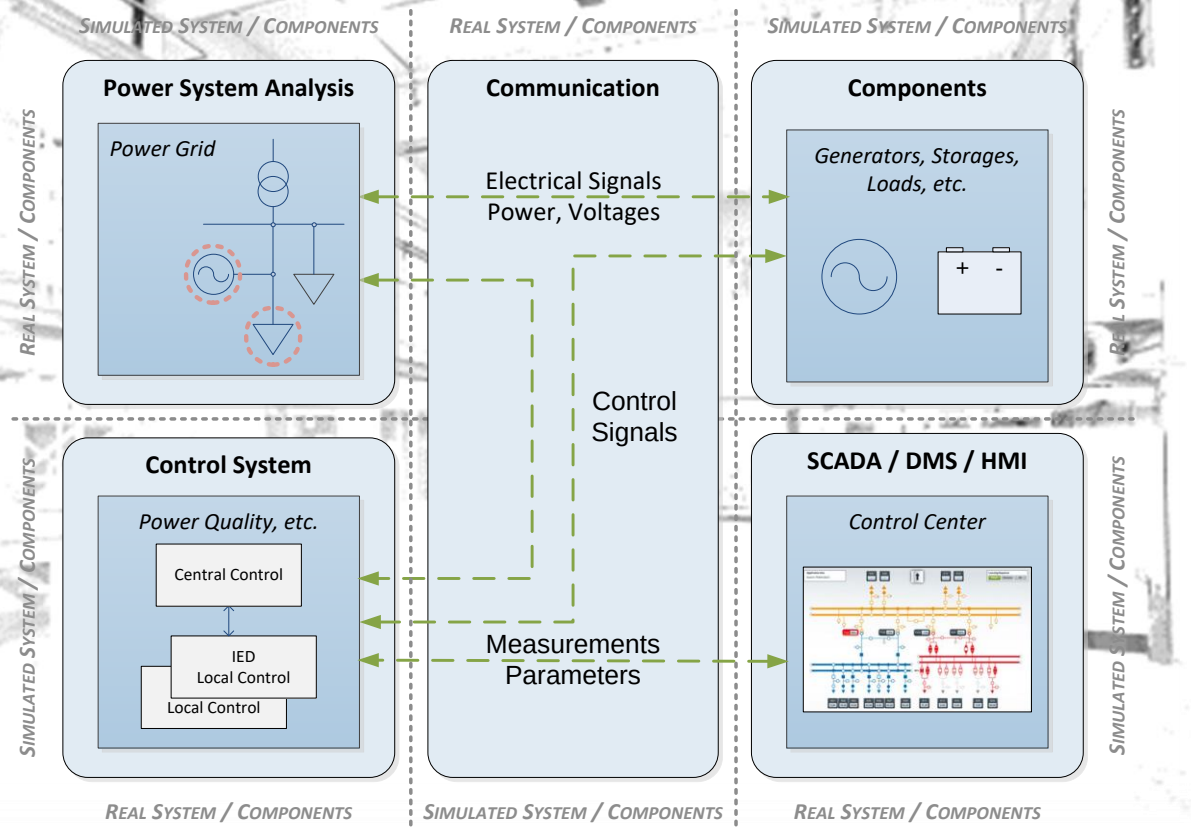

Advanced testing methods and tools

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

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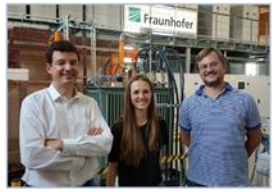
Smart Grid RI “ERIGrid” - Achievements

73
user projects from all over the world gained lab access

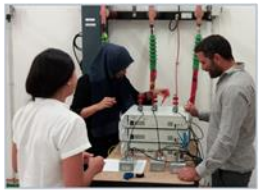
175
engineers accessed best labs of Europe free of charge

20
had companies involved



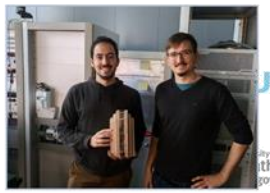
4
multi-side projects (involving more than one laboratory)

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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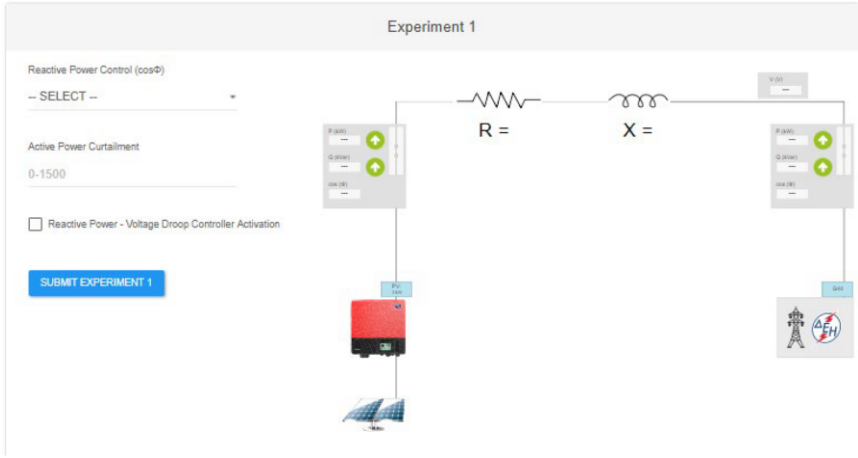
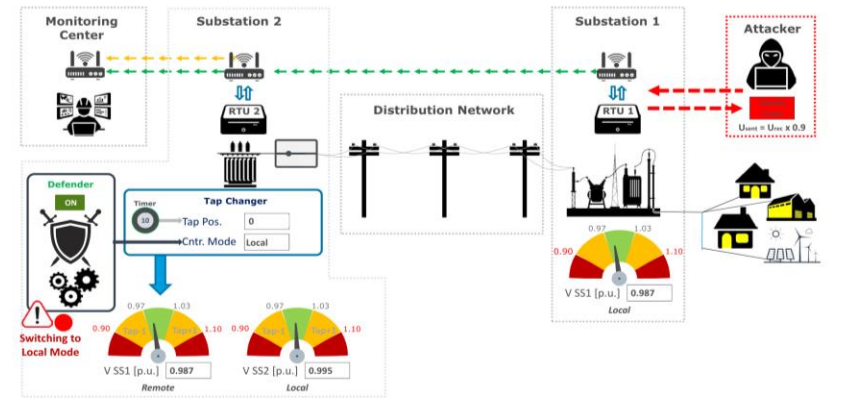
Smart Grid RI “ERIGrid” - Achievements



Remote lab for voltage control experiments



Cyber-resilience tool explaining the impact of cyber attacks

Training of researcher and engineers

- Training schools
- Course/education material
- Tutorials and webinars

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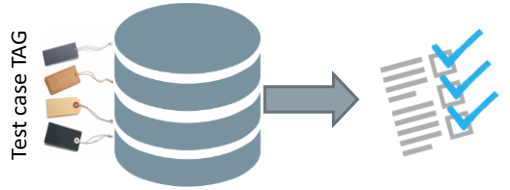
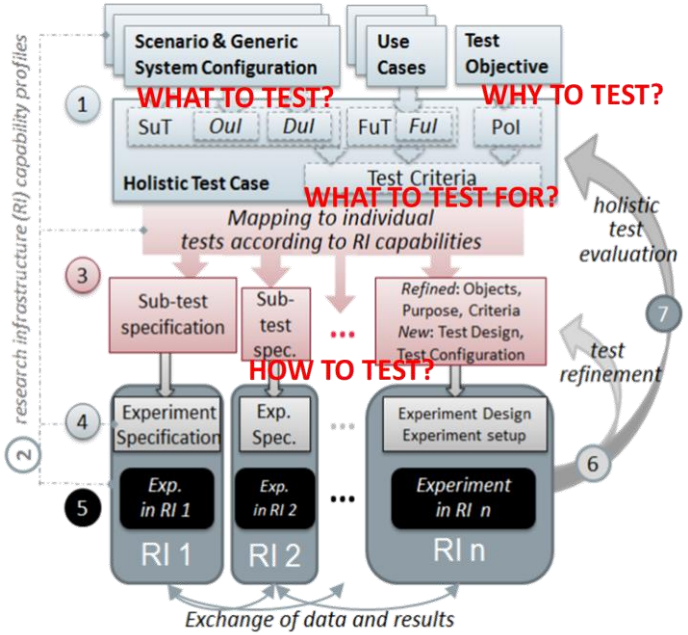
Smart Grid RI “ERIGrid” - Achievements

- Validation methods and tools
  - Integrated pan-European RI
  - System-level validation method and test chain concept
  - Set of open access/source tools (co-/real-time/HIL simulation)
- Training activities
  - Education material (450 impacted students, 450 workshop and 290 webinar participants)
- Lab access programme
  - 73 out of 97 TA user projects supported (~175 persons, ~1,000 lab days)
- Various reports (~50) and over 160 publications …





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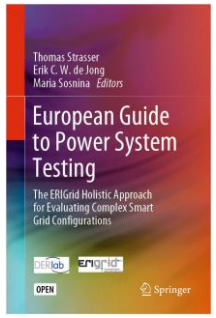
Smart Grid RI “ERIGrid” - Lessons Learned

- Exceptional team work, collaboration and results
- Multi-domain education and training essential
- Great feedback from lab access users
- Open research results contribute to innovation
- Lab-based RIs are essential for energy transition
- Collaboration on international basis important and beneficial
- Attracting enough (industrial) lab user groups



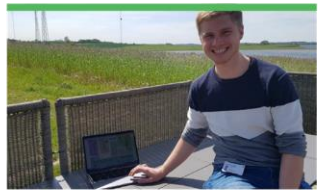
ENABLING A CLEANER DIGITAL DISTRIBUTION GRID

TA project LCA, dedicated to the validation of sensors for smart grid applications in real conditions, horoughly tested the suitability of non-conventional sensor technology for use within their medium voltage gas insulated switchgear.

OPTIMAL CONTROL ALGORITHMS FOR SMART BUILDINGS

The DAMS4IRMA user group tested, validated and analysed the impacts of different control-oriented models of the air-to-water heat pump on the coefficient of performance prediction, especially for the formulation of optimal control problem in presence of variable electricity prices, variable outdoor conditions and variable loads.

NETWORKED FEEDBACK CONTROL OF DER FOR REAL-TIME VOLTAGE REGULATION



TA project TEAM-VAR2 experimentally analysed whether networked control approaches, that use the reactive power capabilities of inverters in distribution grids, are practically able to solve these over- and under-voltage problems.

TRANSIENT CONTROL IN MICROGRIDS

The team of the TA user project TCMG developed a new optimisation method for transient control of networks with a large amount of photovoltaics (PV). The method makes it possible to control all inverters for the PV-system simultaneously.

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Smart Energy Systems “ERIGrid 2.0” - Overview

ERIGrid 2.0 Connecting European Smart Grid Infrastructures

CONSORTIUM COORDINATED BY AIT AUSTRIAN INSTITUTE OF TECHNOLOGY

- 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, smart energy systems, and DER labs
  - 8 virtual facilities

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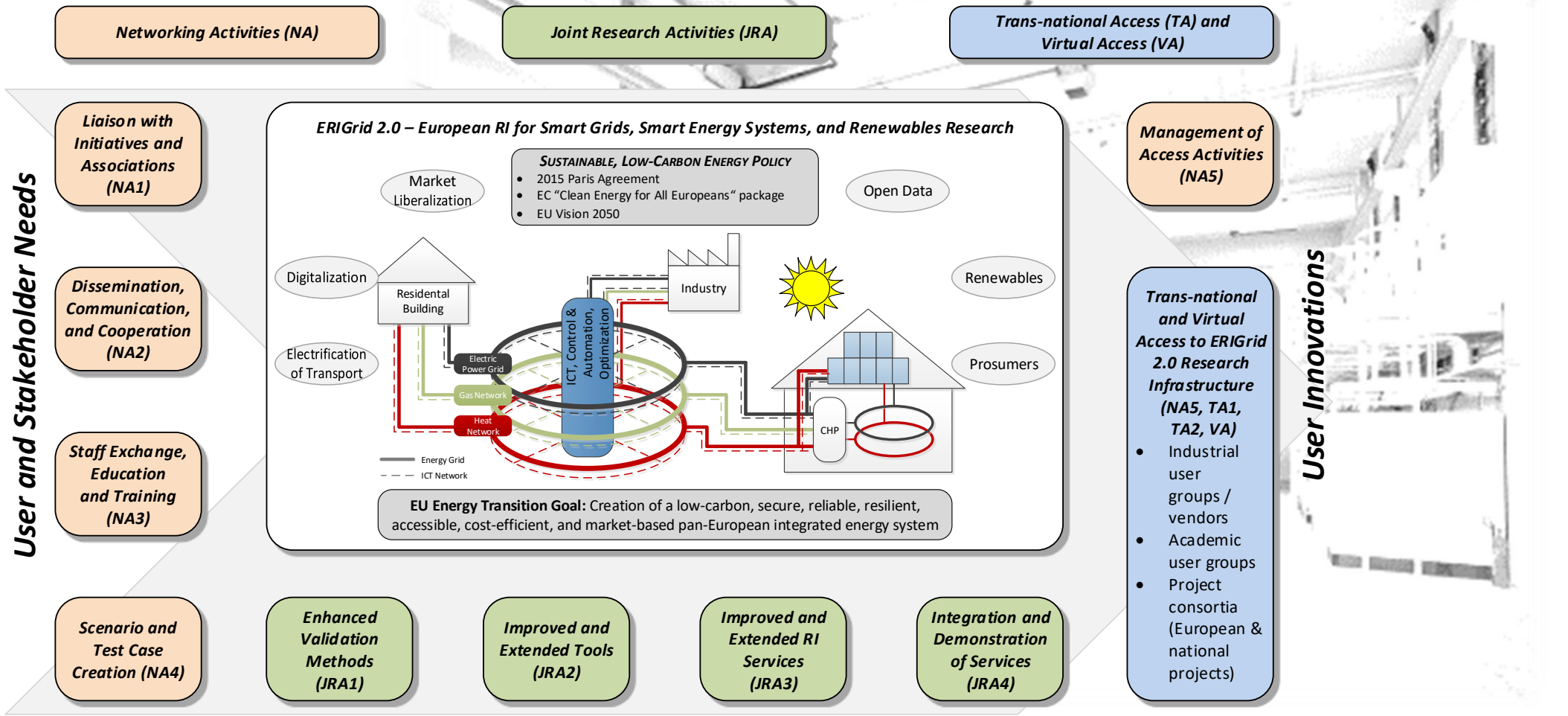
Smart Energy Systems “ERIGrid 2.0” - Approach



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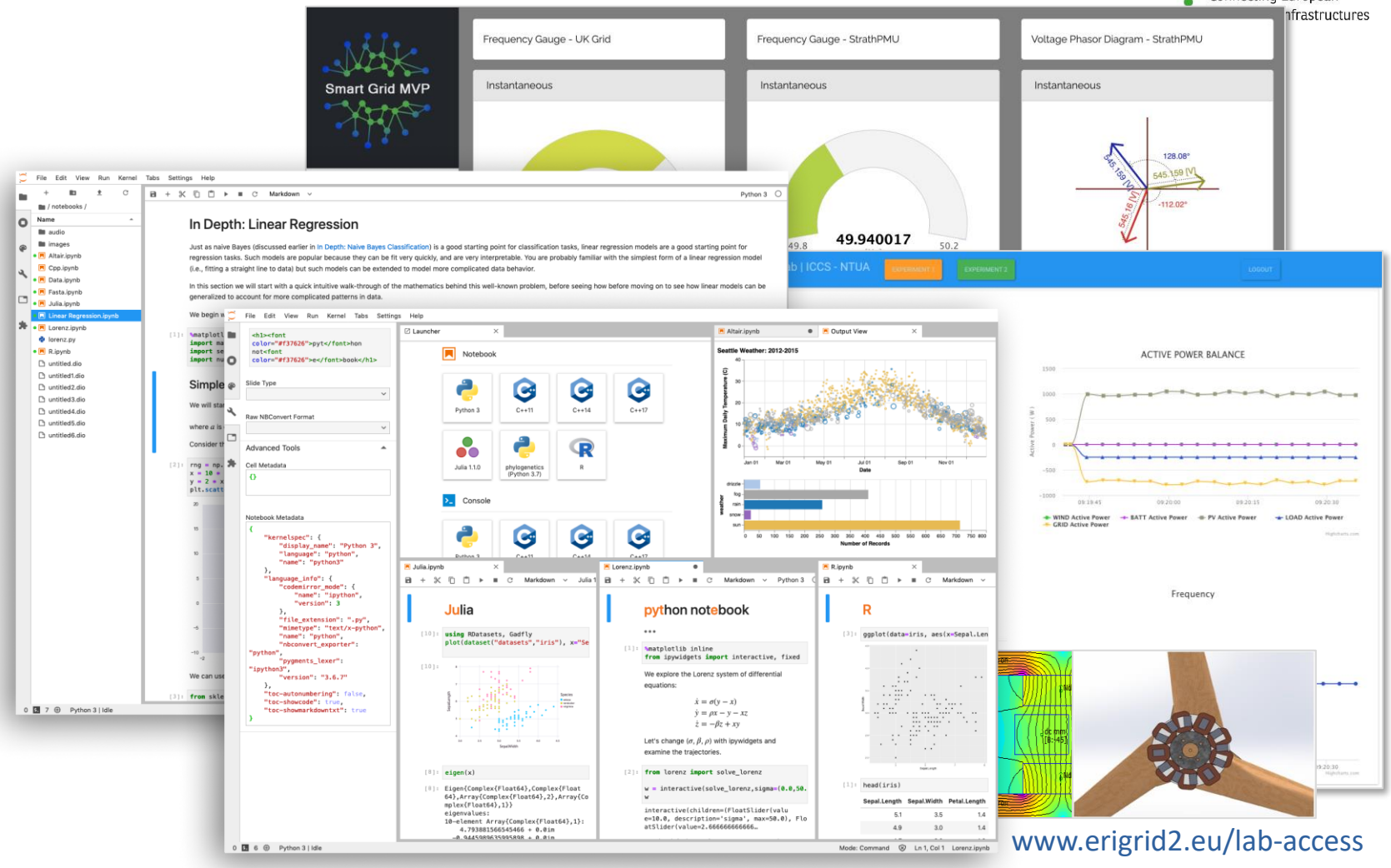
Smart Energy Systems “ERIGrid 2.0” - Virtual Services

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



www.erigrid2.eu/lab-access

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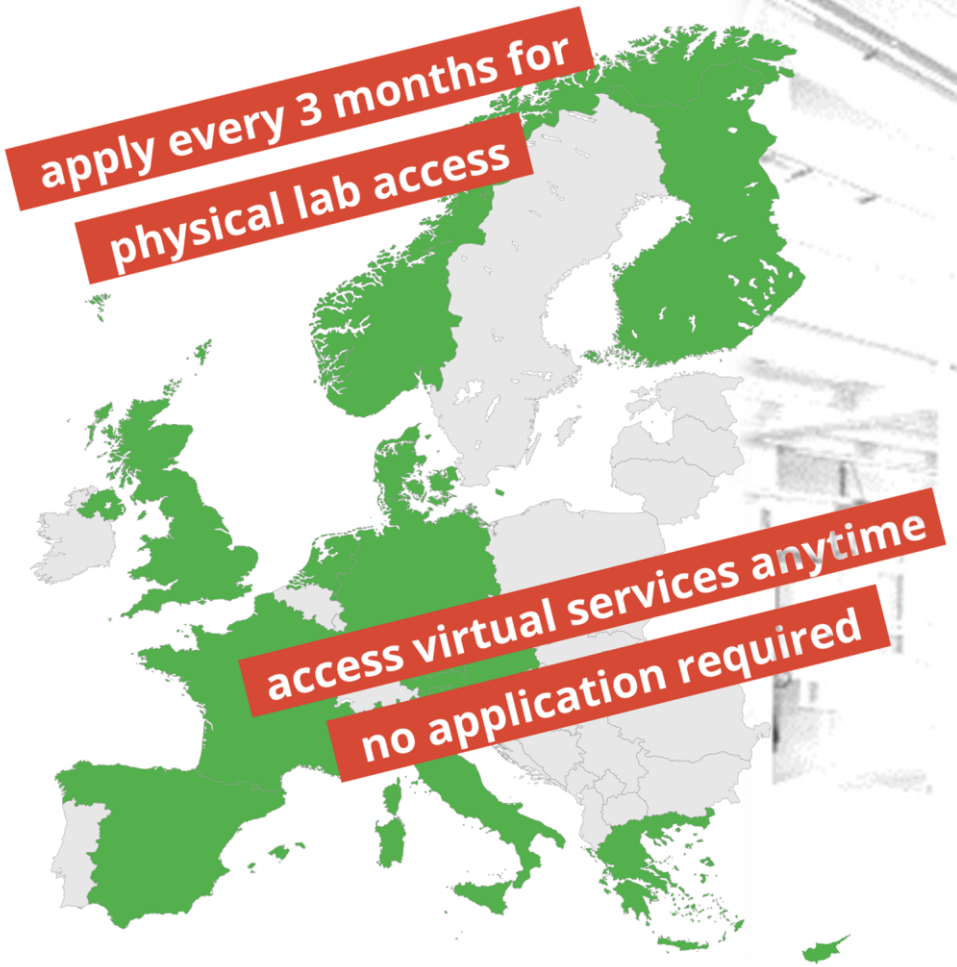

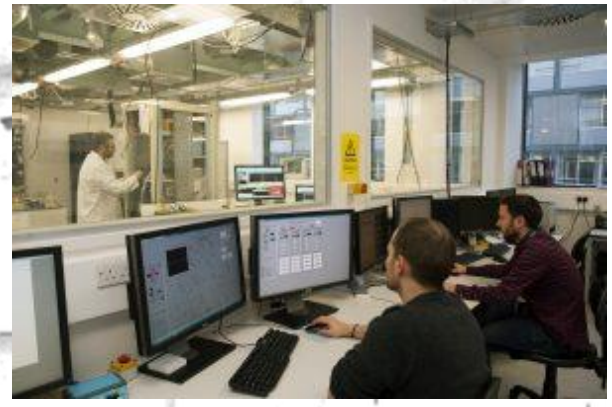

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Conclusions

- Integrated analysis and multi-domain, cyber-physical systems based approach needed for mastering the complexity of smart energy systems
- Methods and tools for system-level testing as well as rapid configuration of lab-setups required
- Smart grid, smart energy systems, and DER research and development services (incl. physical labs) are necessary
- Harmonization and standardization necessary (e.g., IEEE P2004 on HIL)
- Multi-domain education and training essential
- RI/lab-collaboration on international basis very beneficial

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@ERIGrid 2.0 Project

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