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Intelligent Smart Grids: Driving change in urban energy systems – whereto and how?

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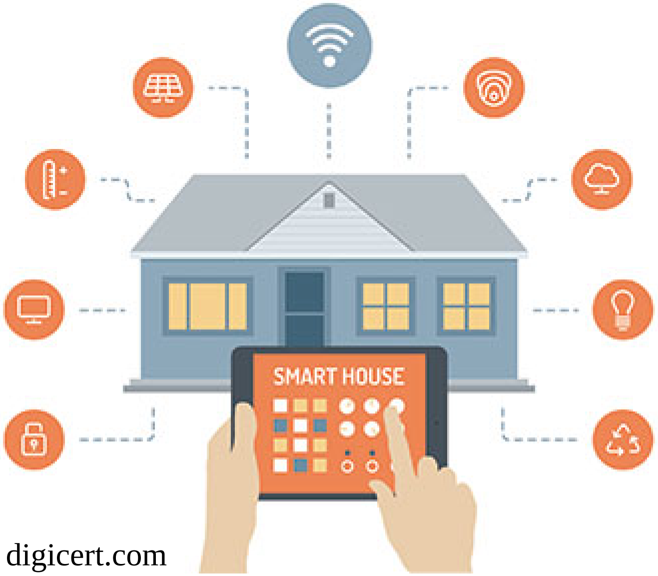
Outline

- New technology
- Paradigm shifts
- Driving change
- Cases of change
- System operators
- Recent policy documents
- Conclusions

New technology – challenges and solutions



digicert.com

- PV, wind power – for renewable electricity production
- Electric vehicles, heat pumps – to save energy with electricity
- Battery storage – to avoid moving electricity

- DC distribution – natural in PV-based microgrids

- Energy meters
- Home automation, Home Energy Management System
- Internet of Things
- Big Data

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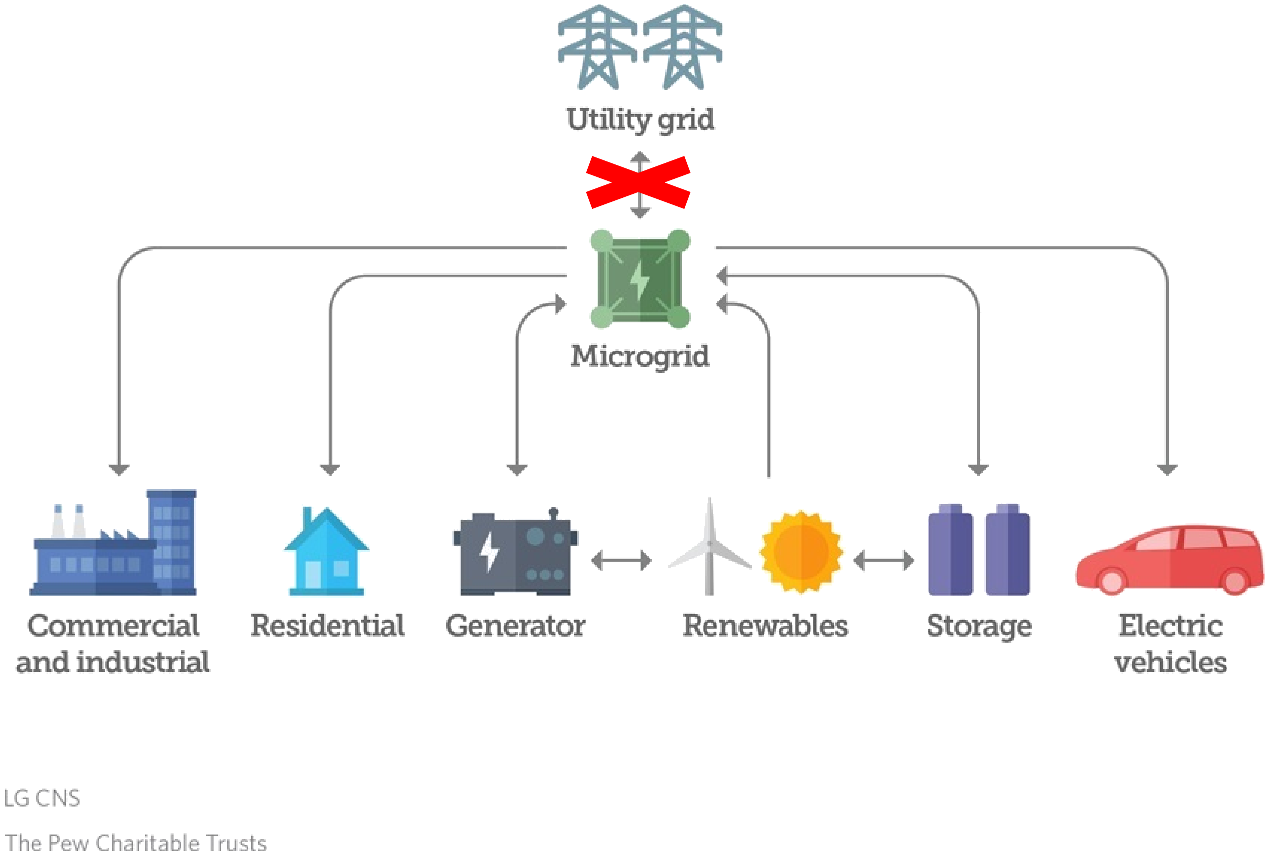
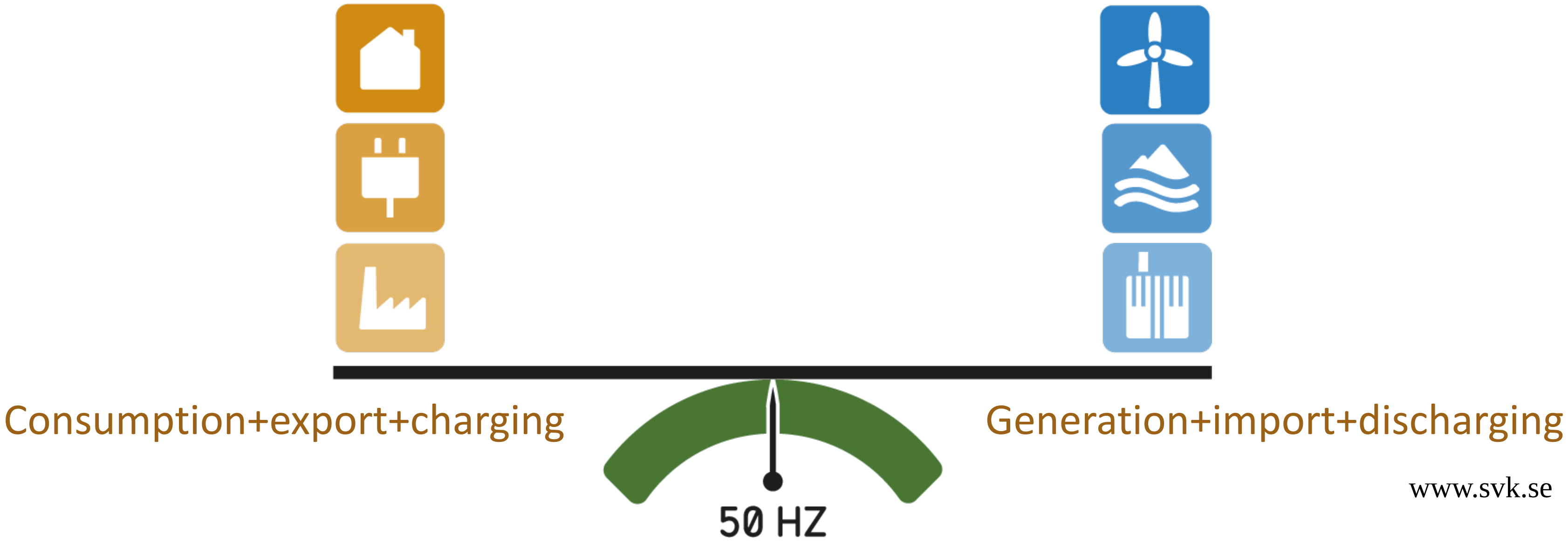
Case: Microgrids includes all new technology



- Potentially affected by all paradigm shifts

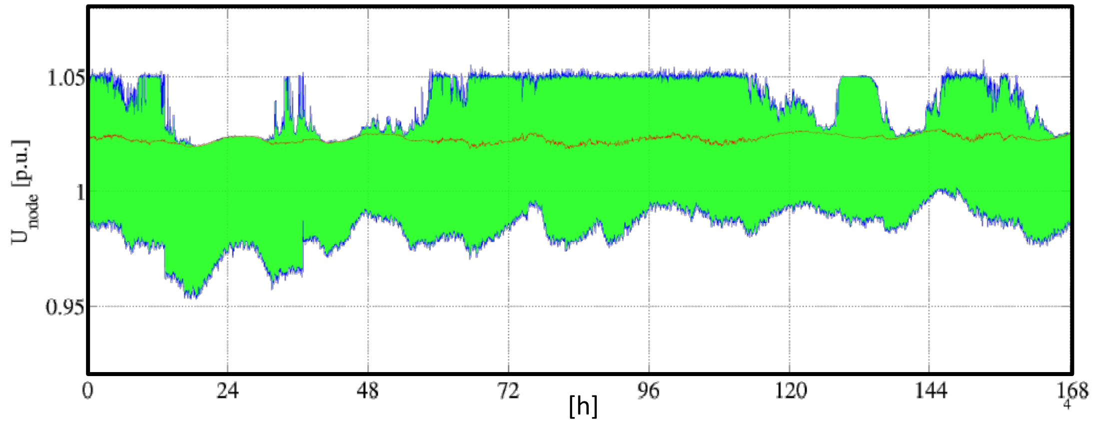
Paradigm shifts in power systems: Power balance



www.svk.se

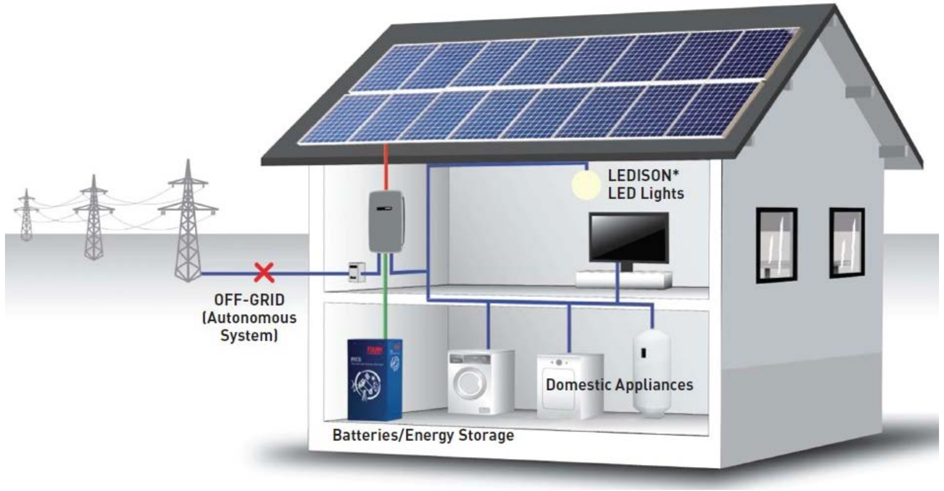
History	Future
Dispatchable generation	Renewable generation both non-dispatchable and variable
Generation follows load	Generation, load, and storage controlled for balance

Paradigm shifts in power systems: Power flow

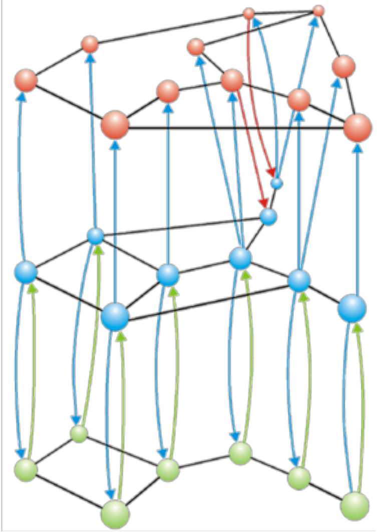


History	Future
Centralized generation → unidirectional power flow	Also distributed generation → bidirectional power flow
Wide margins to make system stay away from limits	Automation for control and curtailment to stay at limits
Generation and load determines branch flows	Generation, load and storage determines branch flows

Paradigm shifts in power systems: Infrastructure



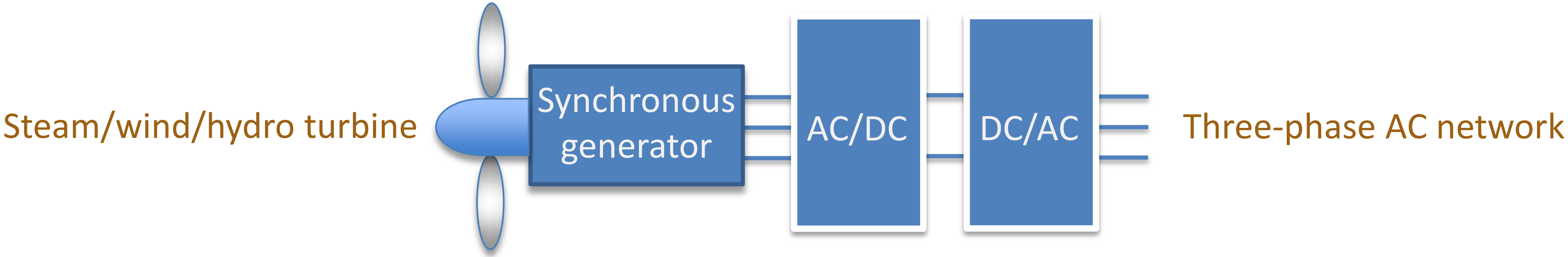
ledison-led-light.co.uk



Johansson & Hassel 2010

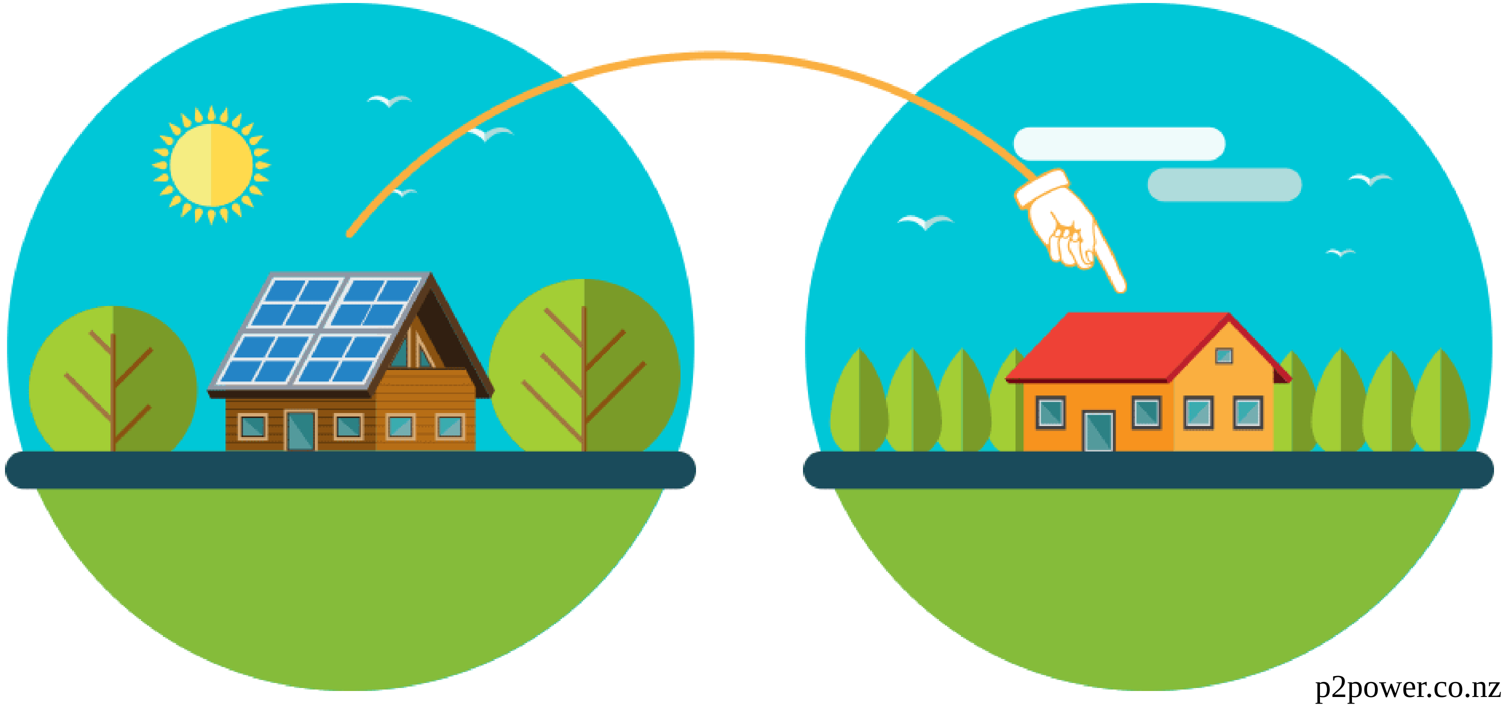
History	Future
Power systems increasingly interconnected	More interconnections but also off-grid
Technical infrastructures independent	Technical infrastructures interdependent

Paradigm shifts in power systems: Equipment



History	Future
Synchronous generator dominates physics	Network sees mainly power electronic converters
Individual control and protection managed on site	Cloud-based integrated control and protection

Paradigm shifts in power systems: Trading



p2power.co.nz

History	Now	Future
Monopoly	Retail competition	Also peer-to-peer

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Drive change to control the future

- Policy
  - EU: Lead transition, not adapt to
  - DK and SE: Energy Commission
- Standards
  - IEEE, IEC, EN, DIN
- Technical requirements
  - ENTSO-E grid codes
- Certification
  - Green Buildings
  - PEER

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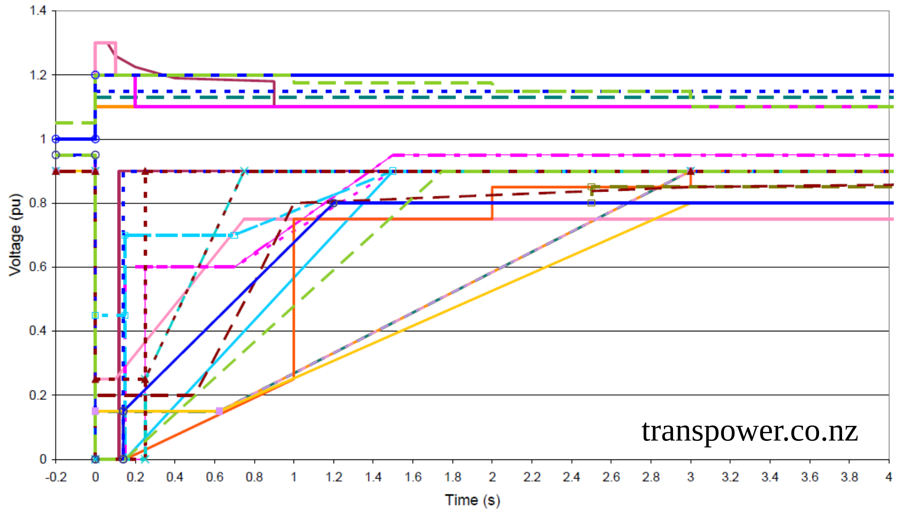
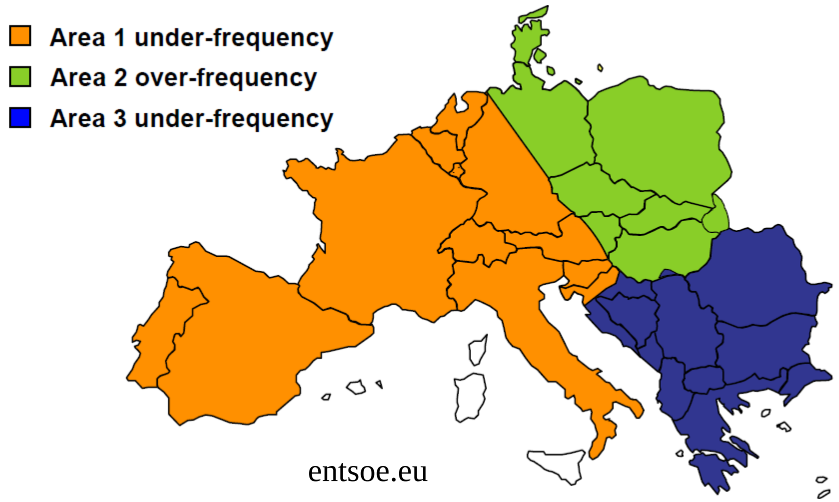
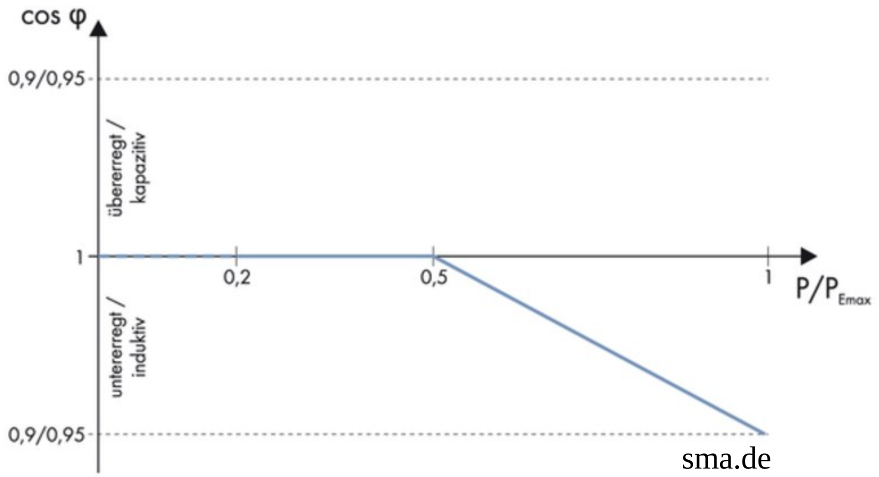
Case: Renewables in the power balance – windpower

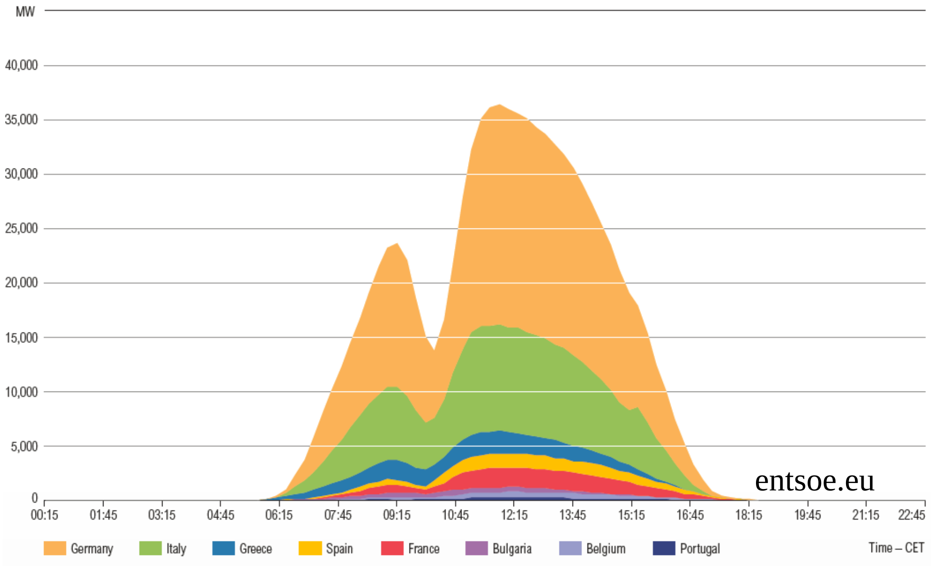




- Windpower a local issue: Power quality and fast trip
- Windpower a systems issue: No trip at v-deviations
  - Eltra-Elkraft 2004, SvK 2005, E.ON Netz 2006
  - ENTSO-E Grid Codes
- Windpower a systems issue: No trip at f-deviations
  - Nov 2006 UCTE blackout, 49,5 Hz→47,5 Hz
- Windpower behaviour important to system operation
  - First like an industrial motor
  - Today like any thermal power plant
- Clearly reflected in connection requirements

Case: Renewables in the power balance – solar PV





- PV a local issue: electrical safety
  - Specific implementation VDE 0126 1999, 2006
- PV a systems issue: voltage
  - Support voltage control, VDE AR4105, 2011
- PV a systems issue: frequency
  - 50,2 Hz→51,5 Hz, VDE AR4105, 2011
  - Modification of 315 000 German units >10 kW
- PV a systems issue: ramping
  - Solar eclipse March 20, 2015

Case: Energy Independence and Security Act 2007

SEC. 1305. SMART GRID INTEROPERABILITY FRAMEWORK.

(a) INTEROPERABILITY FRAMEWORK.—The Director of the National Institute of Standards and Technology shall have primary responsibility to coordinate the development of a framework that includes protocols and model standards for information management to achieve interoperability of smart grid devices and systems.

SEC. 1306. FEDERAL MATCHING FUND FOR SMART GRID INVESTMENT COSTS.

(a) MATCHING FUND.—The Secretary shall establish a Smart Grid Investment Matching Grant Program to provide reimbursement of one-fifth (20 percent) of qualifying Smart Grid investments.

(b) QUALIFYING INVESTMENTS.—Qualifying Smart Grid investments may include any of the following made on or after the date of enactment of this Act:

(c) INVESTMENTS NOT INCLUDED.—Qualifying Smart Grid investments do not include any of the following:

(3) After the final date for State consideration of the Smart Grid Information Standard under section 1307 (paragraph (17) of section 111(d) of the Public Utility Regulatory Policies Act of 1978), an investment that is not in compliance with such standard.

(4) After the development and publication by the Institute of protocols and model standards for interoperability of smart grid devices and technologies, an investment that fails to incorporate any of such protocols or model standards.

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Case: Microgrid development

- Define desirable performance
- Performance standards – Green buildings

- Swedish Green Building Council
  - Green building, miljöbyggnad, LEED (US), BREEAM (UK)
- Green Business Certification Inc.
  - LEED, SITES, PEER, WELL, EDGE, GRESB, Parksmart, Zero Waste
- Performance Excellence in Energy Renewal: Microgrid performance criteria

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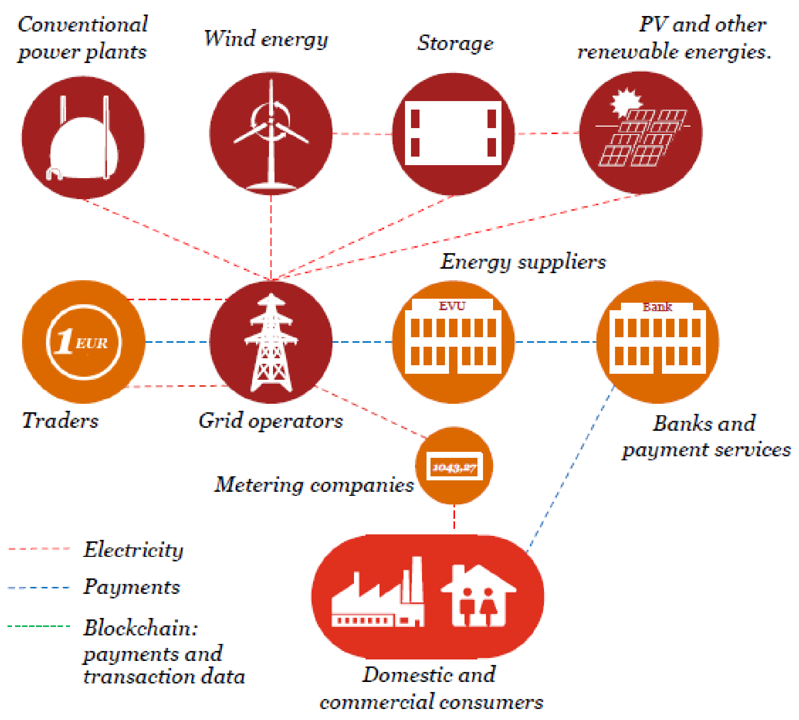
PEER Credits

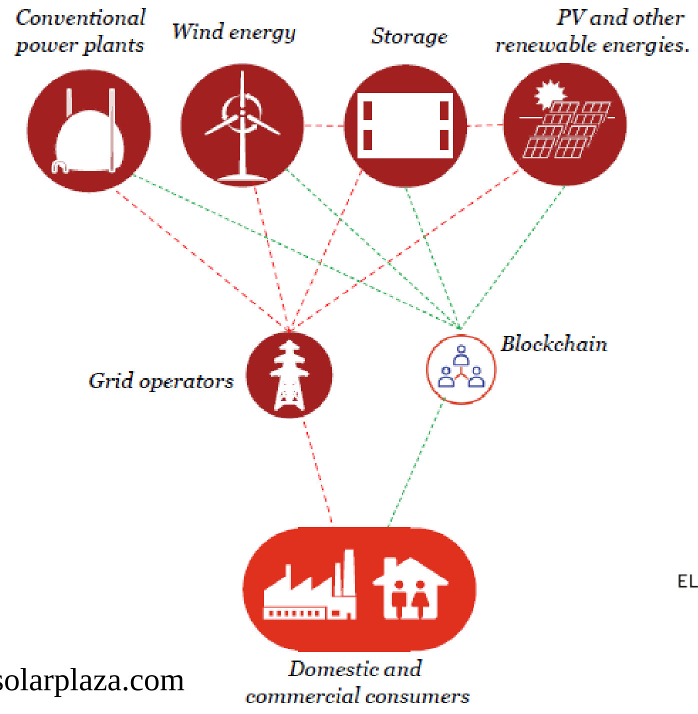
	Reliability & resilience	Operational effectiveness	Energy efficiency & environment	Customer contribution
REQUIRED	Advanced Meters for Reliability and Power Quality	Renewable Portfolio Standard	Improvement Plan	Advanced Metering Infrastructure
	Communications Backbone	Local Air Permits		Data Privacy
	SCADA			Cyber Security
	Emergency Response Plan			Consumer Engagement Programs
	Safety Review of Design Changes			
CORE	23 ASAI (Availability)	50 Source Energy Intensity	20 Load Duration Curve	15 HEMS/EMS Choice
	20 Islanding Capability	20 CO2 Emissions Intensity	20 Waste Identification and Elimination	15 Local Cleaner Power Capability
	10 Power Surety for Critical Loads	10 NOx Emissions Intensity	20 Failure Identification and Elimination	15 Local Demand Response Capability
	10 Distr Redundancy and Automated Restoration	10 SO2 Emissions Intensity	20 Demand Response Capability	10 Access to Real-Time Data
	5 Power Resiliency through Recovery	5 Water Consumption Intensity	5 Electricity Energy Efficiency Savings	10 Local Renewable Generation Capability
	5 Damage and Exposure Prevention	5 Solid Waste Recycled	5 Electricity Cost Savings	5 Access to Dynamic Pricing
BONUS	15 Mitigation of Common Risks and Threats	10 Renewable Energy Certificates	5 Operational Effectiveness Innovations	15 Aggregation
	5 Power Quality Measurement	5 Environmental Impacts	3 System Energy Efficiency	15 Customer Contribution Innovations
	5 Capabilities for Power Quality	5 Energy Efficiency and Environment Innovations	3 Operations and Maintenance Efficiency Value	5 Financial Incentive Programs
	5 Reliability and Resiliency Innovations	2 District Energy	3 Ancillary Service Revenue	
	4 AIFI (Interruption Frequency)	2 Local Cogeneration or CHP	2 Electricity Energy Efficiency Opportunity Cost	
	3 MAIFI (Momentary Interruptions)	2 Local Renewable Generation	2 Operations and Maintenance Opportunity Cost	
	3 CEMMI-5 (Multiple Momentary Interruptions)		1 Reliability and Power Quality Opportunity Cost	
			1 Demand Charge Opportunity Cost	
			1 Ancillary Service Opportunity Cost	
			1 Electricity Price Opportunity Cost	

Case: Peer-to-peer trading

Today's value chain

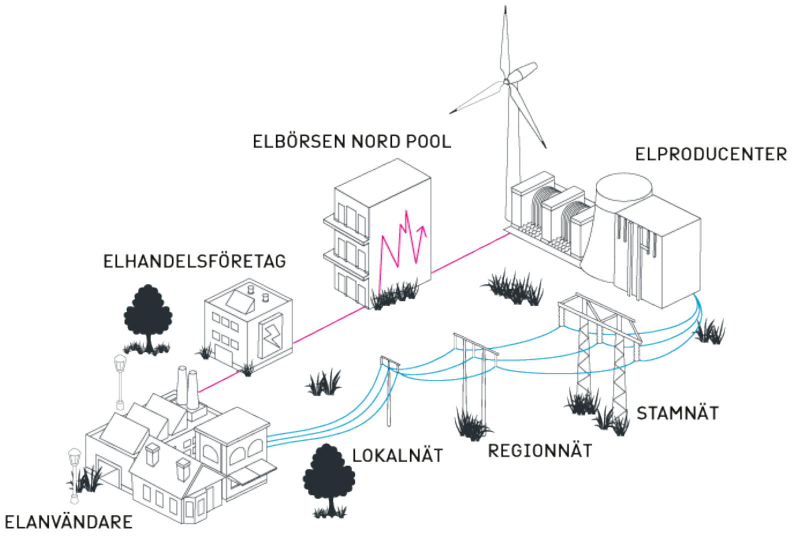


The energy world with Blockchain



solarplaza.com

TSO view of electricity supply



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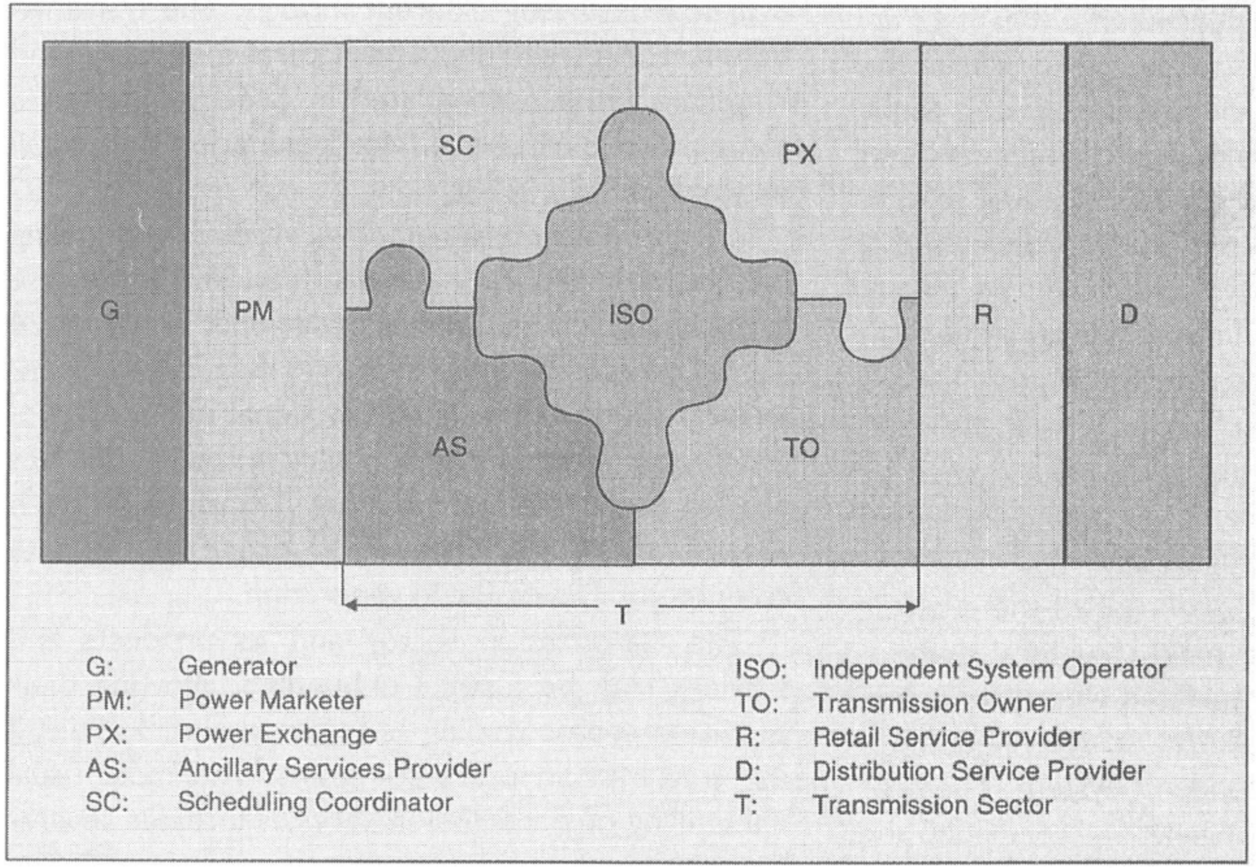
- Peer-to-peer trading of electricity a profound change
- Change in DSO role similar to change of TSO role at deregulation

What does a Transmission System Operator Do?



Rahimi and Vojdani, 1999

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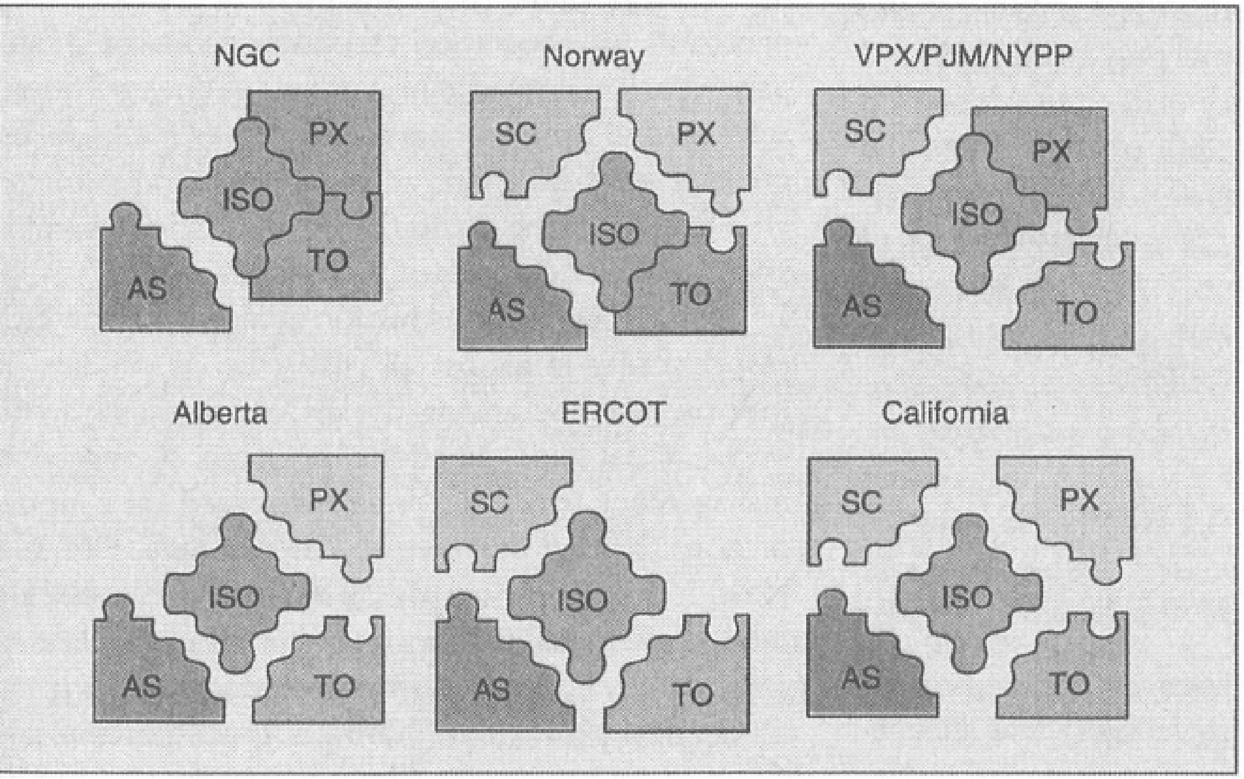
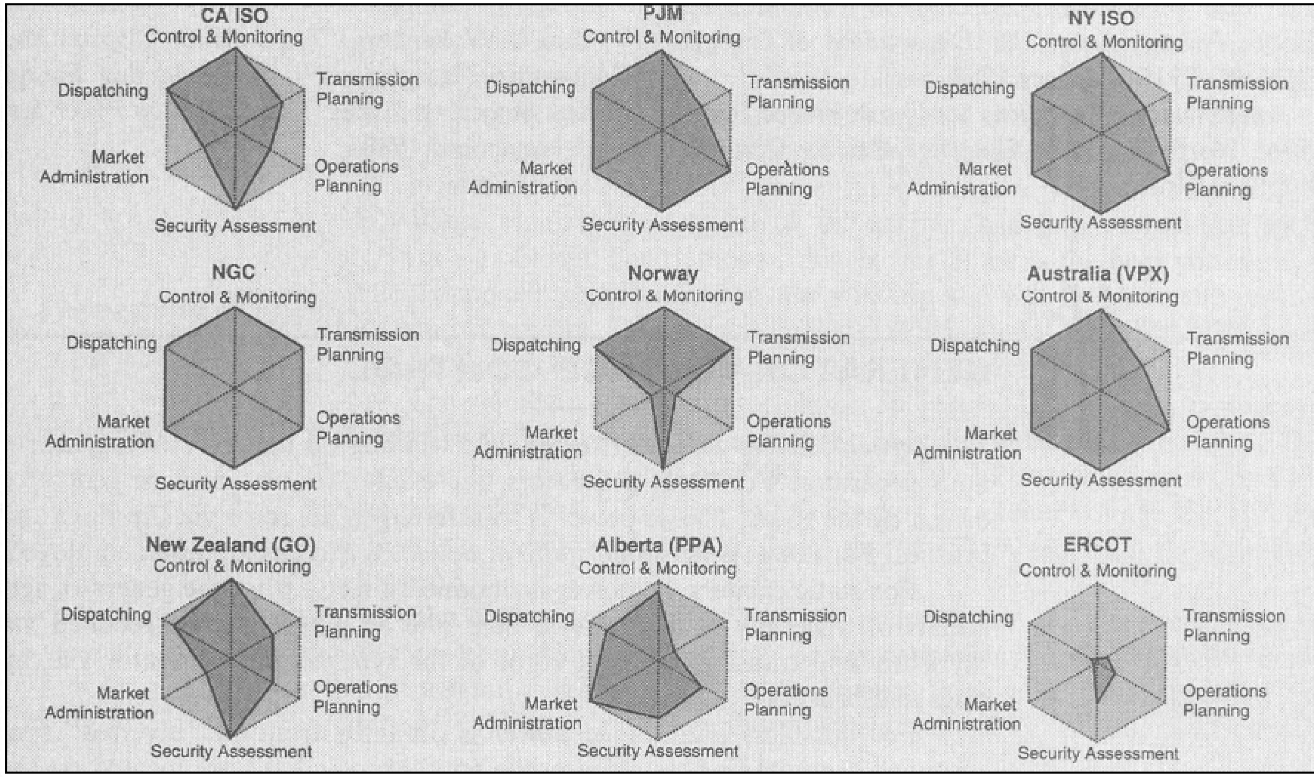
Many functions and tasks





Rahimi and Vojdani, 1999

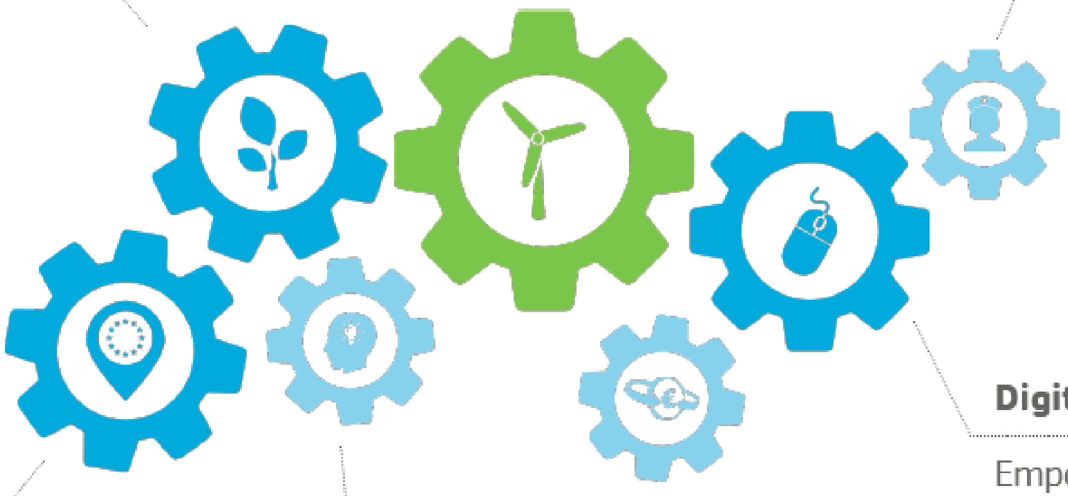
- Implementation of ENTSO-E grid codes currently discussed in Sweden

Swedish Energy Commission Report SOU2017:2

- Goal: By 2045 no net GHG emissions, thereafter negative emissions
  - 100% (of consumption) from renewables 2040, no ban on nucelar power
  - Green certificate system prolonged with 18 TWh to 2030
  - By 2030 50 % less TWh/GNP than 2005
- Generation adequacy: capacity market? demand flexibility!
- White certificates to be investigated
- Energy efficient building rules to focus on used energy – not bought energy
- Today’s distribution network owners will need to become DSO’s
- Adapt taxes/legislation to support products and services in conservation, storage, small-scale trading, transport electrification
- Allowed to experiment with business models and pricing in pilot projects

EU Energy Winter Package 2016

Clean Energy For All Europeans



EU Energy Winter Package 2016

Clean Energy For All Europeans

- Goal 1: *Putting energy efficiency first*
  - Clean energy buildings = connected energy, storage, digital and transport system
    - » Energy Performance of Buildings Directive → renovation, EV charging points
    - » European Buildings Initiative to stimulate investments
  - Ecodesign Working Plan 2016-2019 aims at 30%/600 TWh anual savings 2030
- Goal 2: *Achieving global leadership in renewable energies*
  - By 2030: 43% lower carbon intensity than 2016, 50% electricity from renewables, 27% renewable energy (through national energy/climate plans)
  - Adapt market to renewables – shorter time scales, reward flexibility
  - More electric interconnectors
  - Sustainable forest management for biomass

EU Energy Winter Package 2016

Clean Energy For All Europeans

- Goal 3: *Providing a fair deal for consumers*; combining energy, digital and 5G tech
  - More reliable energy performance certificates
  - Easier to generate/consume/store/share/sell energy directly/as cooperative
  - Right to <u>not</u> use district heating/cooling if own solution has better performance
  - Alleviate energy poverty

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EU Energy Winter Package 2016

Clean Energy For All Europeans

- A new EU DSO entity for rules on grid management/use and ENTSO-E cooperation
- European framework for capacity mechanisms working across borders

- Improve regulation/economics/investments to accelerate clean energy innovation

> - *Based on the successful development of smart grids standards, the Commission will launch in 2017 a two years project to develop common secure communication standards which will ensure a free flow of energy-related data to relevant interested parties. The Commission will publish the results by the end of 2018.*
> - *In 2017 the Commission will establish stakeholder working groups under the Smart Grids Task Force to prepare the ground for network codes on demand response, energy-specific cybersecurity and common consumer's data format. The Commission*

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Conclusions

- Many paradigm shifts occurring in electric power systems
- Microgrid development will be affected by practically all the challenges

- Standards, performance requirements and performance criteria important
- Although stable conditions are important, requirements may need to change
- Organizations also needs to transform – DNO→DSO

- Swedish Energy Commission: flexibility, DSO's, micro trading, regulation pilots
- EU Winter Package: clean energy buildings, flexibility, DSO's, adapt market/regulation

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