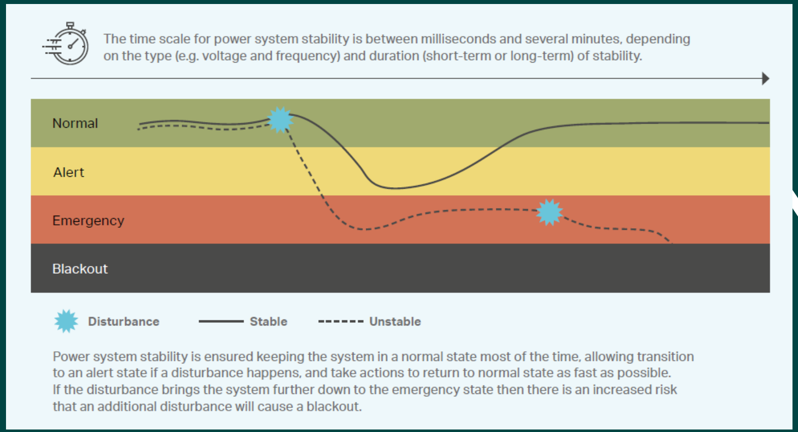
STABIL SYSTEMDRIFT UNDER GRØN OMSTILLING

STABIL SYSTEM OPERATION DURING THE GREEN TRANSITION

HVORDAN KAN STANDARTER UNDERSTØTTE DENNE PROCES



Managing variability and stability during the energy system transition, Megawind 2022

AARHUS UNIVERSITY
DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

DS- ELEKTRODAG
31 JANUARY 2024

BJÖRN ANDRESEN
SECTION HEAD, PROFESSOR (DOCENT)

CONTENT

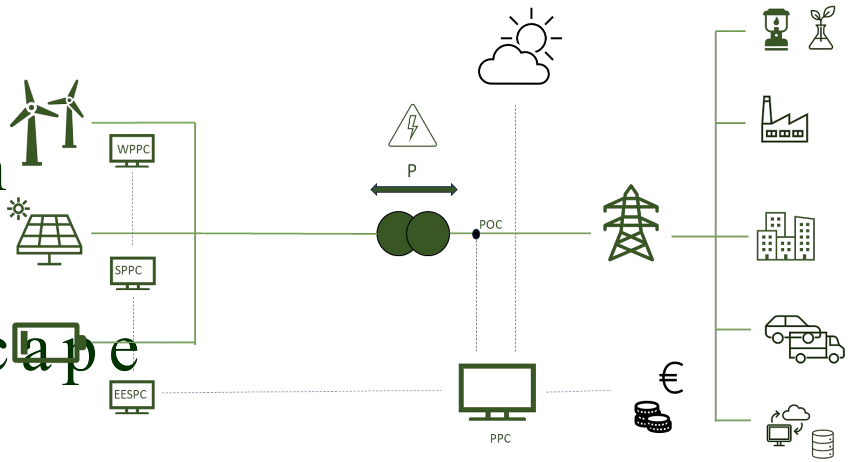
Challenges for a stable system operation

Actual requirements & Standard landscape

Grid Compliance Assessment

Gap Analysis – Standards the missing link

Recommendations & Future tasks



THE ELECTRICAL GRID IN 10, 20, 30 YEARS

In the next 10 to 30 years, we can expect:

1. **Increased Renewable Energy Integration:** More solar and wind power.
2. **Smart Grids and Advanced Metering:** Widespread deployment for grid efficiency.
3. **Advancements in Energy Storage:** Better technologies for grid stability.
4. **Electrification of Transportation:** More electric vehicles, impacting charging infrastructure and grid load.
5. **Decentralization and Microgrids:** Localized power generation for resilience.
6. **Digitalization and IoT Integration:** Enhanced monitoring and control through technology.
7. **Cybersecurity Emphasis:** Focus on protecting digital infrastructure.
8. **Electrification of Industry:** Industrial processes shifting towards electricity.
9. **Grid Modernization Investments:** Efforts to update aging infrastructure.
10. **Policy and Regulatory Changes:** Government policies shaping sustainability, efficiency, and resilience efforts.

STANDARDS SUPPORT THIS TRANSITION

Standards play a pivotal role in facilitating the transition to an advanced electrical grid:

Interoperability:
Standards ensure seamless integration of diverse technologies into the grid, promoting interoperability and compatibility.

Communication Protocols:
Standardized communication protocols enable efficient data exchange between grid components, supporting the implementation of smart technologies.

Cybersecurity:
Standards safeguard the grid against cyber threats, providing criteria and practices for robust cybersecurity.

Grid Resilience:
Standards define guidelines for enhancing grid resilience, ensuring its ability to withstand and recover from disruptions.

Renewable Integration:
Standards facilitate the smooth integration of renewable energy sources, addressing grid codes, power quality, and connection requirements.

Energy Storage:
Standardizing energy storage technologies ensures safety, performance, and efficient integration into the grid.

EV Charging:
Standards for electric vehicle charging infrastructure promote interoperability and efficient energy management.

Demand Response:
Standards guide demand response programs, aiding in balancing supply and demand during peak periods.

Grid Planning and Operation:
Standards provide guidelines for efficient grid planning and operation, covering capacity planning, load forecasting, and system reliability.

THE GRID IN 10, 20, 30 YEARS

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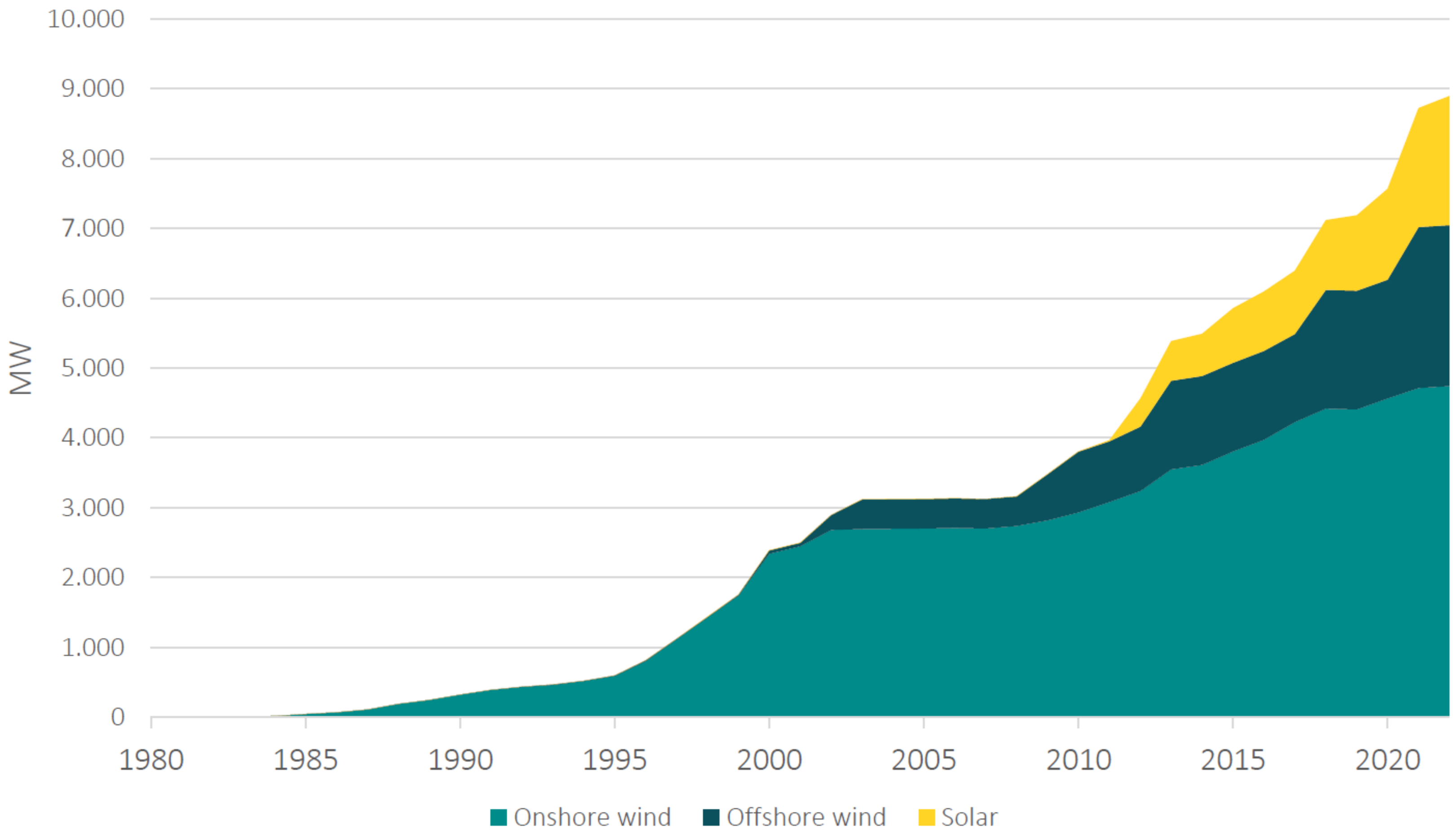
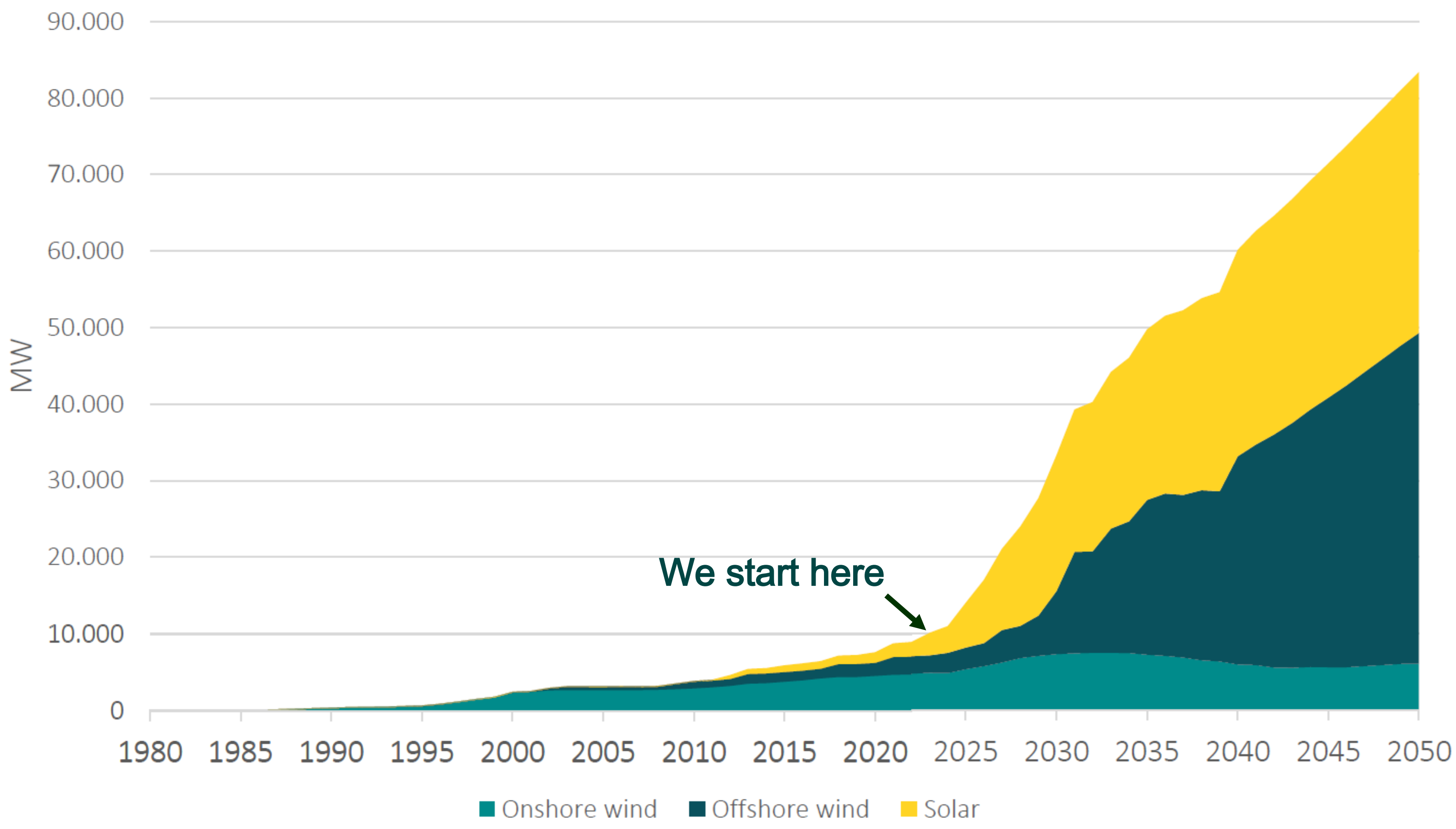
THE ELECTRICAL DK SYSTEM THE LAST 30 YEARS



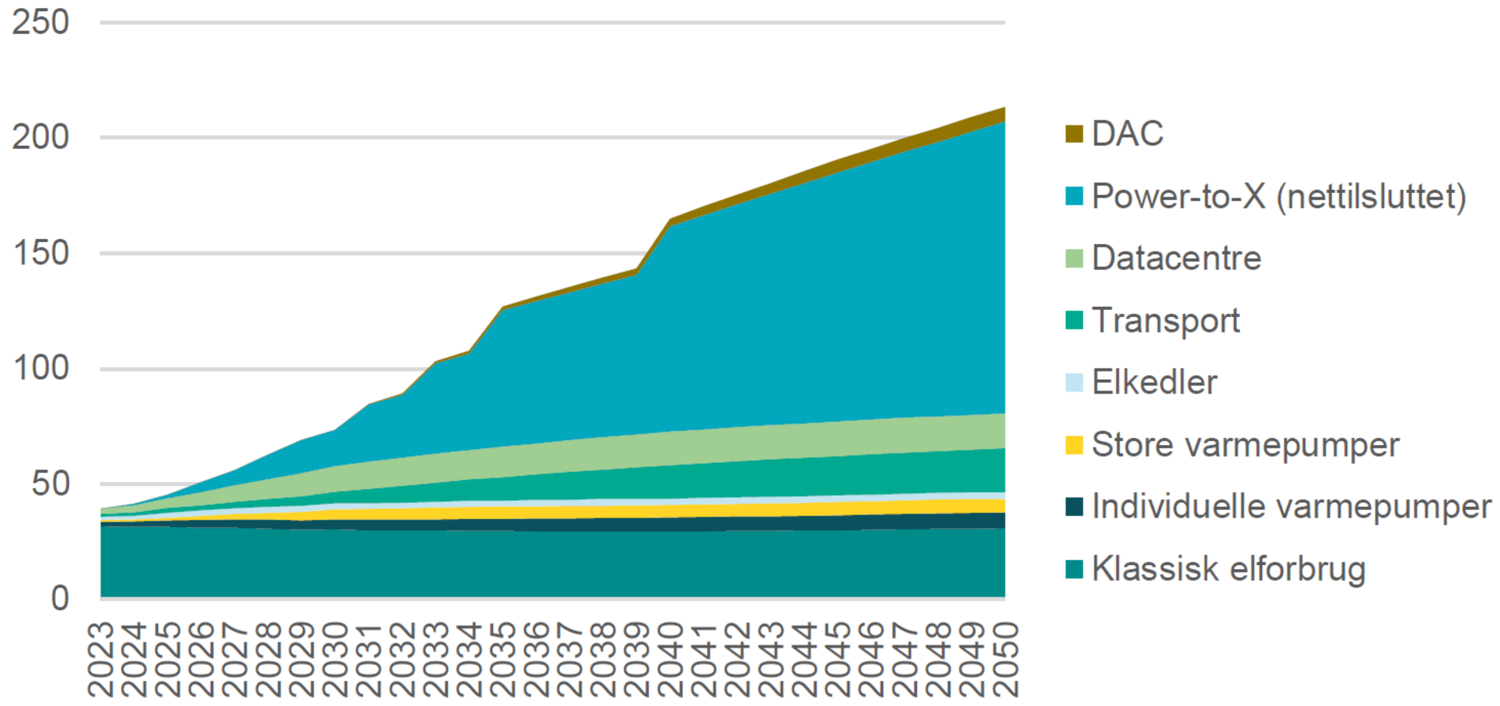
Source: Martin Hartvig, energinet.dk, AF22

THE FUTURE ELECTRICAL DK SYSTEM OUTLOOK



Source: Martin Hartvig, energinet.dk, AF22

THE FUTURE ELECTRICAL SYSTEM OUTLOOK



Source:Energistyrelsen,
Anlayseforudsætninger AF2023

Challenges

4 times more Wind & PV until 2030 in DK

8-10 times more Wind & Sol until 2050 in DK

6 times higher electrical consumption in DK

Need for 2-3 times more El-transport capacity in DK

Investments for the next decade in the grid

Around 5,3 bn € in DK

Around 150 bn € in DE

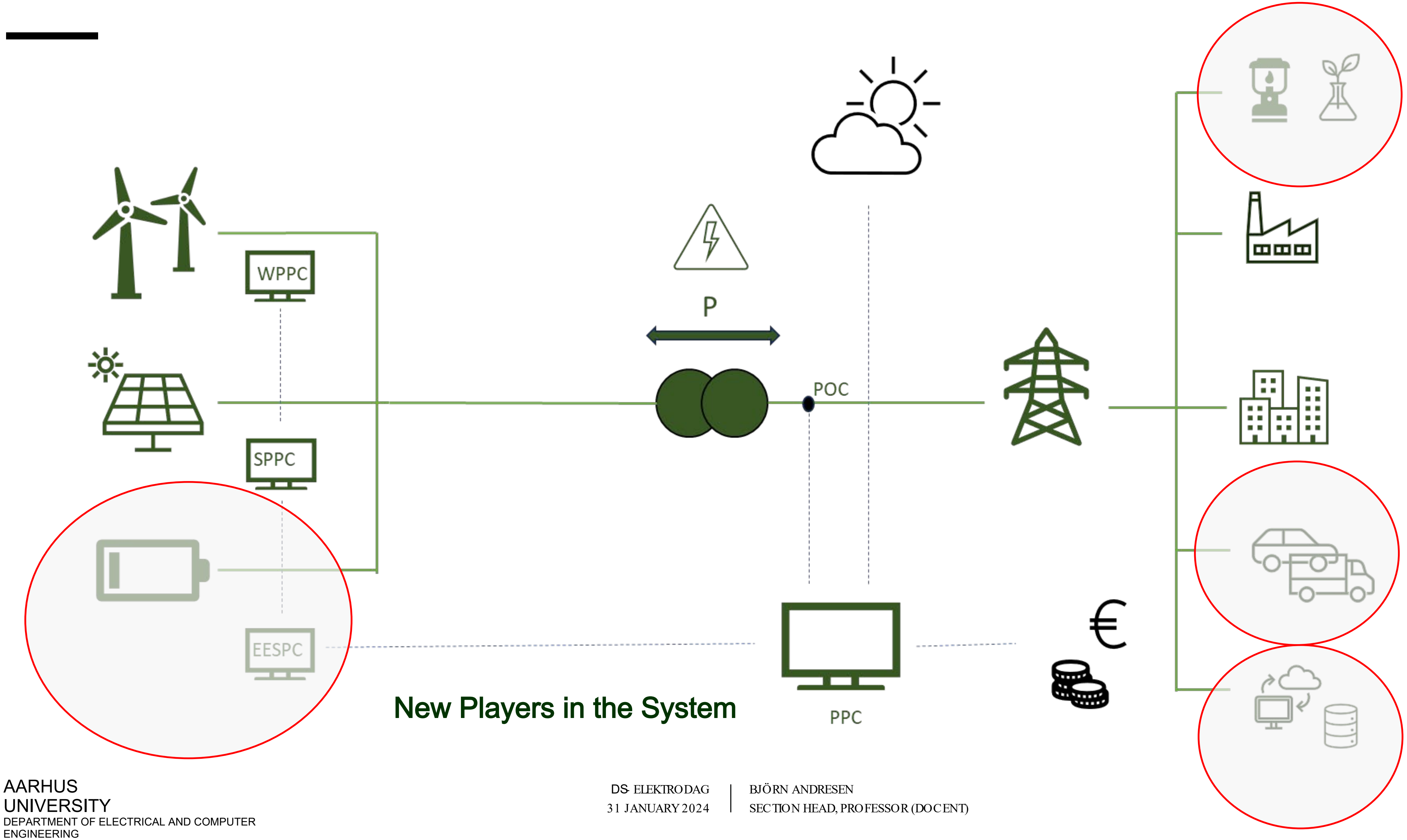
Around 584 bn € in EU

Worldwide doubling of the electrical grid

(> 80 Mil km)

Source: Grids, the missing link- An EU Action Plan for Grids. Nov 2023

THE FUTURE ELECTRICAL SYSTEM SIMPLIFIED



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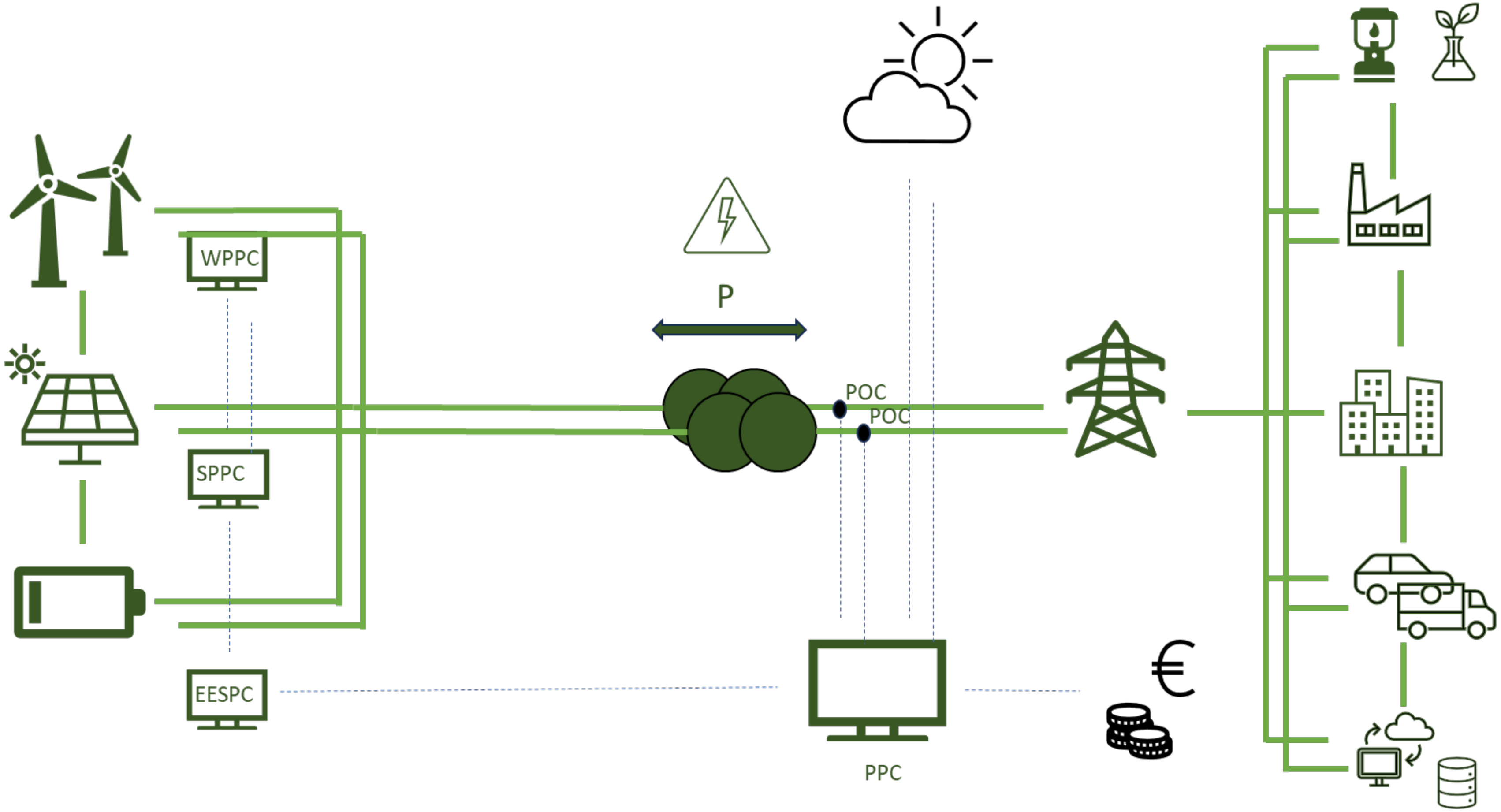
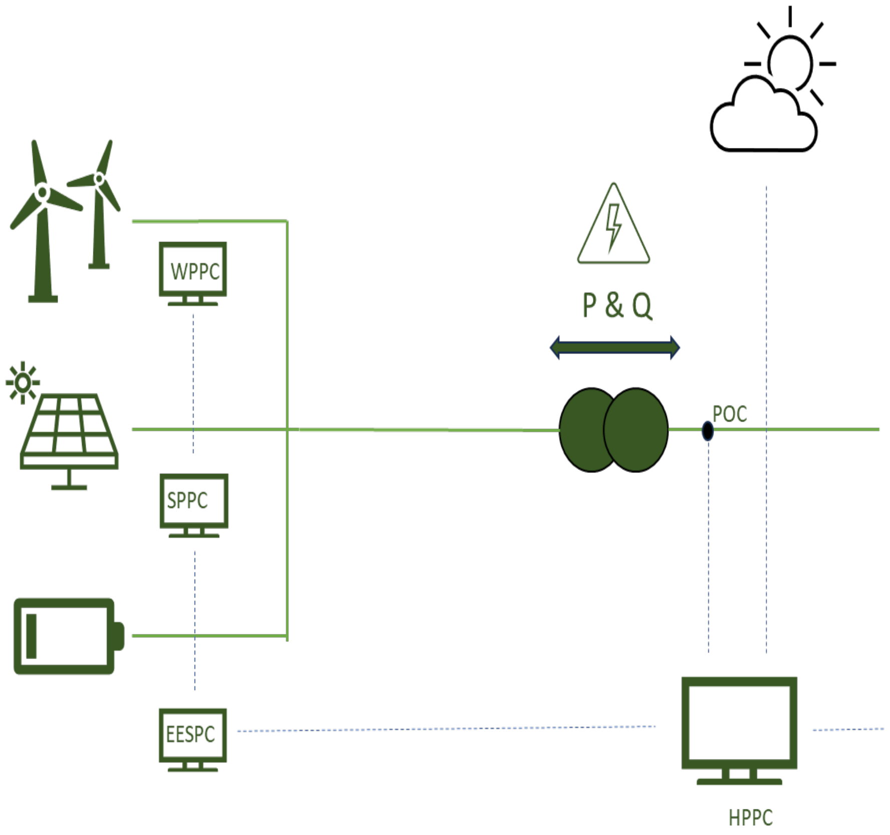
Blackout

THE FUTURE ELECTRICAL SYSTEM CHALLENGE



IEC STANDARD ORGANIZATIONS ROLES & RESPONSIBILITIES

ROLES & RESPONSIBILITIES – POWER GENERATION



Grid connection codes

- Defines requirements on generation and consumer systems – partly "Technology independent"
- RfG, NGC, NERC, … – International and national niveau

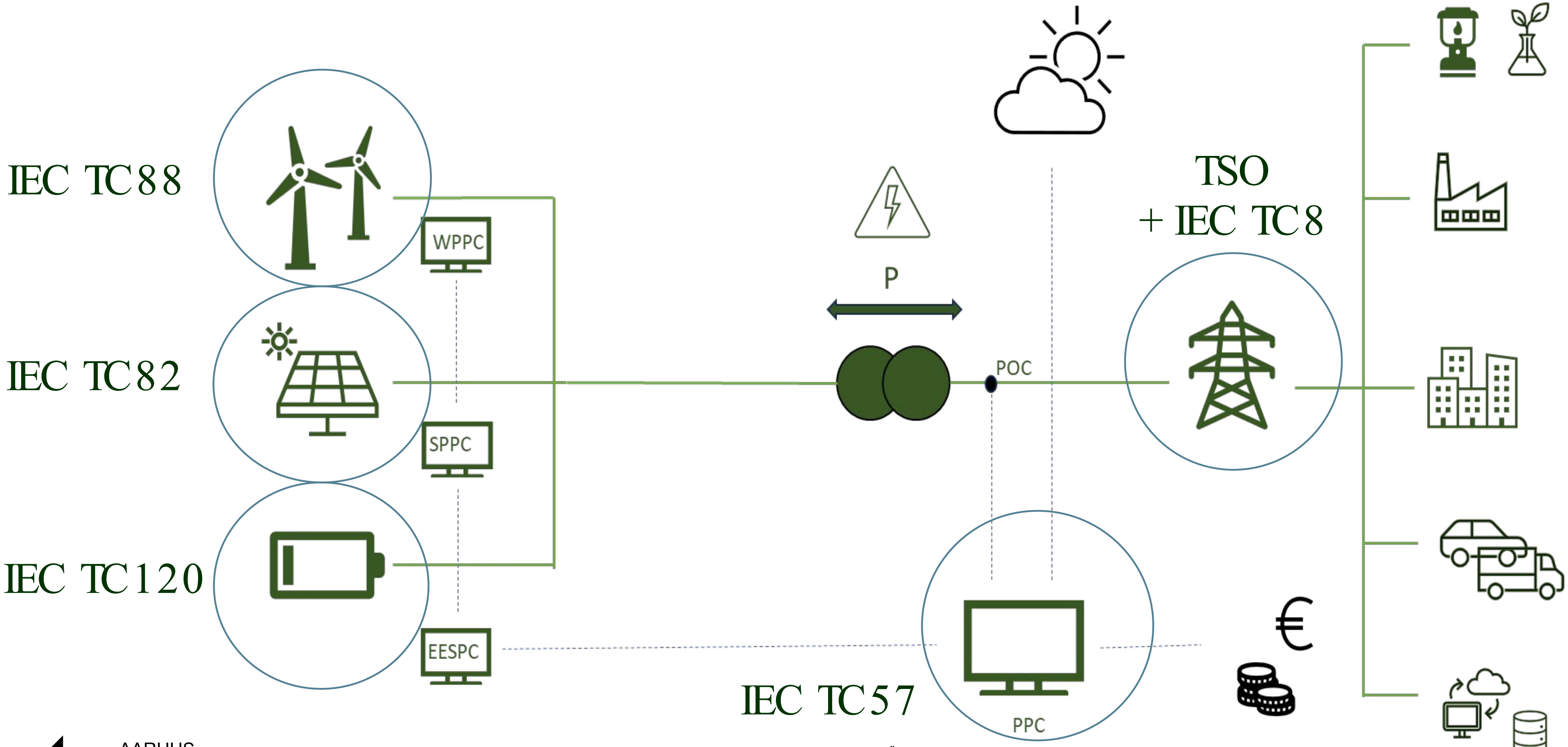
Standards, Specifications

- Standard organisations defines test, simulation and validation requirements in relation to technology areas – Wind, PV, Storage,
- IEC, CEN / CENELEC, ISO, IEEE, VDE, DS – International and national

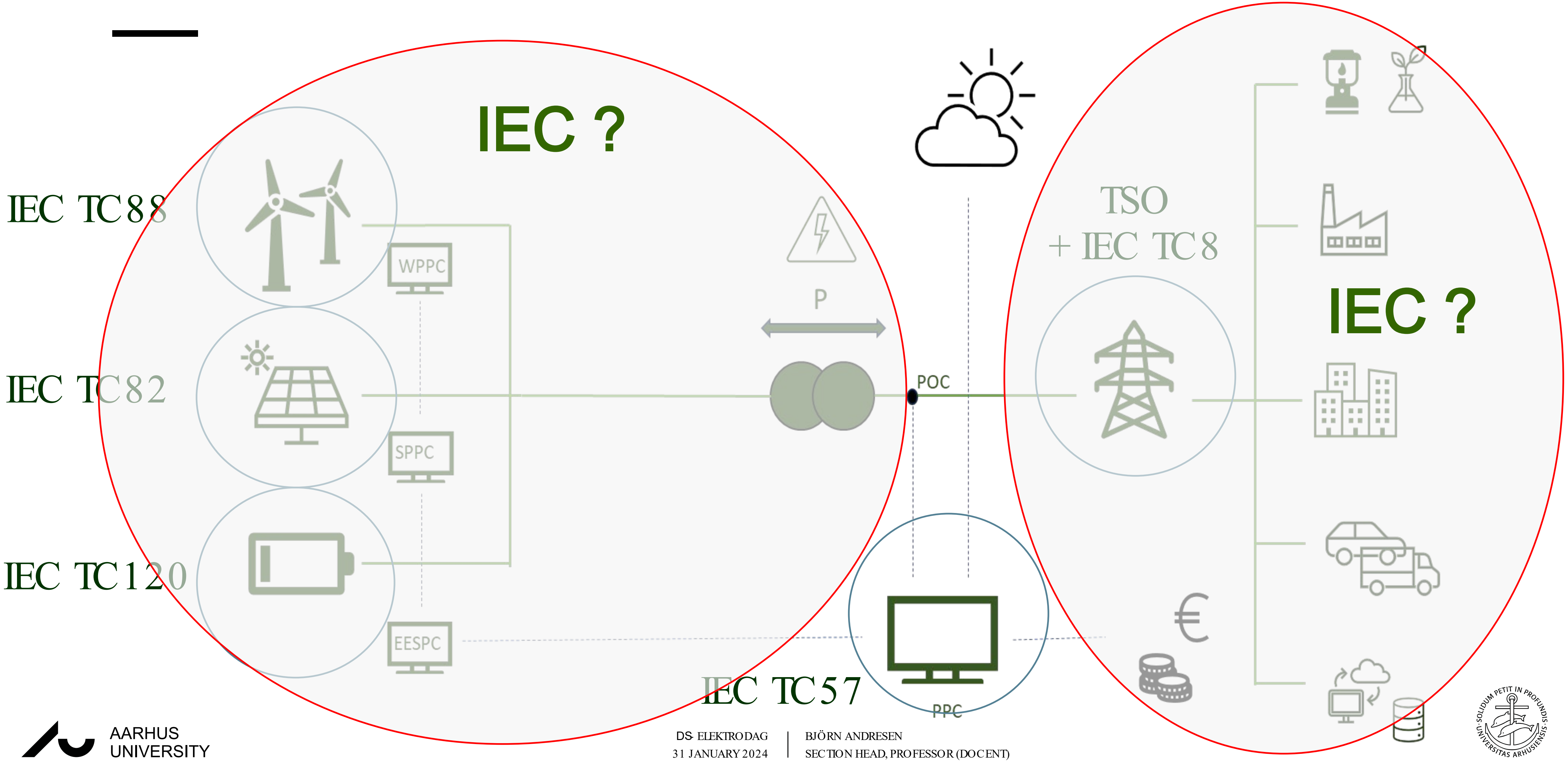
Product Technologies

- Defines specific product specifications, functionalities, certifications and services in relation to the electricity sector
- IEC, IECRE, ISO – International and national

IEC AREAS IN RELATION TO POWER SYSTE



IEC AREAS IN RELATION TO THE FUTURE GI



E.G.PTX–GRID INTEGRATION ASPECTS

Power-to-X (PtX) systems involve the conversion of electrical power into another form of energy or a chemical substance. The applicable IEC (International Electrotechnical Commission) standards for Power-to-X systems may depend on the specific technologies and processes involved. As of my last knowledge update in January 2022, here are some relevant areas and potential IEC standards:

IEC 62282 Series: Fuel Cell Technologies: This series of standards addresses fuel cell technologies, which might be relevant for certain types of Power-to-X systems that involve fuel cells for energy conversion.

IEC 61724 Series: Photovoltaic System Performance Monitoring: If your Power-to-X system involves solar energy, the IEC 61724 series provides standards for the performance monitoring of photovoltaic systems.

IEC 61803: Determination of Power Losses in High-Voltage Direct Current (HVDC) Converter Stations: For PtX systems involving HVDC technology, this standard provides guidance on determining power losses in HVDC converter stations.

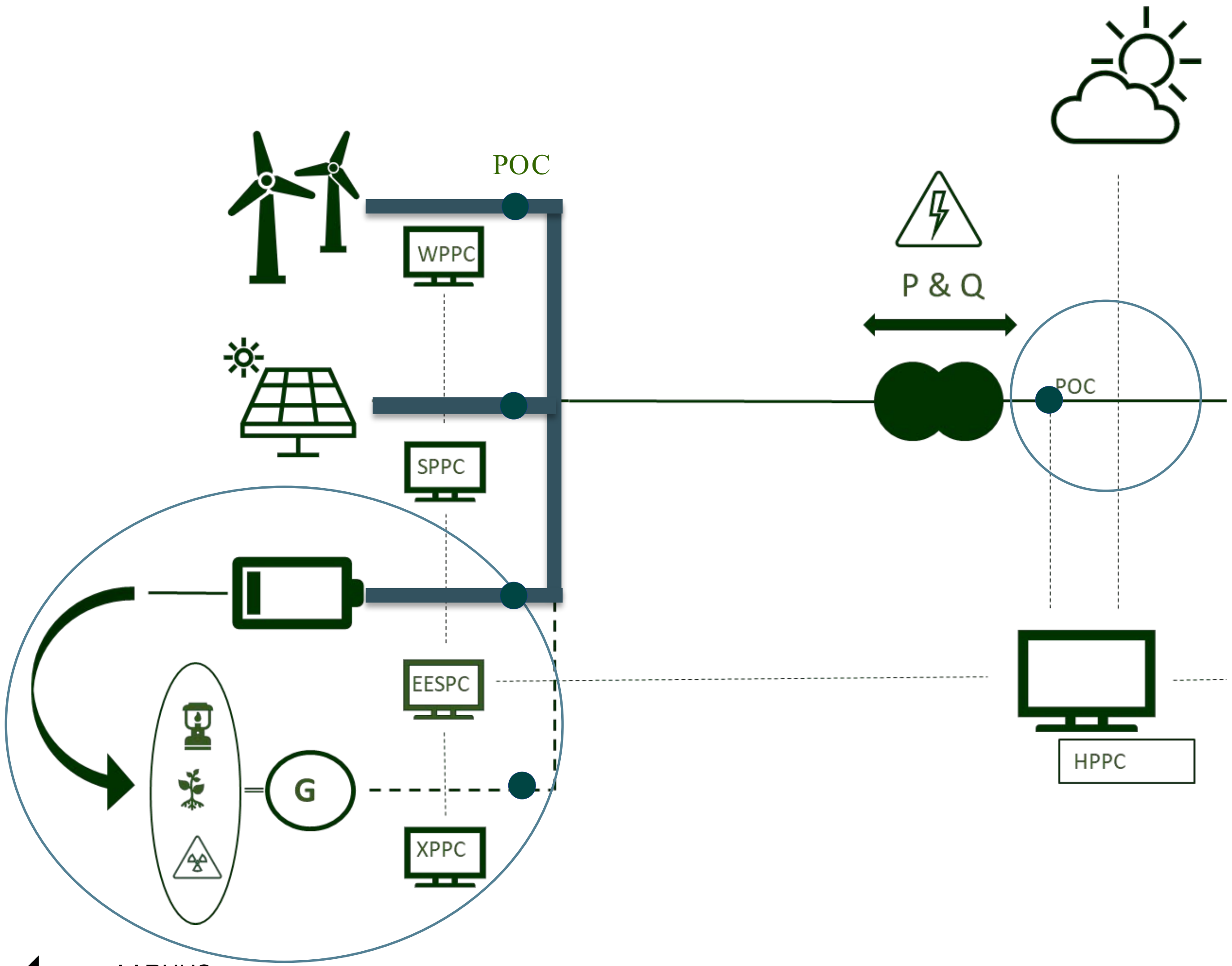
IEC 61400 Series: Wind Turbines: If your PtX system involves wind energy, the IEC 61400 series provides standards for the design, operation, and maintenance of wind turbines.

IEC 61400-24: Lightning Protection of Wind Turbines: For PtX systems that include wind turbines, this standard addresses lightning protection, an important consideration in electrical systems.

Depending on the specific applications, safety standards for electrical appliances may be relevant.
Please note that the applicability of standards will depend on the specific technologies, components, and processes used in your Power-to-X system. Always refer to the latest editions of standards and consider consulting with experts in the field or relevant regulatory bodies to ensure compliance with the latest industry requirements. Additionally, standards may have been updated or new ones introduced after my last update in January 2022.

GAPS & CHALLENGES

CHALLENGES FOR POWER PLANT/GENERATION



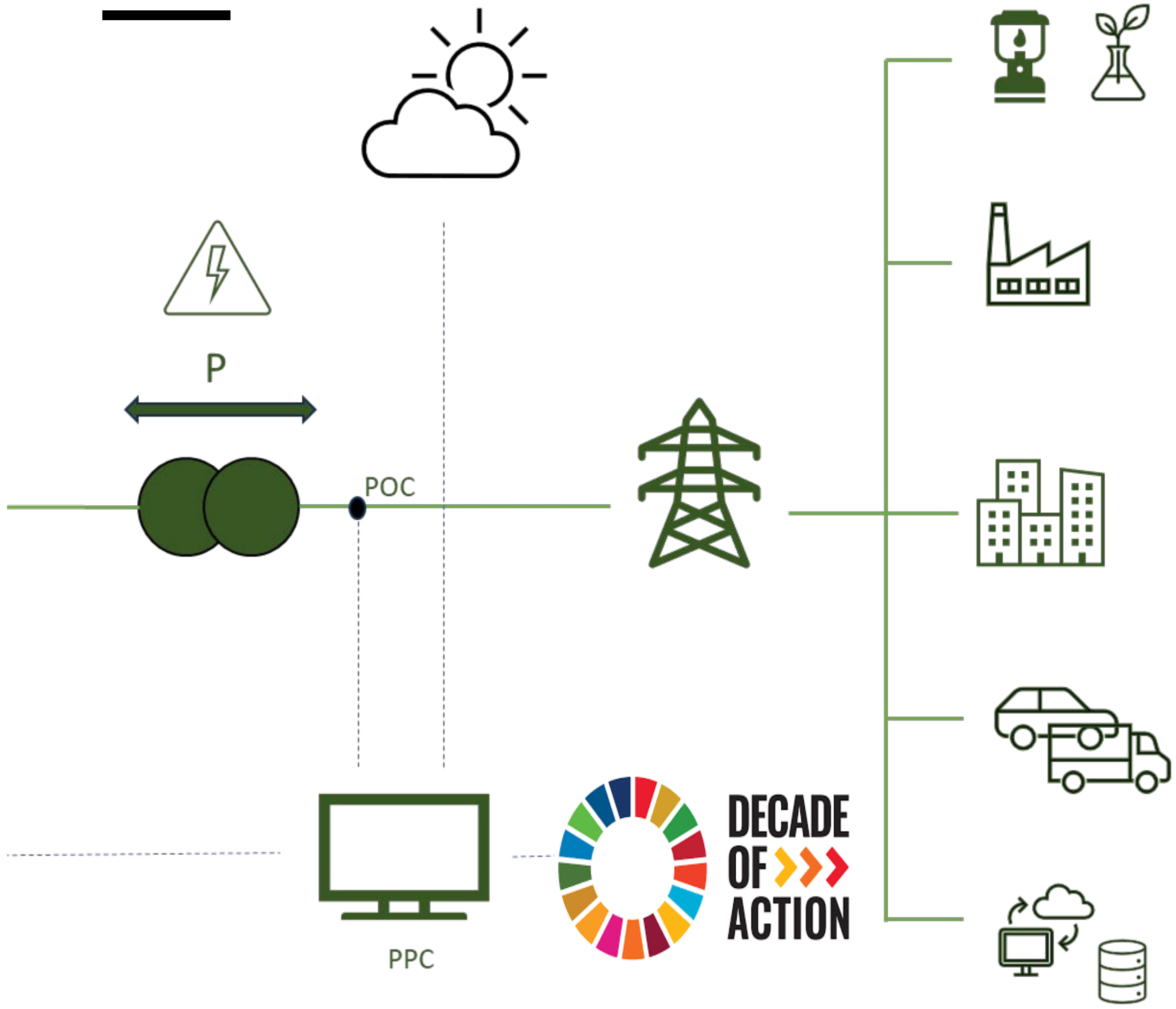
Grid codes

- Requirements for Generators (RfG)
- Demand Connection Code (DCC)
- High Voltage Direct Current (HVDC)
- Direct connection – Direct lines
- Storage Systems
- Grid Forming / Grid Following
- Ancillary services

Standardization

- Validation procedures
- Simulation models
- Communication interface
- Protection design
- Power Quality requirements

CHALLENGES FOR CONSUMER SYSTEMS



Grid codes

- Demand Connection Code (DCC)
- Robustness requirements
- Direct connection – Direct lines
- Energy Islands
- V2G
- Storage Systems
- Ancillary services

Standardization

- Validation procedures
- Simulation models – Load models
- Communication interface
- Protection design
- Power Quality requirements
- Certification process

OPPORTUNITIES AND THE WAY FORWARD

GRID CODES, REQUIREMENTS & STANDARDS

TC	Number	Titel	Types of publications			
			Basic	System	Unit	Product
1	IEC 60050	International Electrotechnical Vocabulary	Y			
8	IEC 60038/AMD2/FRAG1 ED7 Amendment 2	Standard voltages for LVDC supply and LVDC equipment (Proposed horizontal standard)		Y		
8	IEC TR 62511:2014	Guidelines for the design of interconnected power systems		Y		
8	IEC TR 63282 ED2	LVDC systems - Assessment of standard voltages and power quality requirements		Y		
8	IEC TS 62749:2020	Assessment of power quality - Characteristics of electricity supplied by public networks		Y		
8	IEC TS 62786 ED1	Distributed energy resources connection with the grid (whole series)		Y		
8	IEC TS 63060:2019	Electric energy supply networks - General aspects and methods for the maintenance of installations and equipment		Y		
8	EC TS 63222-1:2021	Power quality management - Part 1: General guidelines		Y		
8A	IEC 62934:2021	Grid integration of renewable energy generation - Terms and definitions	Y			
8A	IEC TR 63401-1 ED1	Interconnecting inverter-based resources to low short circuit ratio ac networks		Y		
8A	IEC TR 63401-2 ED1	Dynamic characteristics of inverter based resources in bulk power systems - Part 2: Sub- and Super-synchronous Control Interactions		Y		
8A	IEC TR 63401-3 ED1	Fast Frequency Response and Frequency Ride-Through from Inverter-Based Resources during Severe Frequency Disturbances		Y		
8A	IEC TR 63401-4 ED1	Dynamic characteristics of inverter-based resources in bulk power systems - Part 4: Behaviour of Inverter-Based Resources in Response to Bulk Grid Faults		Y		
8A	IEC TR 63411 ED1	Grid Connection of Offshore Wind via VSC-HVDC System		Y		
8A	IEC TS 63102:2021	Grid code compliance assessment methods for grid connection of wind and PV power plants		Y		
8A	IEC TS 63406 ED1	Generic RMS simulation models of converter-based generating units for power system dynamic analysis			Y	
8B	IEC TS 63276 ED1	Guideline for the hosting capacity evaluation of distribution networks for distributed generations			Y	
82	IEC 62116	Utility-interconnected photovoltaic inverters - Test procedure of islanding prevention measures				Y
82	IEC 62446 :2009	Grid connected photovoltaic systems - Minimum requirements for system documentation, commissioning tests and inspection				Y
82	IEC 62894:2014	Photovoltaic inverters - Datasheet and name plate				Y
82	IEC TS 62910:2020	Utility-interconnected photovoltaic inverters - Test procedure for under voltage ride-through measurements				Y
82	IEC TS 63217:2021	Utility-interconnected photovoltaic inverters - Test procedure for over voltage ride-through measurements				Y
82	IEC 62920:2017/AMD1:2021 Amendment 1	Photovoltaic power generating systems - EMC requirements and test methods for power conversion equipment				Y
82	IEC TS 63106-1:2020	Simulators used for testing of photovoltaic power conversion equipment - Recommendations - Part 1: AC power simulators				Y
85	IEC 61557-1:2007,	Electrical safety in low voltage distribution systems up to 1000 V a.c. and 1500 V d.c. - Equipment for testing, measuring or monitoring of protective measures - Part 1: General requirements	Y			
88	IEC 61400-21-1	Wind energy generation systems - Part 21-1: Measurement and assessment of electrical characteristics - Wind turbines			Y	Y
88	IEC 61400-21-2	Wind energy generation systems – Part 21-2: Measurement and assessment of electrical characteristics – Wind power plants			Y	
88	IEC 61400-27-1	Wind energy generation systems - Part 27-1: Electrical simulation models - Generic models			Y	Y
88	IEC 61400-27-2	Wind energy generation systems - Part 27-2: Electrical simulation models - Model validation			Y	Y
95	IEC/IEEE 60255-118-1:2018	Measuring relays and protection equipment - Part 118-1: Synchrophasor for power systems - Measurements	Y			
95	IEC 60255-181:2019	Measuring relays and protection equipment - Part 181: Functional requirements for frequency protection	Y			
120	IEC TS 62933-2-2 ED1	Electric Energy Storage Systems - Part 2-2: Unit parameters and testing methods - Application and performance testing				Y

Currently over 200 standards in relation to Grid requirements validation, protection, simulation etc. collected and classified

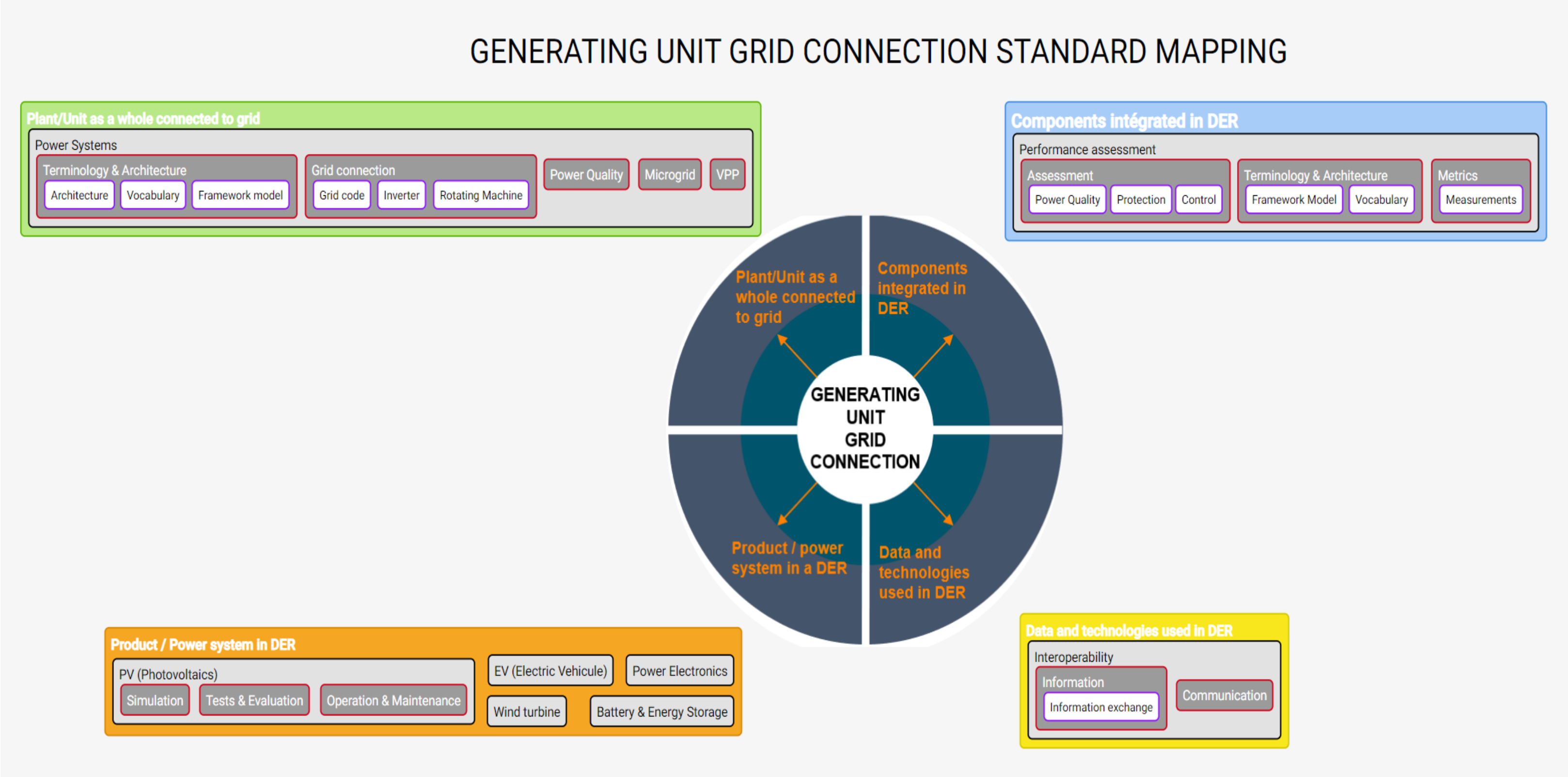
Basic
- Overall requirements in relation to the electricity sector.
- Definition of frequency ranges, voltage ranges, terminology …

System
- Requirements on generation and consumer systems
- Measurement procedures, power system operation, simulation models, ..

Units
- Defines unit specific functionalities and services
- Wind Turbine, PV-system, Electrical Energy Storage System, …

Products
- Defines specific component functionalities
- Power converter, Transfomer, switchgear, ….

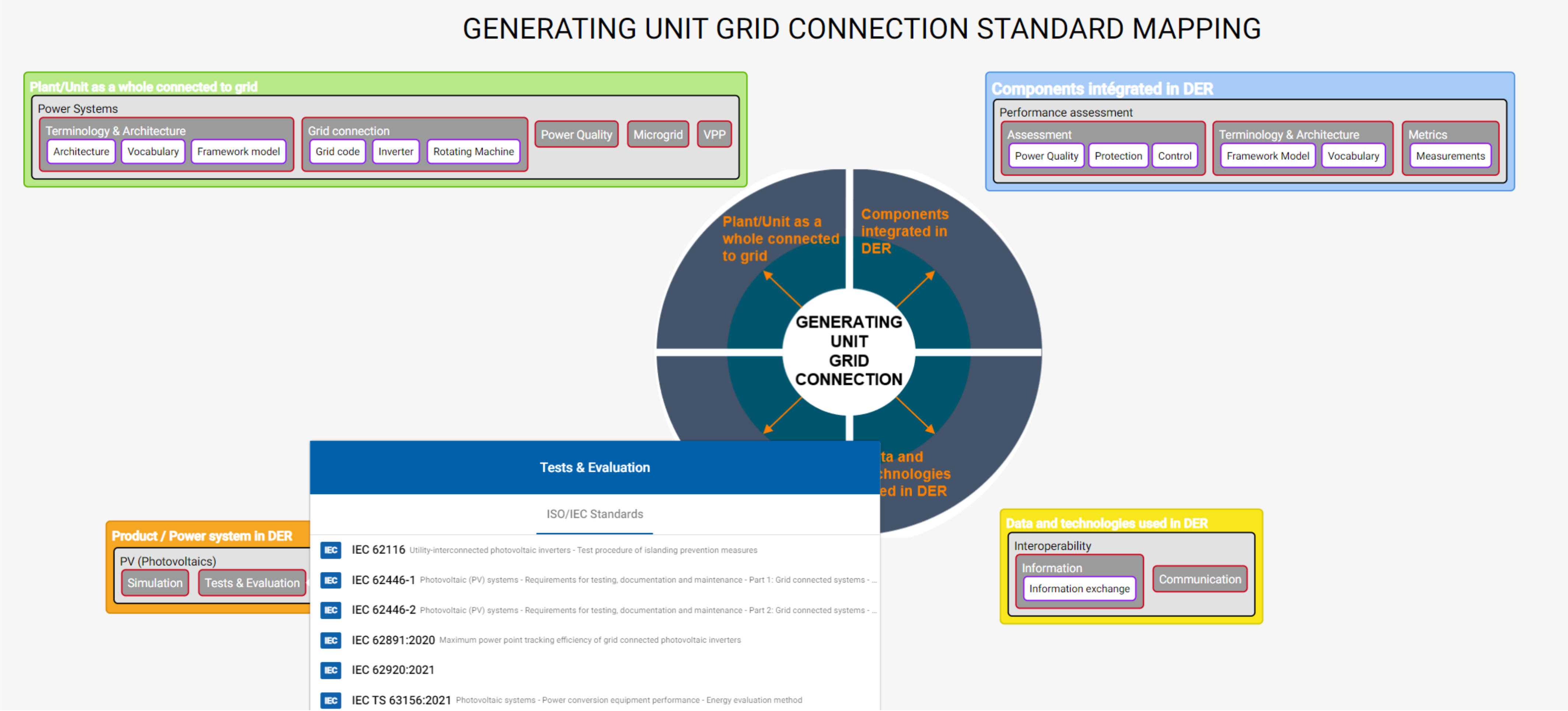
GRID MAPPING – HORIZONTAL FUNCTIONS – TC8



https://mapping.iec.ch/#/maps

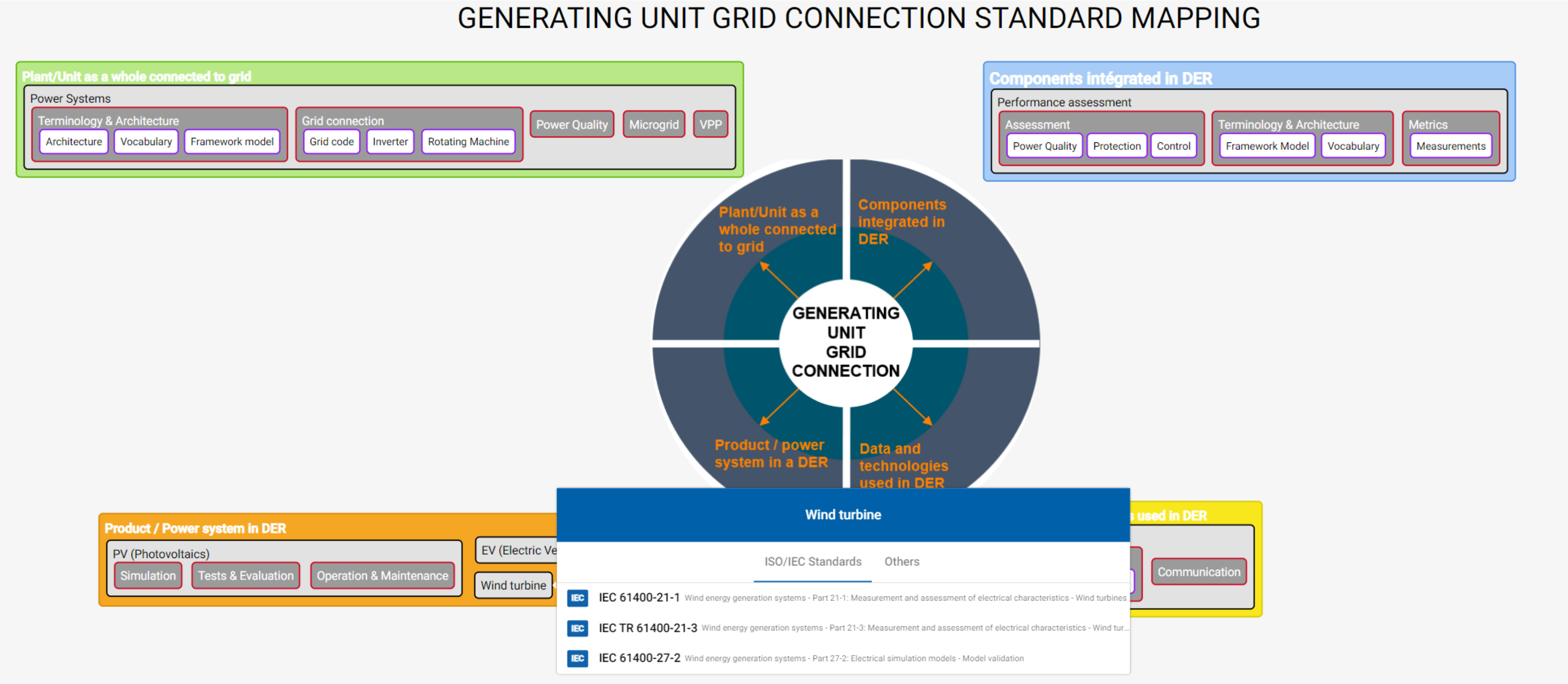
- Grid mapping – overview
- Gap analysis
- Alignment across TC's
- Horizontal function
    - Grid connection
    - System validation
    - Power Quality
- Simulation models
- Performance evaluation
- Communication

GRID MAPPING – HORIZONTAL FUNCTIONS – TC’S



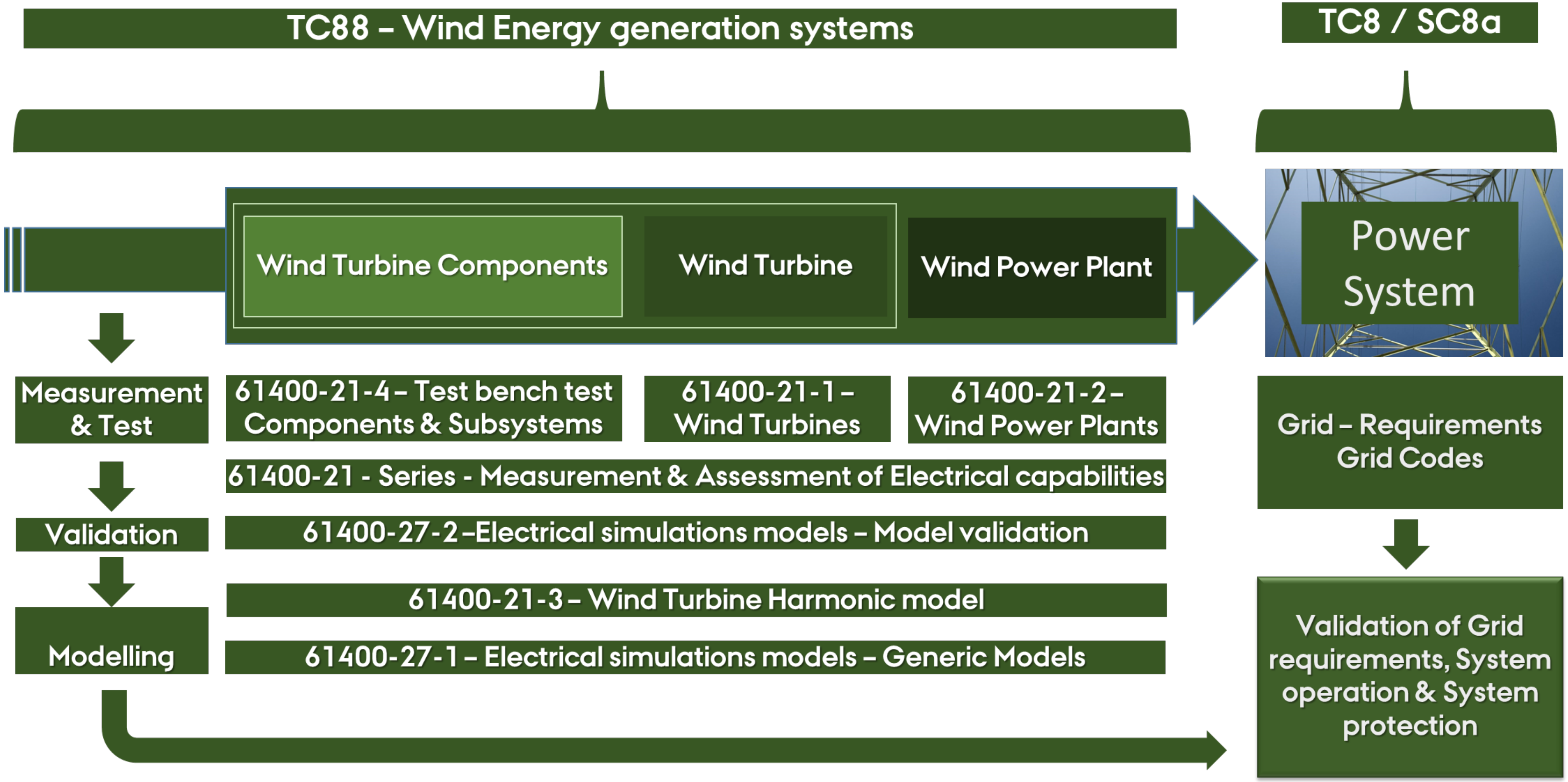
https://mapping.iec.ch/#/maps/161

GRID MAPPING - HORIZONTAL FUNCTIONS - TC'S



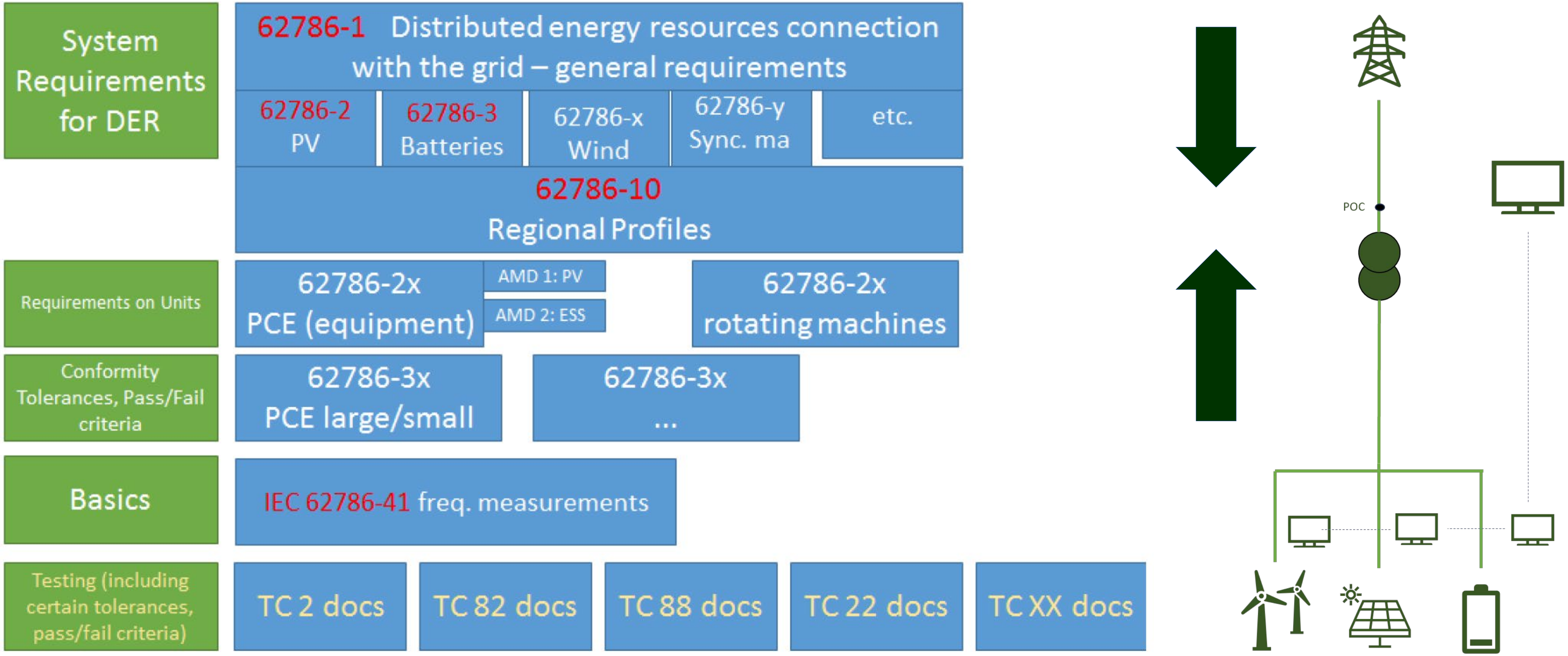
https://mapping.iec.ch/#/maps/161

TC88 – WIND ENERGY GENERATION SYSTEMS – GRID RELATED STANDARDS



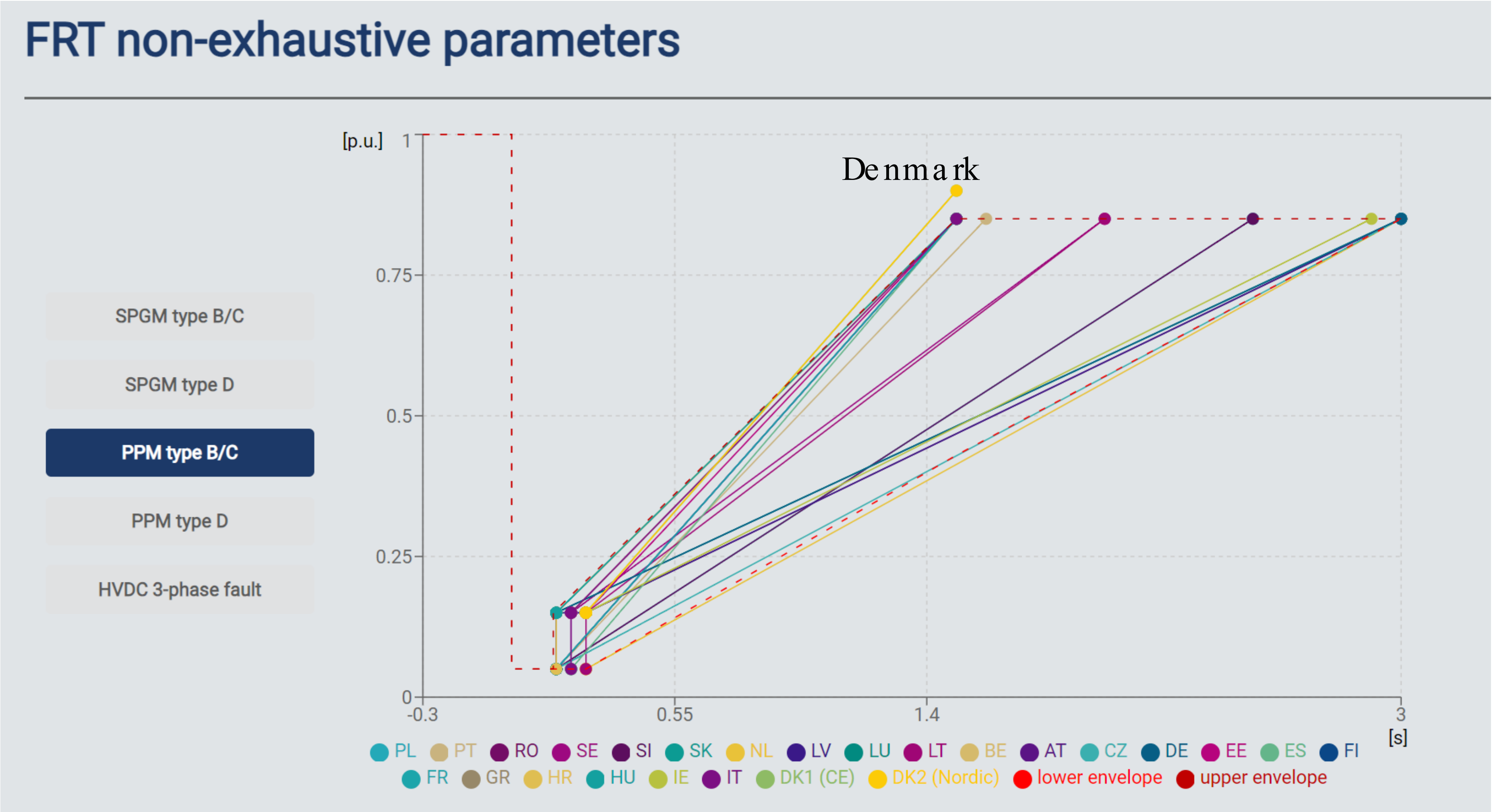
TC8- SYSTEM ASPECTS

Draft Structure of IEC TS 62786 series (and related topics)



EUROPE

RFG- GRID CODES - ENTSOE- IMPLEMENTATION PLATFORM



https://imp.entsoe.eu/public/reports/data-view/frt

EU LEVEL – CENELEC

EN 50549- Series:

This European Standard is intended to serve as a technical reference for the definition of national requirements where the RfG European Network Code requirements allow flexible implementation.

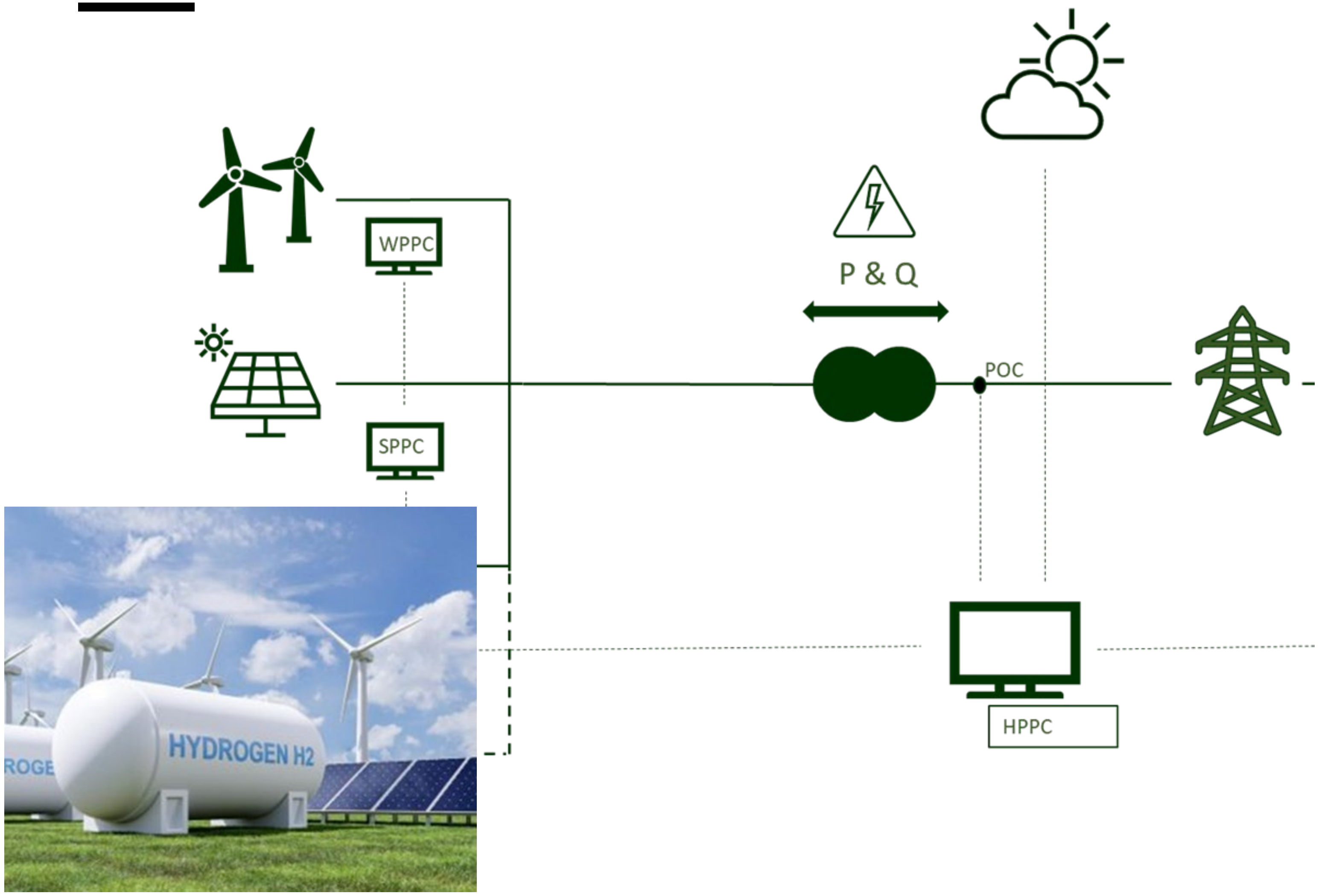
EN 50549- 1 : Requirements for generating plants to be connected in parallel with distribution networks - Part 1: Connection to a LV distribution network – Generating plants up to and including Type B

EN 50549-2: Requirements for generating plants to be connected in parallel with distribution networks - Part 2: Connection to a MV distribution network – Generating plants up to and including Type B

EN 50549- 10: Requirements for generating plants to be connected in parallel with distribution networks - Part 10: Tests for conformity assessment of generating units

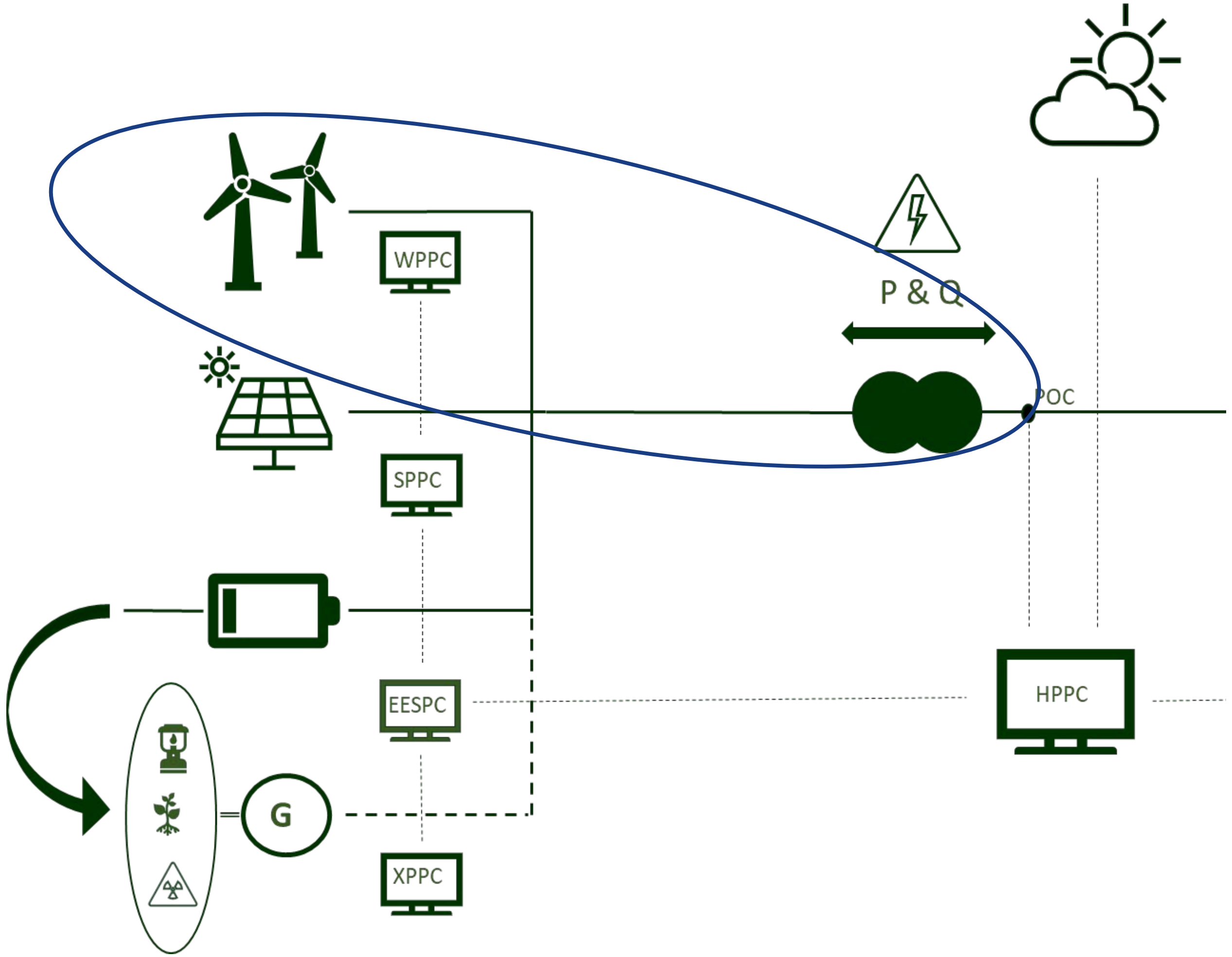
Ongoing - CLC/TS 50549-20: Requirements for generating plants to be connected in parallel with electrical networks - Part 20: Definitions and tests of the electrical characteristics of grid forming generating and storage units

MISSING STANDARDS & REGULATIONS



- Missing IEC TC for PtX
- Missing IEC TC for HPP
- Missing IEC TC Demand side
- Missing IEC rules for H_2WT/PV
- Missing PQ Guides for HPP/DCC
- Missing Simulation models
- Missing Certification e.g. IECRE
- Common Operation of XtP
- ……….

SCOPE TC88 – WIND ENERGY GENERATION SYSTEMS



Current scope:

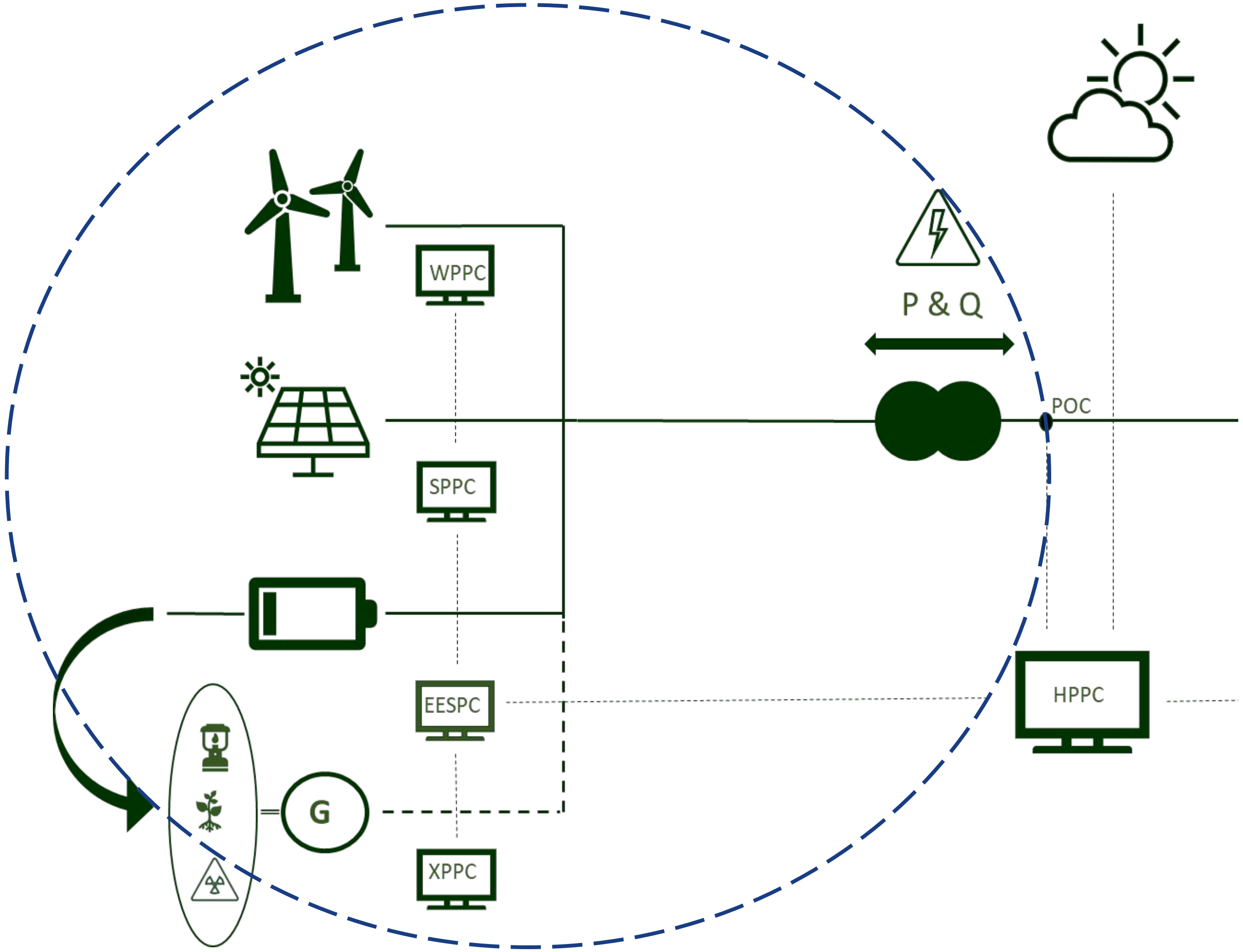
Standardization in the field of wind energy generation systems including wind turbines, wind power plants onshore and offshore and interaction with the electrical system(s) to which energy is supplied.

These standards address site suitability and resource assessment, design requirements, engineering integrity, modeling requirements, measurement techniques, test procedures, operation and maintenance.

Their purpose is to provide a basis for design, quality assurance and technical aspects for certification. The standards address site-specific conditions, all systems and subsystems of wind turbines and wind power plants, such as mechanical, and electrical systems, support structures, control and protection as well as communication systems for monitoring, centralized and distributed control and evaluation, implementation of grid connection requirements for wind power plants, and environmental aspects of wind power development.

The TC 88 standards will be developed based on and in agreement with appropriate IEC/ISO standards.

PROPOSED NEW SCOPE TC88 WIND ENERGY GENERATION SYSTEMS



Propose

- To de … energy from wind … raction with, syste … ons)
- To su … ergy as susta … nergy syste
- IEC/ … ll systems and … anical and elect … rmation exch … sses the intera … energy stora … e the power plant … wind power plant
- The … ements ….
- IEC/ … ppropriate IEC-a … s to secure a cohe … andards are on fu … om of solut … ir purpose is also

Power-to-X (… t) to generate prima rily hyd… ations such as power-to-fuel, powe… -to-methane and power-to-me…

29. september 2023

Vindmøller skaber muligheder i PTX-værdikæden – men det kræver standarder

Næste skridt i den grønne omstilling er PtX og grønne brændstoffer. Også her kan standarder bane vejen for konkurrencedygtige løsninger og eksportsucces. Alle med viden på området kan være med til at sætte fremtidens markedskrav.

Den danske vindmølleindustri bygger selvsagt ikke elektrolyse- eller ammoniakanlæg. Men alligevel vil de internationale standarder, som udstikker de tekniske spilleregler for fremtidens grønne energiinfrastruktur, få stor betydning for vindmøllebranchens fremtid. Derfor er det helt afgørende, at industrien er med til at sætte de kommende standarder for PtX-værdikæden. En værdikæde, der er lang og kompleks, men som oftest begynder med netop vind.

THE WAY FORWARD

- Climate change is a Global problem
- The energy sector is globally *still* the largest emitter of Greenhouse Gasses (GHG) - around 70 %
- The next decade needs *very* fast actions and implementation of existing solutions
- Standardization, especially within the grid code compliance area has become more and more complex and the standardization landscape dramatically increased in its complexity
- Need for National & International collaboration on all levels – *It's a common goal*
- Alignment of related standardization activities is of high relevance to avoid misleading definitions and over-standardization

Thanks’ a lot

Questions ?

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