Fraunhofer IEG

Fraunhofer IEE

Fraunhofer EMI

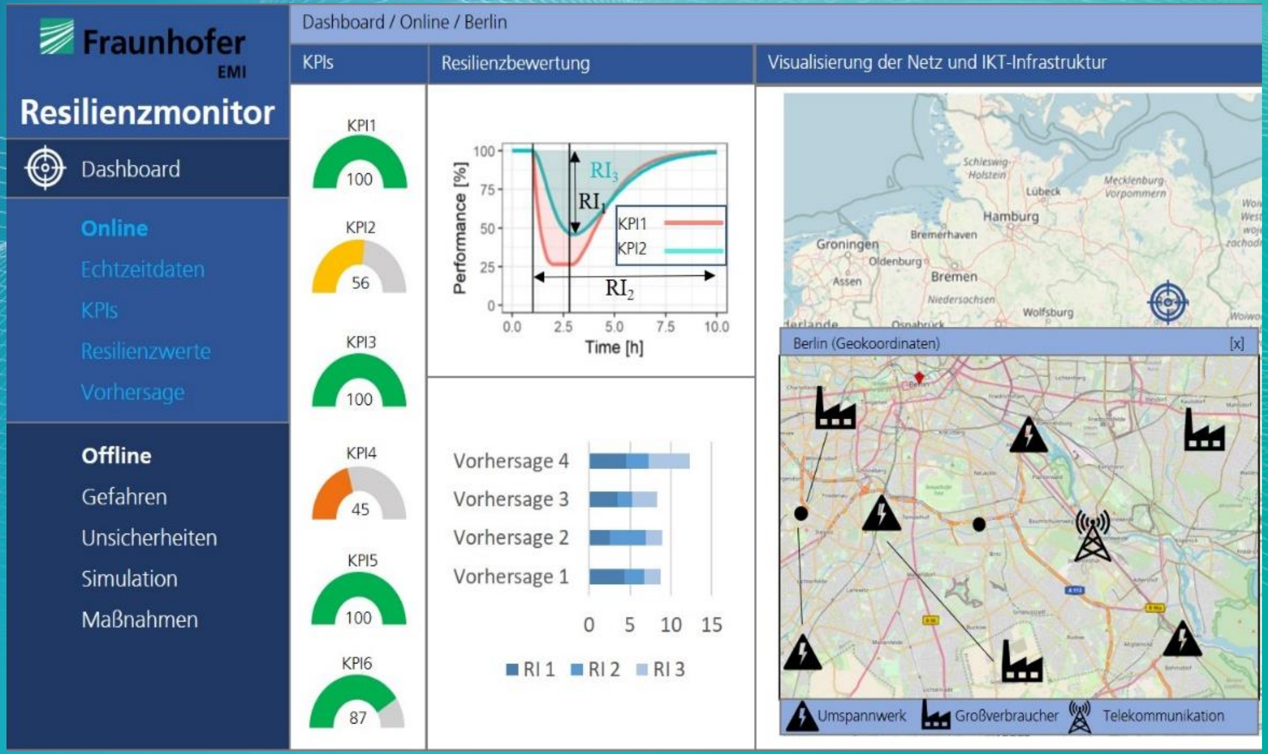
Fraunhofer IOSB

Fraunhofer ISE

RESIST

–

Resilient Power Grids to support the Energy Transition



Overview

Presentation of the project idea

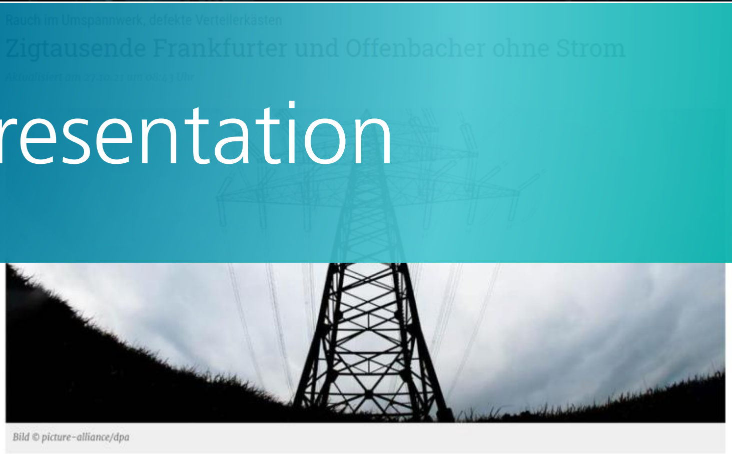
- Status quo: Resilience in power supply
- *The goal of RESIST:*
  A 'Resilient-by-design' power supply
- Presentation of the consortium, its expertise and tools

Presentation of the work packages

- Presentation AP 1- AP 5

Summary and outlook

Project Presentation

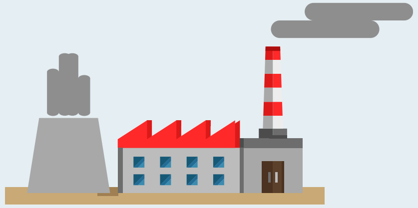


Current developments require to increase power system resilience

Presentation of the project idea

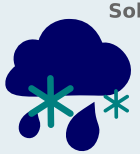
Until today:

- **Conventional stability guarantors**
  Large power plants (coal, nuclear) support robustness of electricity supply



Current developments due to energy transition and climate change

- **Phase out of large power plants**
- **Decentralization of producers**
- **Increasing digitization**
- **Increasing complexity/connectivity**
- **Climate change increases extreme weather events**



<u>Resilient power grid:</u>
Power supply remains permanently available even in the event of massive disruptions and unexpected events.

Resilience of the power grid decreases:

due to growing vulnerabilities

- **Robustness losses due to lower inertia**
- **More extreme weather events**
- **Increased vulnerability due to cyber attacks**
- **Increasing complexity/connectivity favors cascading effects in case of incidents**

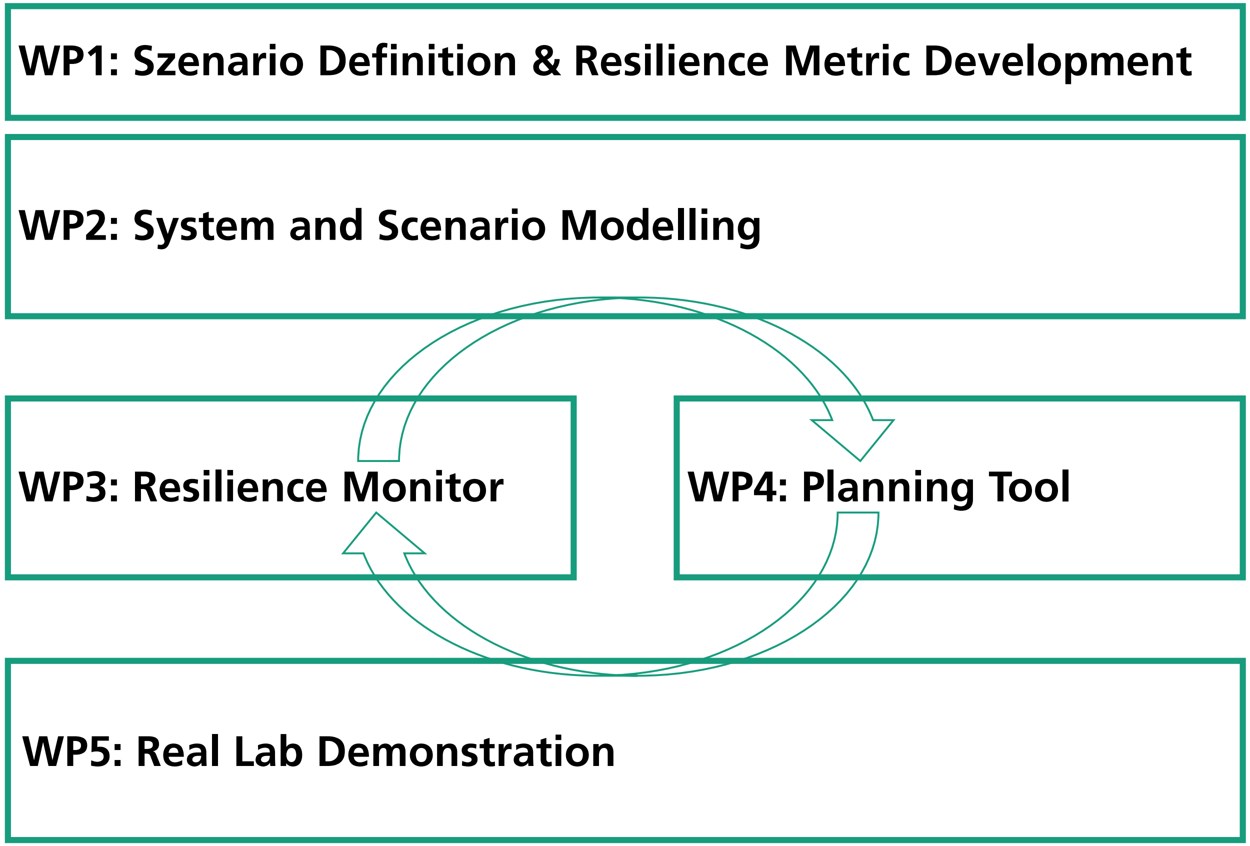
RESIST

StromResist wants to pave the way to *resilient-by-design* power supply

Presentation of the project idea

- **Method development for quantification and real-time detection of power system resilience.**
- **Derive conceptual and technical options for action to increase resilience in the short and long term.**
- **Predictive capability for overall resilience with respect to the impact of structural changes in the network.**
- **Method development for the integration of a "resilient-by-design" approach in the implementation of the energy transition**
- **Implementation of new methods in the real laboratory**

Overall structure of the project



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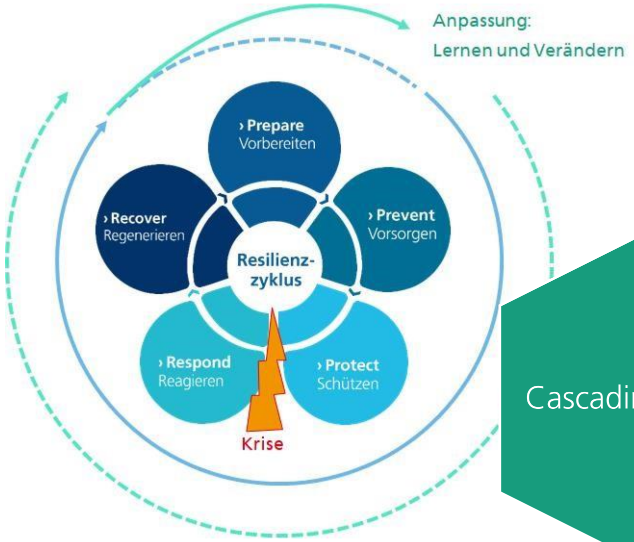
Resilience management meets power supply benchmark technology

Presentation of the project idea

Resilience Management

Resilience engagement strategies are applied to map and implement resilience in power supply in a structured and comprehensive way.



- Creation of the threat scenarios (Technical defect, extreme weather event, cyber attack)
- System analysis
- Parameter development for quantitative resilience measurement
- Resilience evaluation + strategy development based on the resilience cycle
- Cascading effects
- Proposed measures

- Adaptive inverter technology
- Network planning
- Business model innovations for future electricity markets
- ICT systems for power grid management
- Real-time monitoring
- Formation of supply islands

Benchmark technology

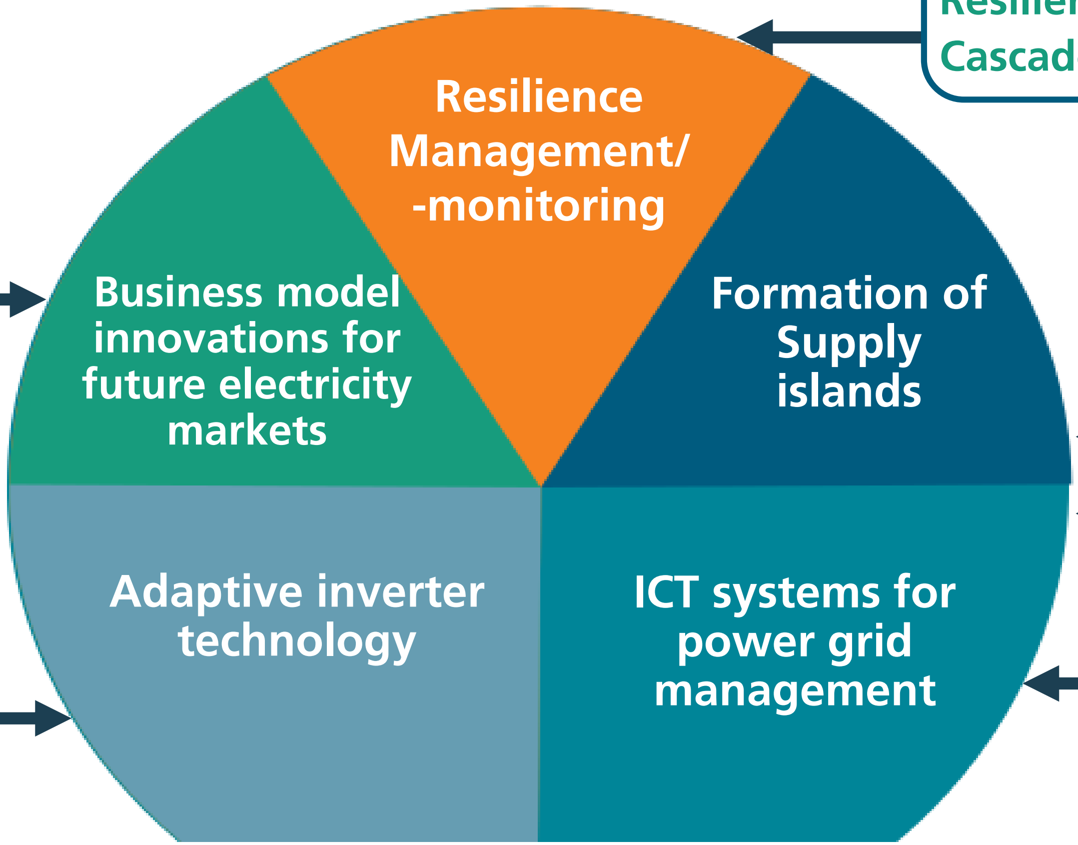
Further development of technologies in power supply through simulations as well as hardware

Consortium possesses expertise in the field of Power Systems and Energy Transition

The consortium

Fraunhofer EMI
Resilience Monitor
Cascade effects

Fraunhofer IEG
Variable electricity price tariffs



Power supply aspects

Fraunhofer IEE
DSA tool
Grid planning tool
Virtual power plant

Fraunhofer ISE
Resilient Inverter

Fraunhofer IOSB
(Digital) substation

The consortium's tools cover all levels of power supply

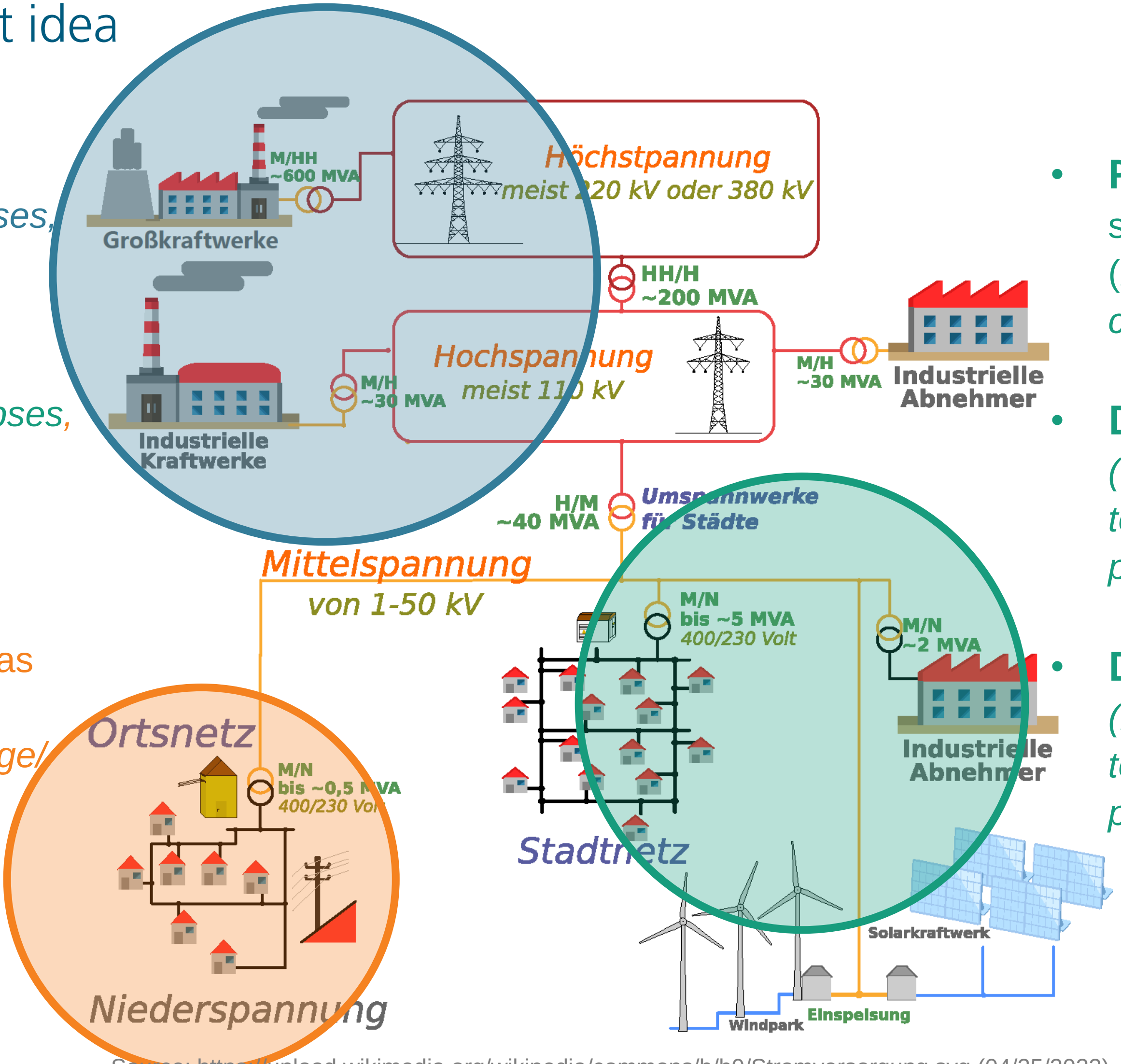
Presentation of the project idea

- **PyDyn (EMI)**
  (network topology, oscillations, frequency stability, network collapses, line failure, system split)

- **CaESAR (EMI)**
  (Infrastructure topology, grid collapses, power plant outages, critical infrastructure affected).

- **Resilience inverter (ISE)**
  Operation in interconnected grids as well as islanded grid sections
  (load/generation time series, voltage/frequency stability, line failure, ..)

- **Variable electricity prices (IEG)**



Source: https://upload.wikimedia.org/wikipedia/commons/b/b0/Stromversorgung.svg (04/25/2022)

- **Planning tool (IEE)**
  static
  (network topology, line failure, short circuits, cascade effects)

- **Digital station (AST)**
  (Line failures, short circuits, ICT topology, [network collapses, power plant failures, ...])

- **DSA Monitor (IEE)**
  (load/generation time series, grid/ICT topology, voltage/frequency stability, power plant outages, ..)

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Overview

WP1: Szenario Definition & Resilience Metric Development

WP2: System and Scenario Modelling

WP3: Resilience Monitor

WP4: Planning Tool

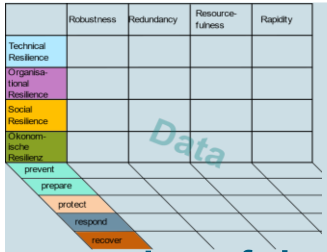
WP5: Real Lab Demonstration

Work Packages

Methodological foundations for a holistic resilience analysis are formed

Presentation of the work packages - WP 1 *Scenario definition and resilience metrics development.*

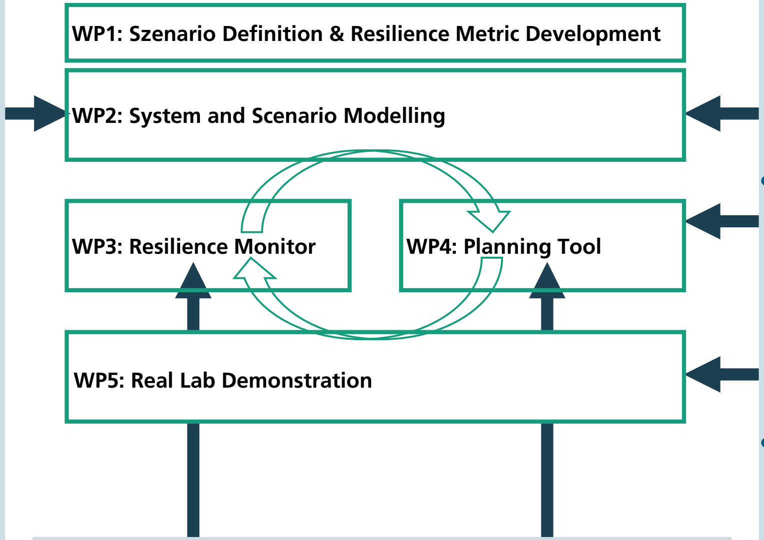
Methodological basis for the holistic resilience analysis of the considered power supply architecture



1. creation of the resilience metric

Basis for quantitative resilience measurement

- **Scales of consideration**
  Federal, state, regional, local and components
- **Structure based on the resilience cycle**
  (Prepare, Prevent, Protect, Respond, Recover)
- **Mapping of all resilience dimensions**
  (technical, organizational, social, economic)
- **And all resilience properties** (robustness, redundancy, adaptive capacity, speed, anti-fragility)



3. Development of methodological approaches to the resilience monitor, strategy tool and resilience inverter.

1. Definition of threat scenarios

- **Technical defect**
  Line protection does not trip, fault in HV grid or HV/MS substation, loss of supply to MV grid, regional blackout
- **Extreme weather event**
  electrical tower is destroyed, loss of supply to LV grid, loss of several HV lines, loss of communication path, ...
- **Cyber attack**
  Manipulation of station communication, manipulation of remote monitoring/control of the Virtual Power Plant.

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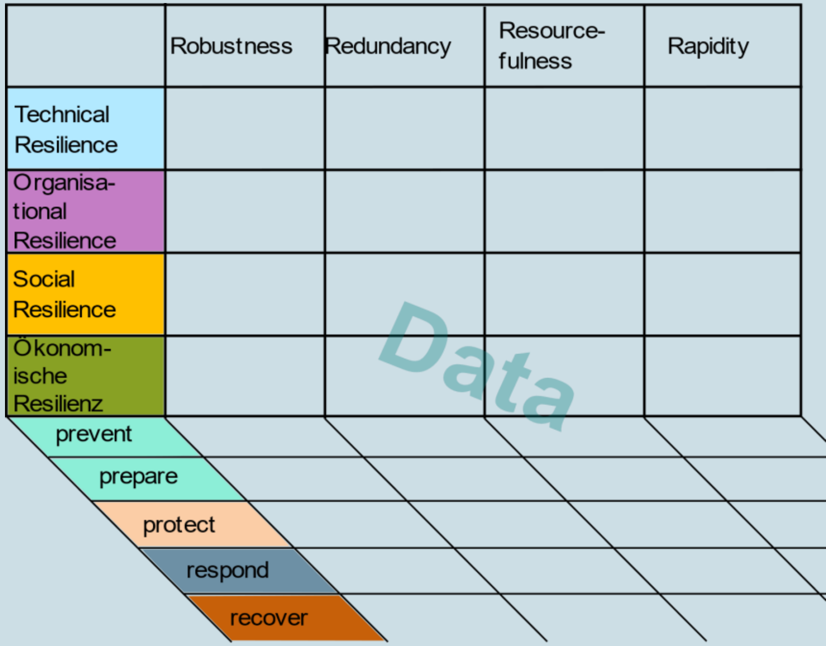
KPI list of the R-metric covers all resilience dimensions

Presentation of the work packages - WP 1 *Scenario definition and resilience metrics*

KPI1: Short-term warning network stability	Voltage/current/frequency (substation, island operation, ..)
KPI2: Physical integrity of the system	Percentage readiness of the islands
	Percentage of destroyed/defective technical components
KPI3: Redundancies	Percentage of grid-stabilizing components on the grid/ full capacity
	Control reserve/redispatch power Percentage target of actual
	Redundancies [percentage of maximum value] (ICT/physical infrastructure [e.g., lines])
KPI4: Control capability	Percentage of functioning communication (VPP/ substation,..)
	Percentage control of DER/VPP/loads, etc.
KPI5: Completeness information	Percentage of available system/network data [e.g. after/in case of IT attack].
KPI6: Consumer/society losses	Number of households affected
	Number of critical infrastructure affected
	Power not provided
KPI7: Costs operator	Costs (measures + defaulted service)

Selection of defined key performance indicators from different resilience dimensions (color-coded).



(Further) development of systems for the simulation of failure scenarios

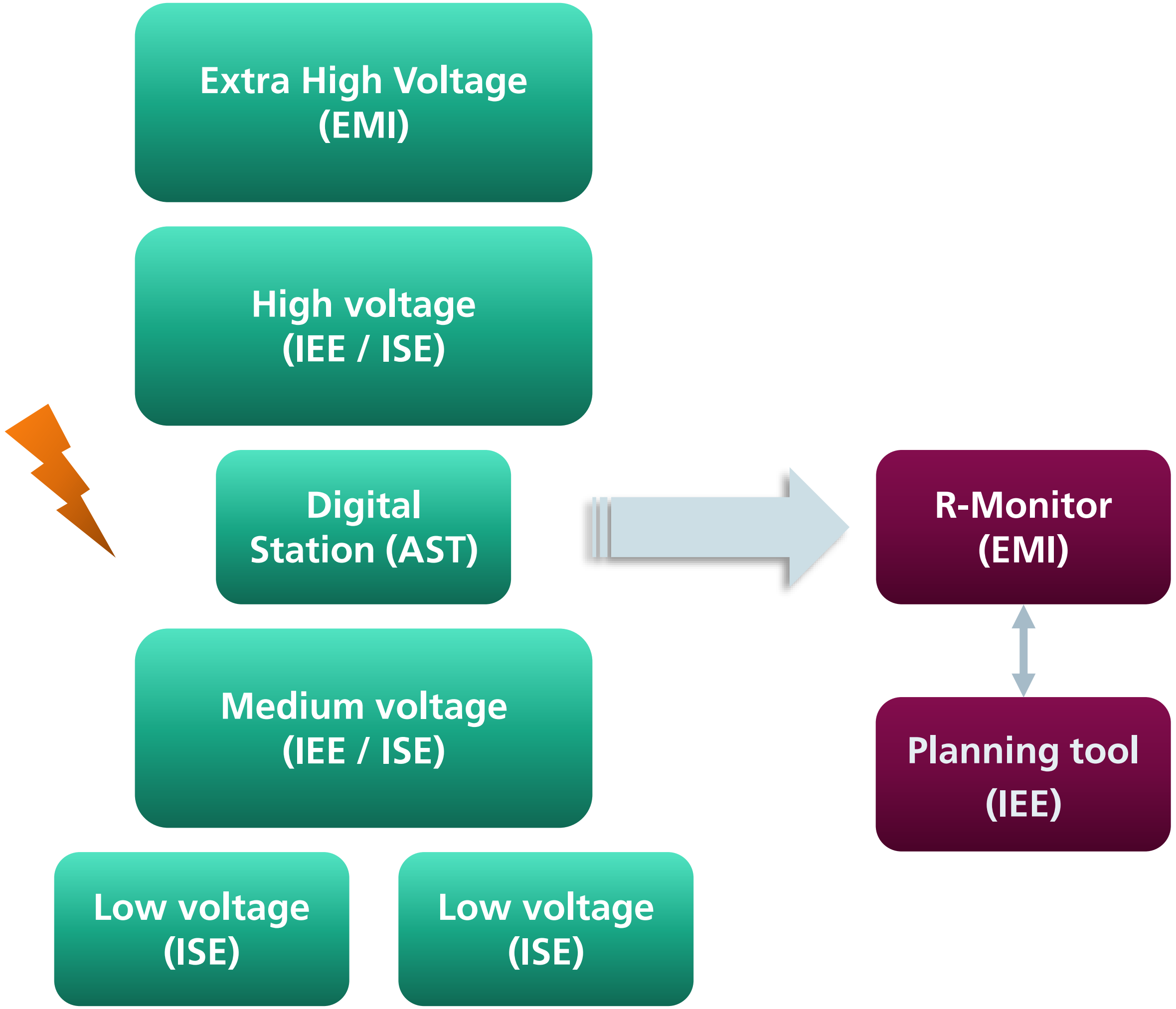
Presentation of the work packages - WP 2 *Modeling of the systems and scenarios*

Generation of the data basis for the resilience monitor

- Complete description of the models as a basis for the development of the Resilience Monitor.
- Further development of simulation models of different power supply units
- Integration of the failure scenarios from WP 1 into systems for simulating the effects
- Generation of simulation data for the resilience monitor

Estimation of the impact of failures for targeted simulations

- Transfer of failures into simulatable scenarios
  - S1 Technical defect
  - S2 Natural disaster
  - S3 IT attack



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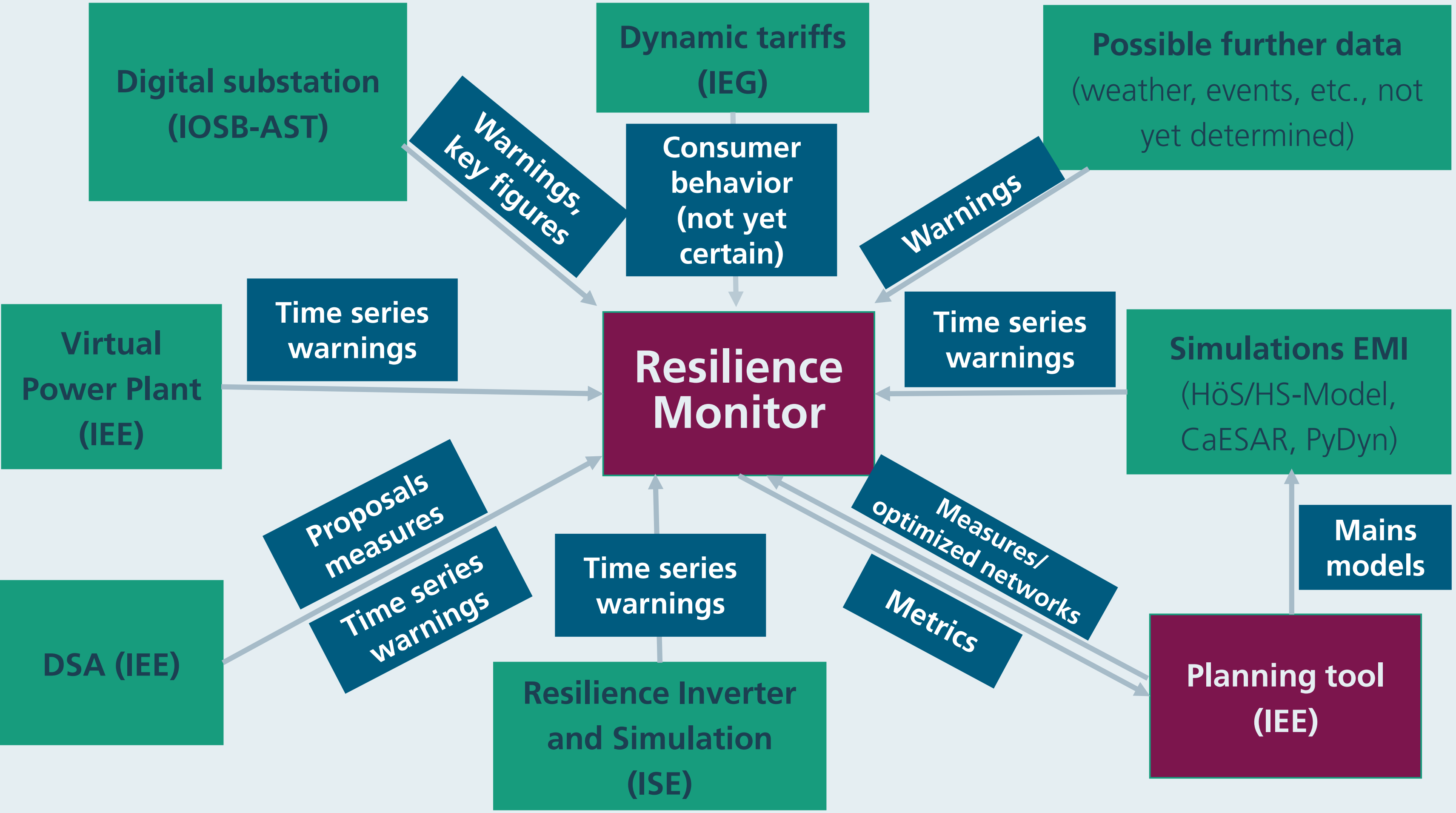
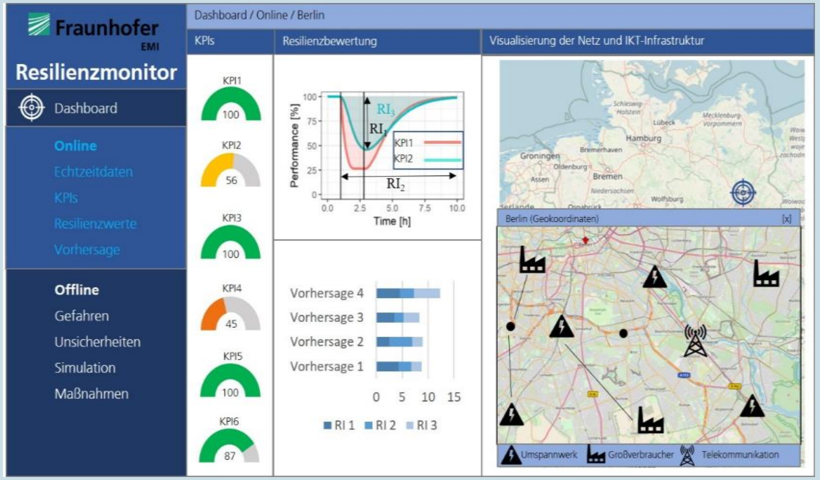
R-Monitor enables real-time analysis through information from other tools

Presentation of the work packages - WP 3 *Resilience* Monitor

- Preparation of the data sets by displaying the KPIs (defined in AP1)
- Processing of the simulated scenarios, derivation of situation criticality
- Visual representation of system resilience, display warnings, references measures
- (Accessible) breakdown of the different network components/levels and resilience dimensions.



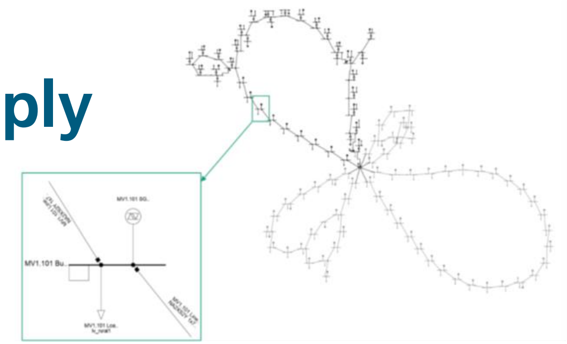
R monitor concept



Concept R-Monitors Surface

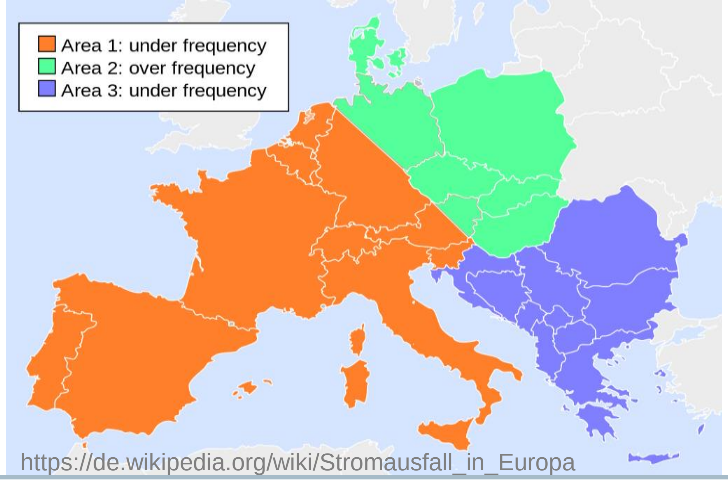
Further tool developments extend investigation of power supply

Presentation of the work packages - WP 3 *Resilience* Monitor



PyDyn

- **Simulation of the transmission network**
- **Failure transmission lines**
- **Possible consequence: system split**

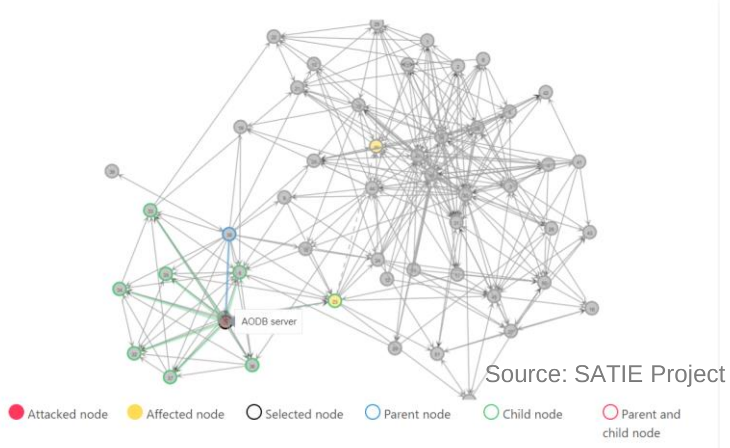


https://de.wikipedia.org/wiki/Stromausfall_in_Europa_im_November_2006

CAESAR

Graph theoretical approach

- **Study of socio-technical aspects**
- **Critical infrastructure affected**
- **Cascading effects in a sociotechnical context.**



Source: SATIE Project

Formation of supply islands

to bridge disruptions in the upstream supply system

- **Large-scale supply island**
  County level, 96 local grid transformer stations.
- **Local supply island/ supply support point**
  Agricultural network island

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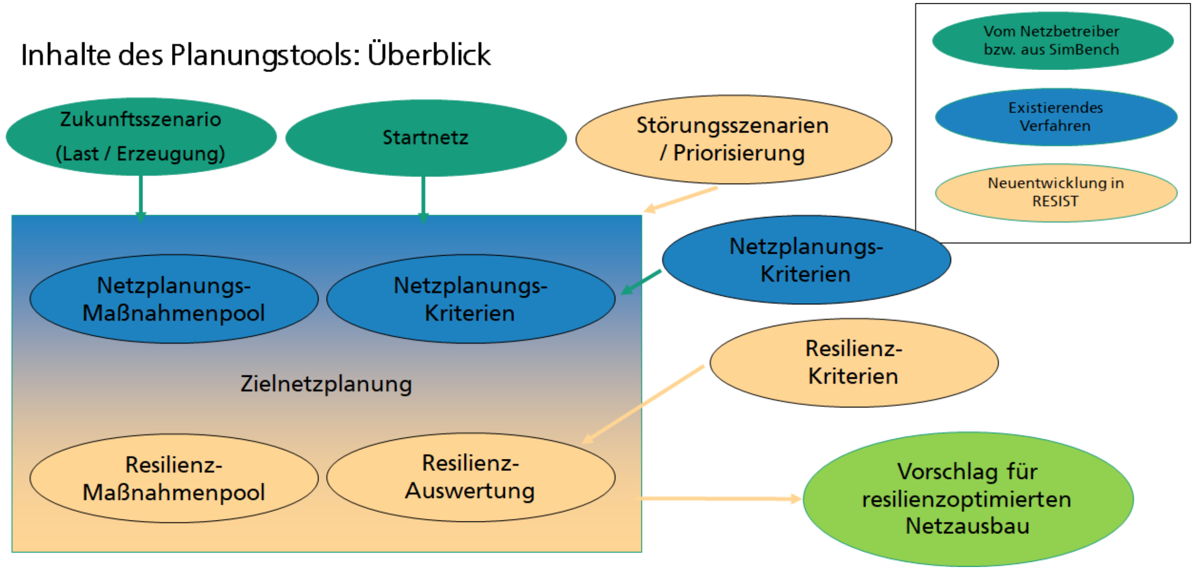
Further tool developments extend investigation of power supply

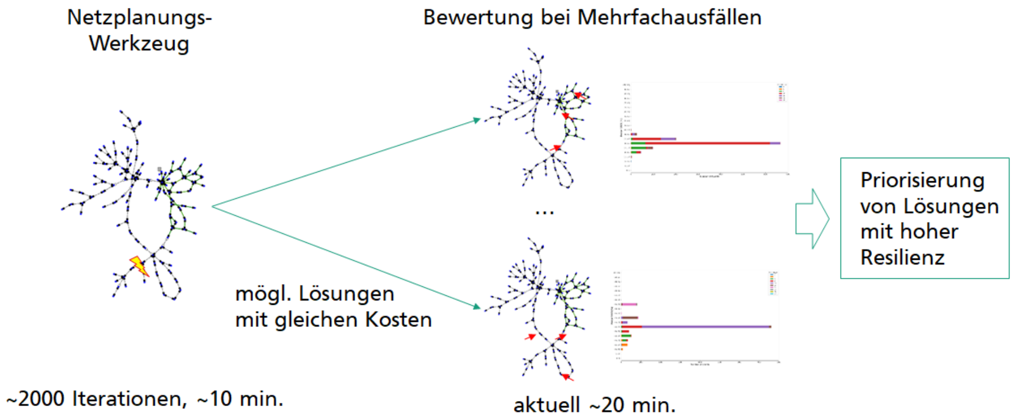
Presentation of the work packages - WP 4 *Decision tool*

Decisions in network planning, which is essentially driven by covering the requirements of normal operation and, if necessary, (n-1) cases, also have an impact on the performance of the system during major disruptions (initially focusing on multiple failures and communication outages).

These influences are systematically examined in order to arrive at recommendations for leveraging improvement potential.



Example: Implementation of target network planning and assessment of resilience with regard to multiple failures.



Laboratory tests for evaluation and optimization

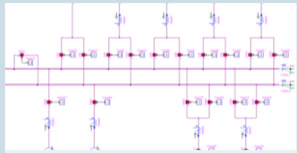
Presentation of the work packages - WP 5 *Real Lab Demonstration*

Damage scenarios

Test specifications

Test environments

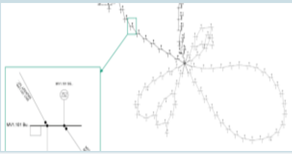
ISE
Network model in HIL with resilience inverter



IOSB-AST
Laboratory demonstrator
Digital station

IEG
Integration of planning variants

IEE
Planning tool



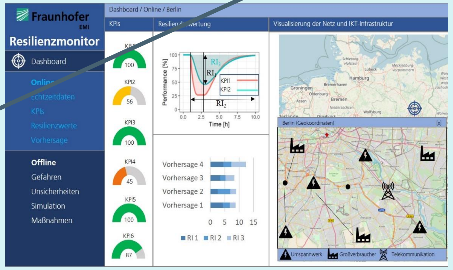
IEE
Mains island
Medium voltage network

IEE
grid island, agricultural learning lab

IEE
Virtual Power Plant

Parameterization and optimization of the inverter

EMI
Resilience Monitor



Execution of tests

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