Smart Grids, Smart Meters and Renewables Integration at E.ON

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Core businesses

E.ON core business: Renewables

- E.ON is the second-largest operator of offshore wind farms in the world, with 11,000 MW of generation capacity in UK, Germany, Sweden & Denmark

- In partnership with DONG Energy and Masdar, E.ON operates the world's largest wind farm, the 630 MW "London Array"

- The 302 MW "Amrumbank West" in the North Sea is E.ON's first commercially operated offshore wind project in German waters

E.ON core business: Distribution Networks

Map of E.ON's distribution networks

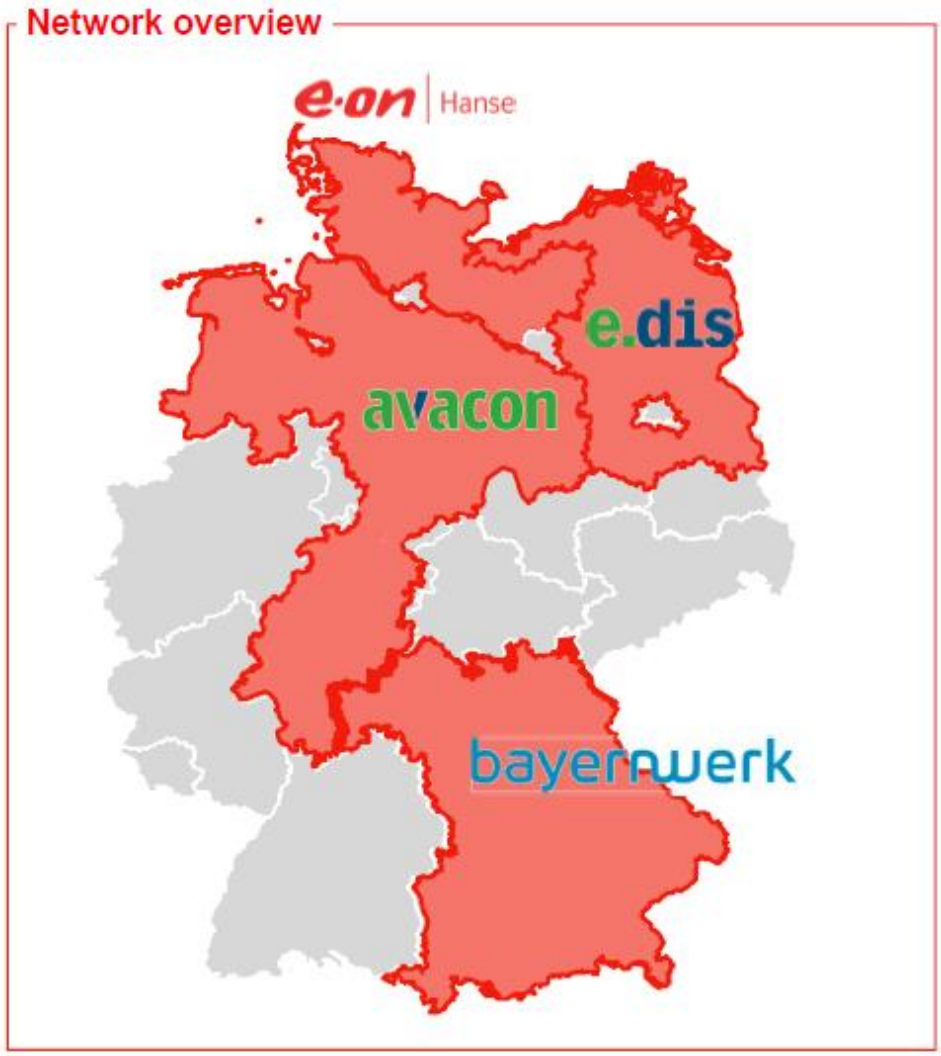
Regional Unit	Network length ('000 km)		Market share (in %)	
	Power	Gas	Power	Gas
Germany	352	59	19	14
Sweden	134	2	24	60
Hungary	84	18	50	20
Romania	79	20	17	49
Czech R.	65	4	27	6
Slovakia	37	-	40	-
Spain	32	-	5	-

Growth platform Turkey

- Enerjisa owns three distribution companies in Turkey (Ayedas, Baskent, Toroslar)
- Combined network length: ~200,000km
- ~9m customers

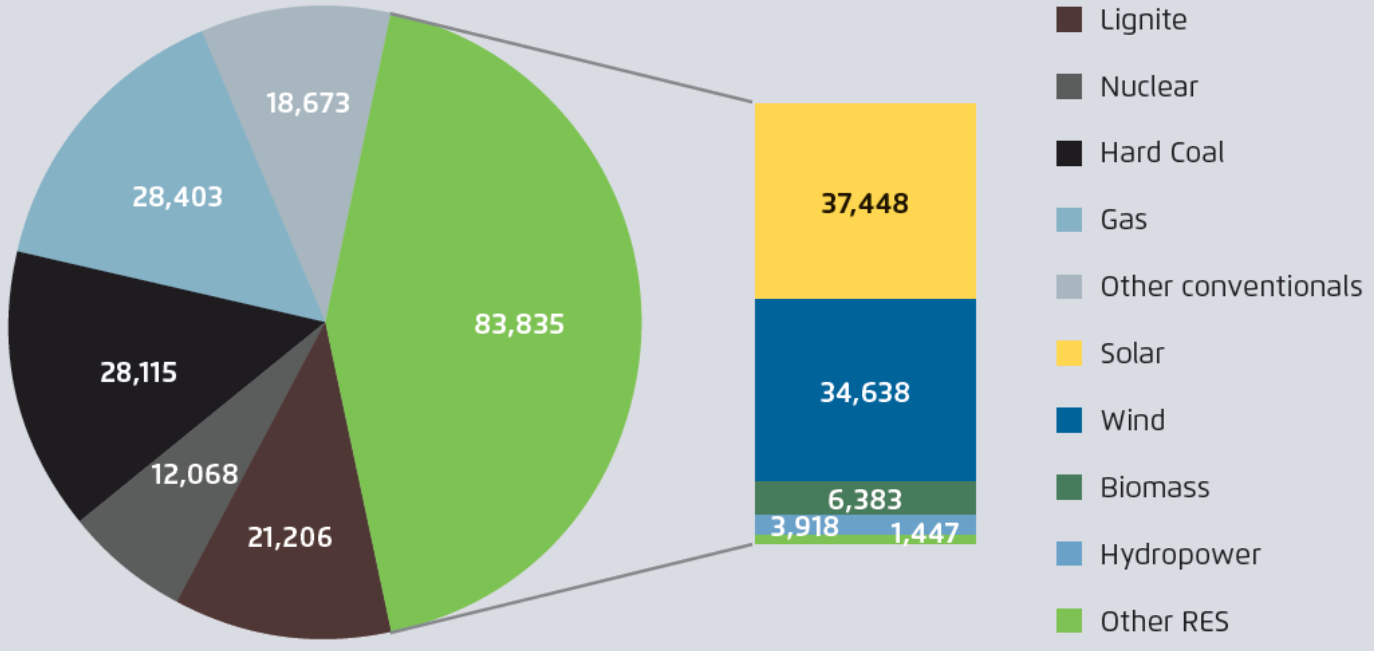
Grid Automation and Renewables Integration

E.ON’s distribution networks in Germany



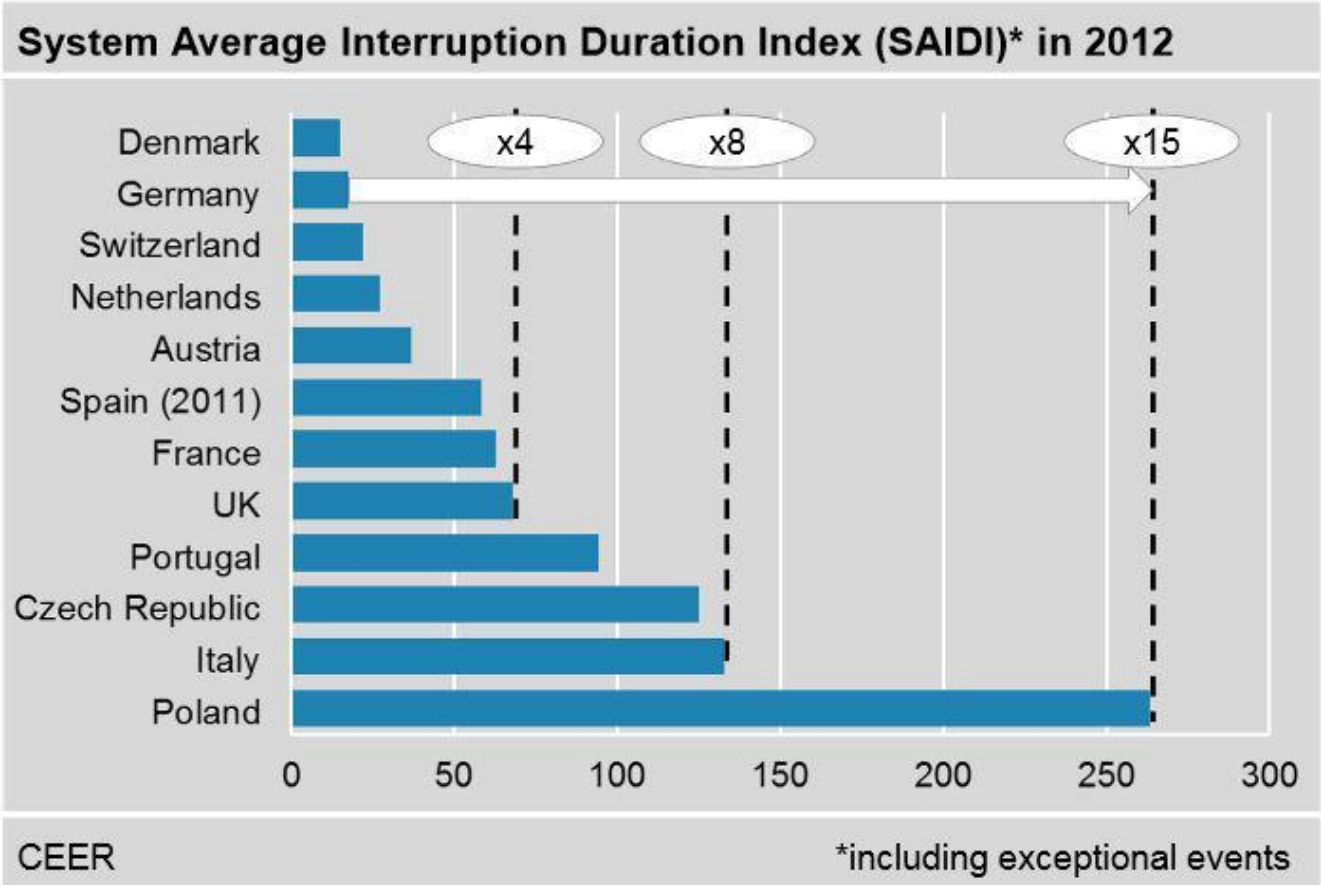
Germany has ca. 80 GW capacity of Wind & PV

Installed capacity 7/2014 in MW (Total: 192 GW) Figure 4



BNetzA, 2015, p.29.

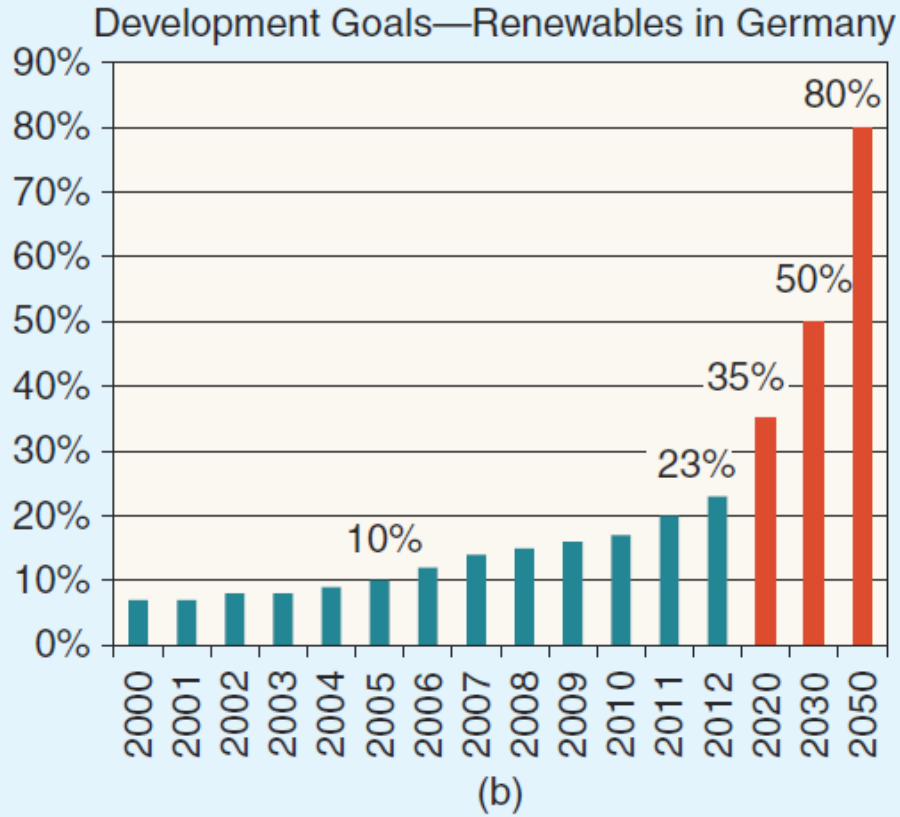
Yet the Power System is extremely reliable



RES capacity expected to increase to 80% by 2050

Renewables in Germany 2012	
Feed in	135 TWh
—Wind	46 TWh
—Photovoltaics	27 TWh
Percentage	23%
Number of Facilities	>1.1 Mio.
Costs of EEG	20.4 Mrd. €
EEG Contribution	52.77 €/MWh

(a)



(b)

Source: IEEE power and energy magazine

Challenge for SOs when facing high penetration of RES

- Intermittent energy sources such as Wind and Solar PV require a **flexible** power system with significant **reserves** – flexibility / reserves can be
  - sourced from generators, loads and storages
  - delivered using Ancillary Services such as Frequency Response, or directly by customers acting on real-time price signals

- RES such as Rooftop Solar PV are typically connected at LV. This is a part of the distribution network that has almost no **monitoring**

- **Reverse power flows** in the distribution system
  - often accompanied by voltage rises
  - require re-coordination of protection systems

- Additional power flows cause **congestion** in the transmission system

German System Operators have solved these issues

- Any generator or load can sign-up to provide ancillary services, as long as they satisfy the technical requirements (e.g. ramping, availability, etc)
  - Smaller loads & distributed generators (DG) are aggregated into a VPP that receives a single dispatch signal from the TSO
- Telemetry from SCADA systems (incl. Dynamic Line Rating), inverters and smart meters is consolidated into a wide-area monitoring system (WAMS) and used for Active Network Management
- Transmission System congestion is resolved through generator re-dispatch and RES curtailments (short-term) and by grid re-enforcement (long-term)
- Voltage rise in distribution networks is managed through power factor control of inverters, LV tap-changers and RES curtailments

Support for SOs in the German Renewables Act 2014

- Solar PV and Wind plants must be controllable by the System Operator in order to maintain system stability (both frequency and voltage) – otherwise the plant's output is capped at 70%

- Solar PV and Wind inverters must have frequency and voltage ride-through capabilities as dictated by the Grid Code

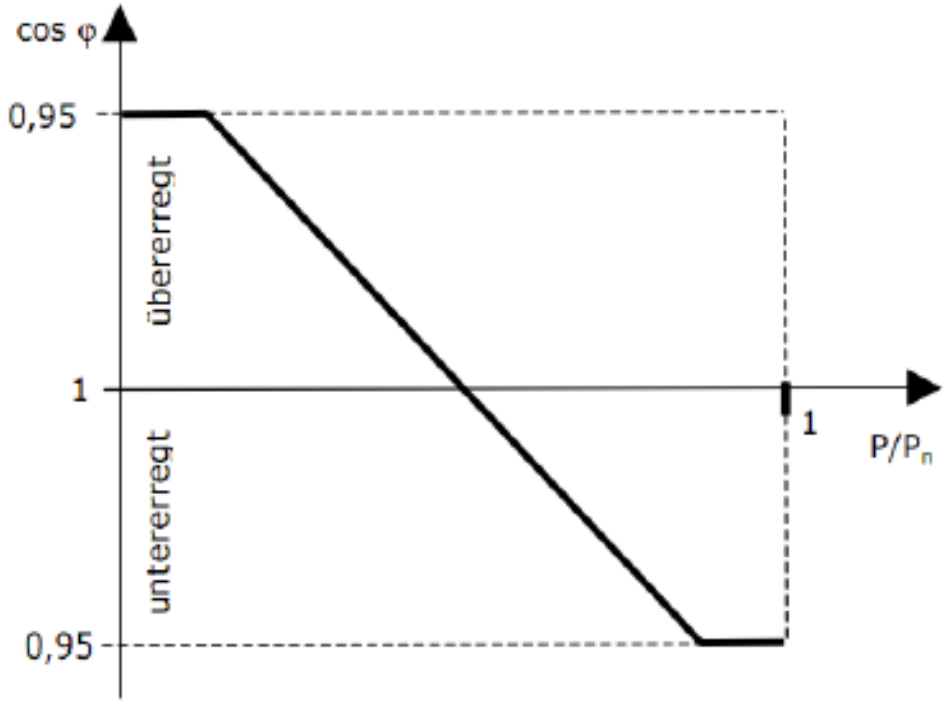
- RES Feed-in management (or curtailment) costs are socialized over end customers as part of the EEG subsidy to RES producers
  - RES curtailments in 2014 comprised 1.35% of the total net power generated from RES, resulting in € 82.6 million in EEG transfers

RES can be costly to integrate if no energy is to be lost

Country	Denmark	Germany	Spain	Ireland	France	Italy
Share wind + PV of demand (energy)	41%	15.6%	25.5%	17%	5%	12.4%
Total wind installed (MW)	4855	40456	22845	2230	9120	8700
Wind capacity factor MWh/(MW*8760) [%]	30.8	15.8	25.4	25.9	21.2	19.6
Total PV installed (MW) Total	610	38236	4428	0	5292	18800
Solar capacity factor MWh/(MW*8760) [%]	11.2	10.4	20.2	0	12.6	14.1
Maximum instantaneous wind + PV penetration for 1 h (%)	140%	56.3% (11-05-2014)	65.4% (23-12-2013)	50%	21.5%	46.18% (26-04-2014)
Curtailment/total PV generation (%)	0	0.18% (2013)	< 1.5%	0	0	0
Curtailment/total wind generation (%)	0.2%	0.93% (2013)	< 1.5%	4.3%	0	0.8%

Sources: BNetzA, German TSOs, Terna, REE, Energinet.dk, EDF, and Eirgrid (2014)

Power factor control of PV inverters

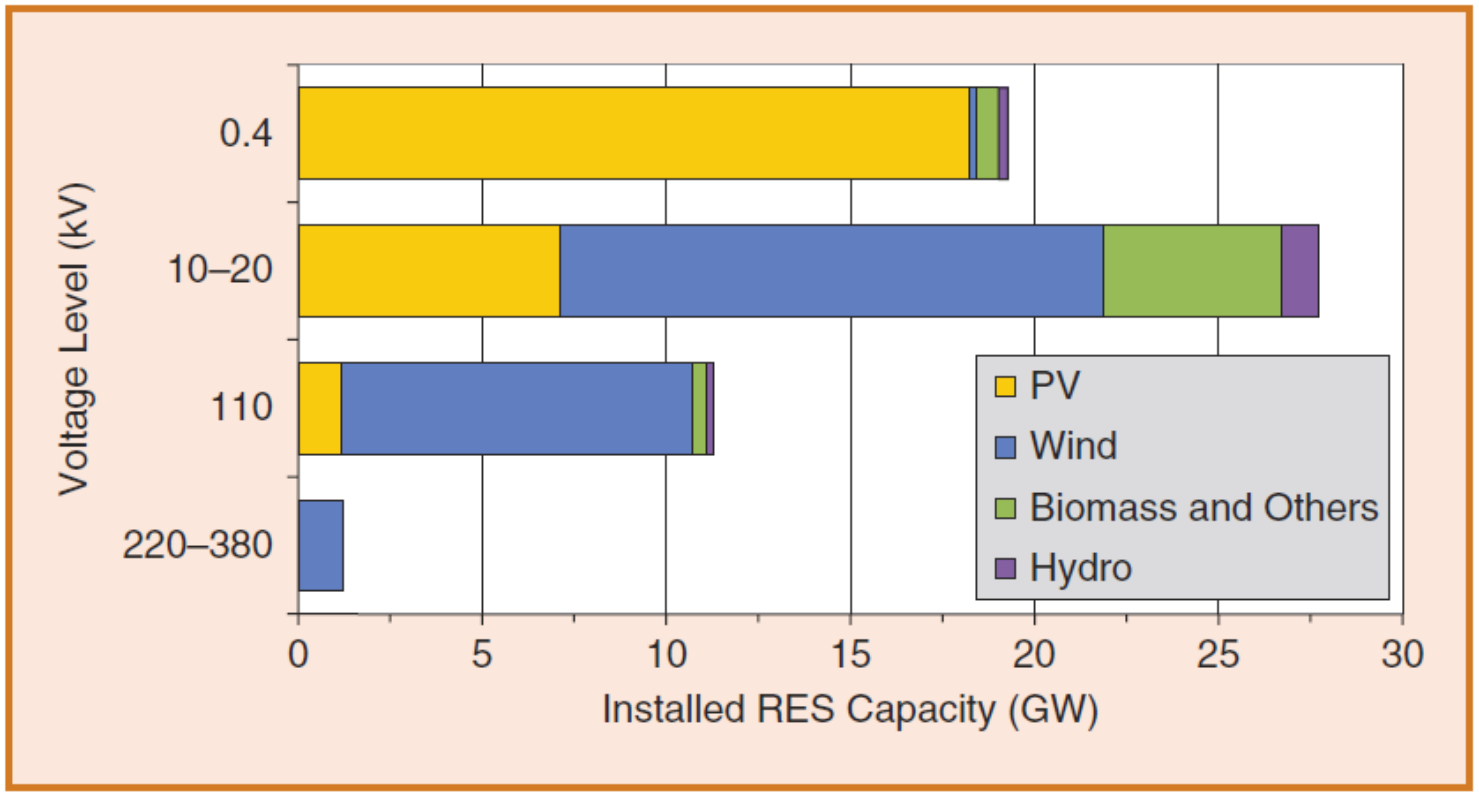


Source: Medium voltage guideline 2008 page 29

System operator may demand the supply of reactive power with cos(φ) between 0,95 and 1

Ca. 1.4 mill. PV plants connected in GER by Apr. 2014

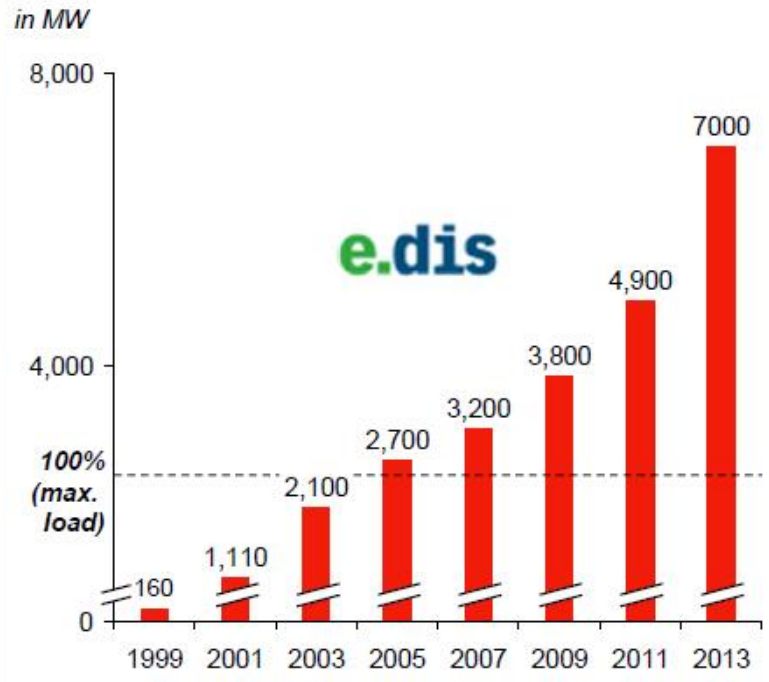
Nom. voltage levels of RES on the German System



Source: IEEE power and energy magazine, vol. 11, issue 2

RES integration is a significant challenge for E.ON grids

Example E.DIS: RES installed capacity



→Today's RES capacity is three times the amount of peak load

Key challenges

- Distribution grid originally designed to distribute power up to maximum load
- RES installed capacity exceeds maximum load in a region nearly factor 3
- Now, expansion of the distribution grid required as well as increased deployment of smart technologies

Energiewende – E.ON as an innovation pioneer

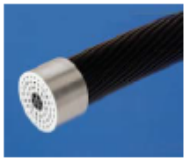
Examples of application of smart technologies

Controllable mid-voltage/low-voltage-secondary sub-station

Enables an increased in-feed of renewables in low voltage networks by dynamic voltage regulation

Dynamic line rating (high-voltage)

Increase of line capacities by taking account of varying weather conditions



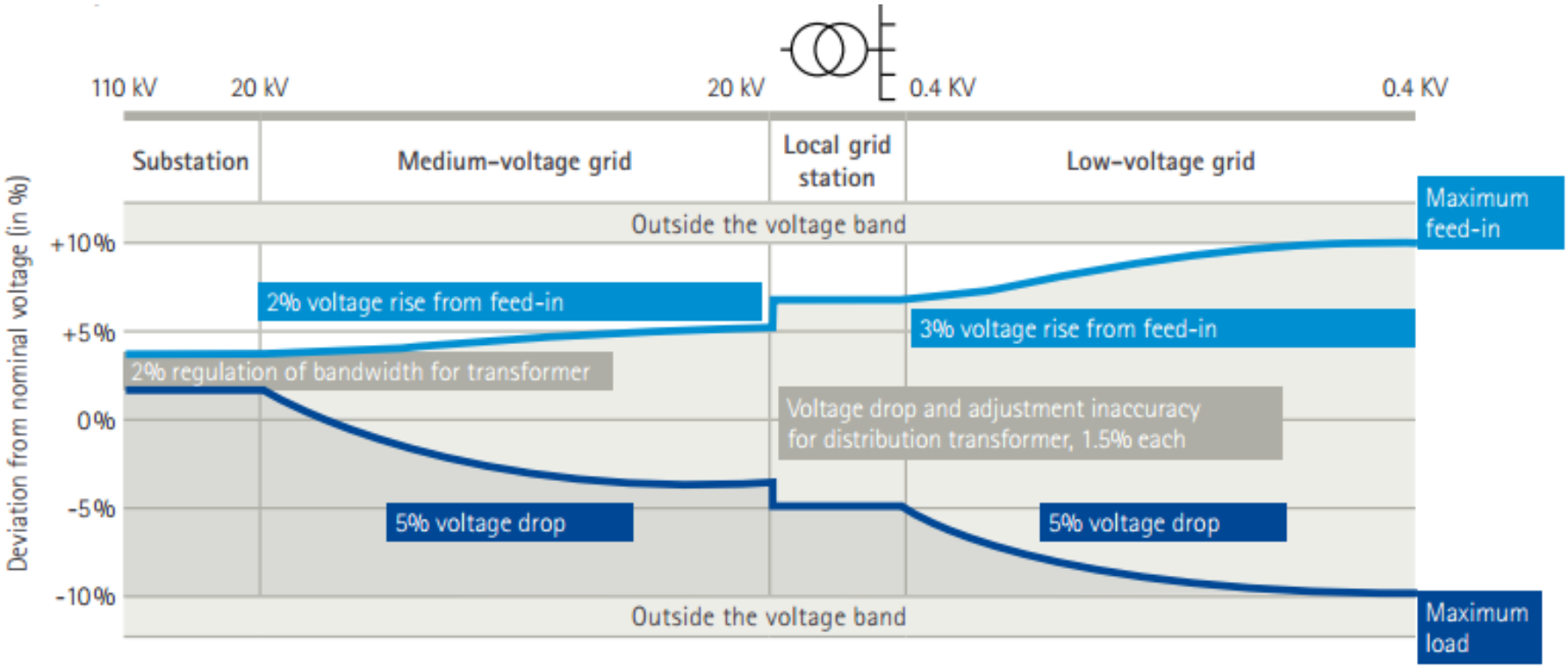
High temperature lines

Increased capacity of conductors by using temperature-resistant materials

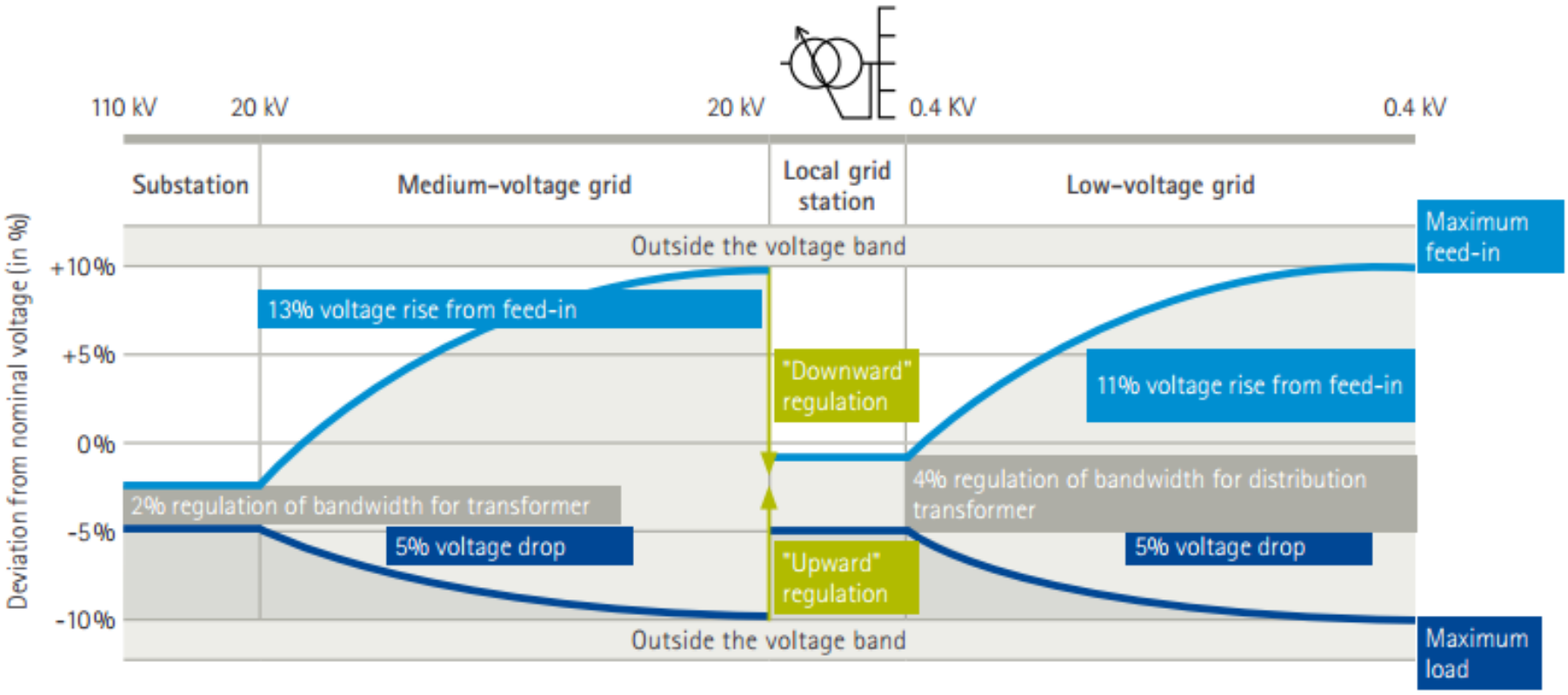
Intelligent in-feed management (EisMan)

Intelligent curtailment of renewable generation in case of grid congestion allows integration of all RES requesting connection to the grid

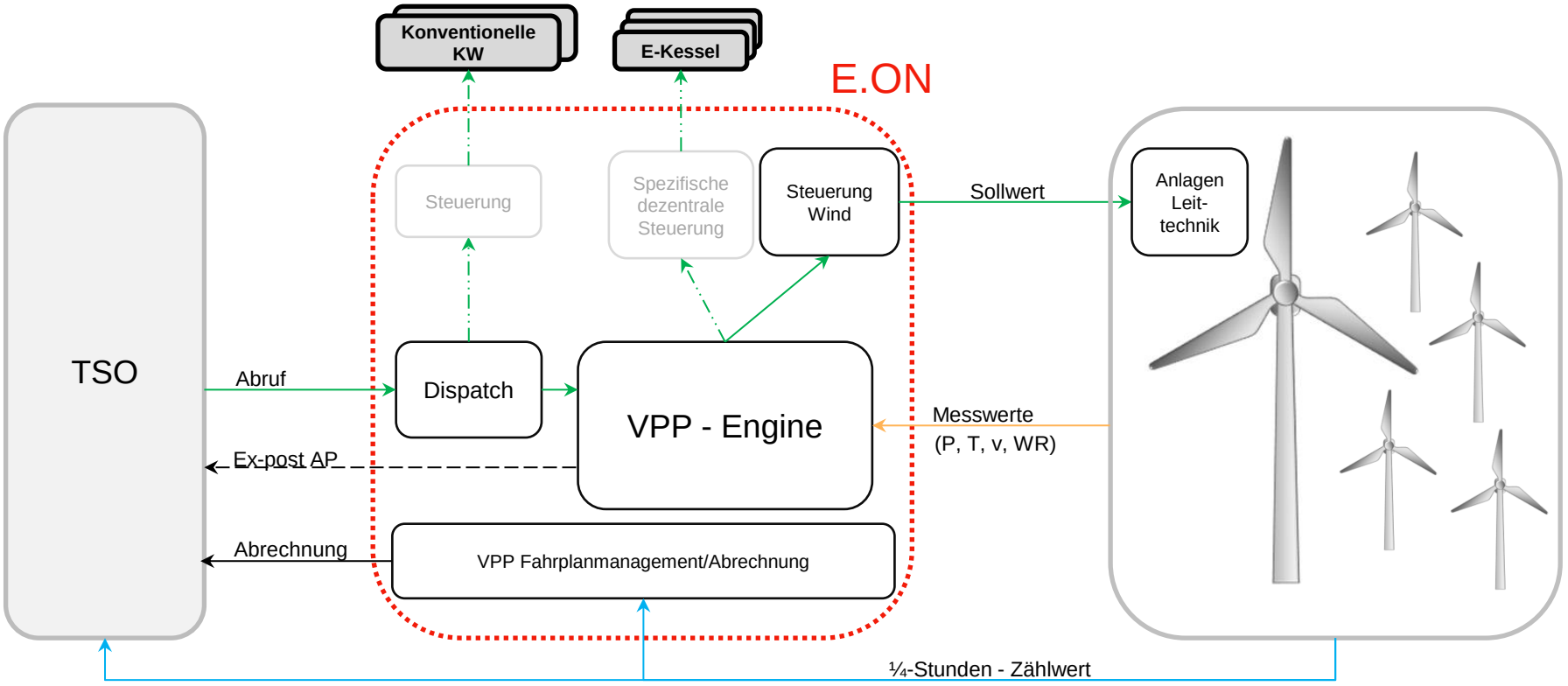
Voltage rise in LV grids is not allowed to exceed 3%



E.ON Solution: OLTC allows for a voltage rise of up to 10%



Frequency control in Germany via a Virtual Power Plant



Sollwert der Leistung, Höhe des RL-Abrufs

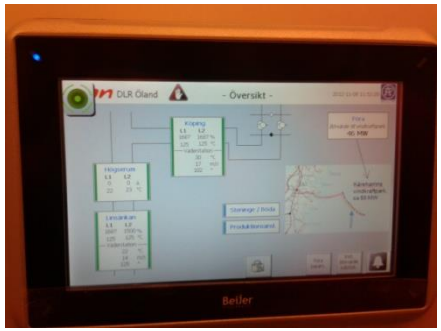
Livewerte

Abrechnung und Arbeitspunkt

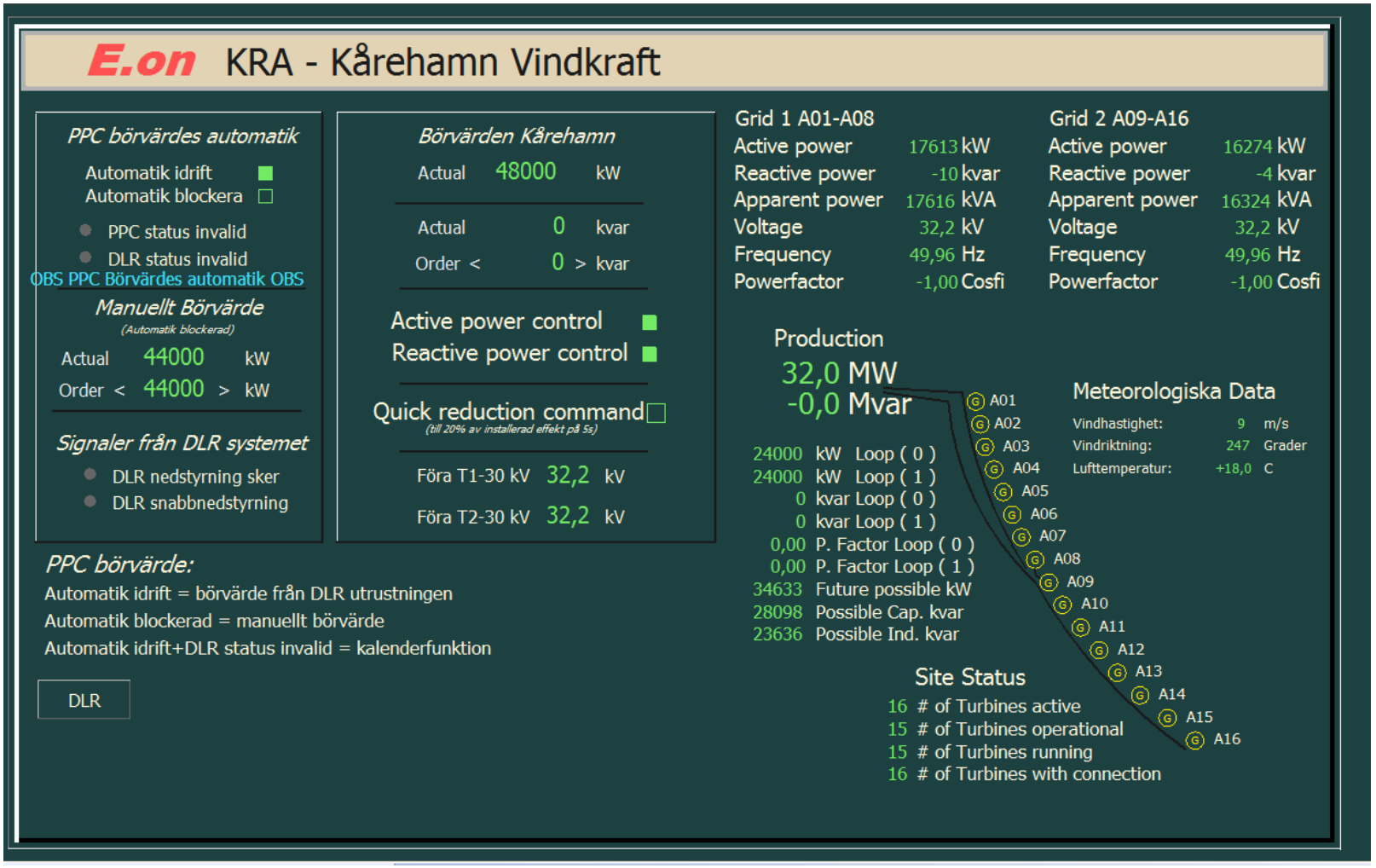
15 Minuten Leistungsmittelwerte

Dynamic Line Rating in Sweden

- In Linsänkan and in Köping two Alstom-relays will be placed with a weather station.
- In Högsrum two Donuts will be installed.



Integration of DLR with SCADA



Smart Metering

EniM Project… Smart Meter rollout in Germany

Verteilnetzbetreiber

e.on

bayernwerk

e.dis

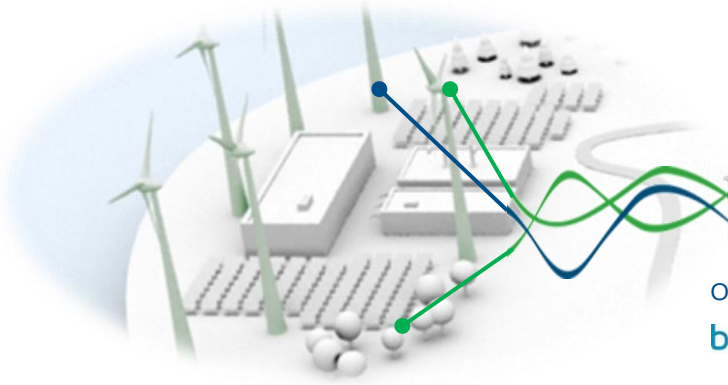
avacon

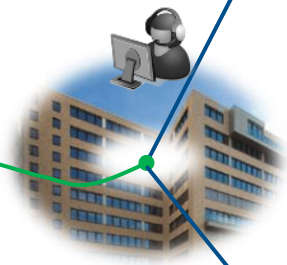
Hanse Werk

Kommunikation
Wide Area Network (WAN)

Powerline (PLC)

Öffentlicher Mobilfunk
(800-2400 MHz)
Privater Mobilfunk
(450 MHz)





e.kundenservice NETZ

Ortsnetzstation

bayernwerk

e.dis

avacon

Hanse Werk

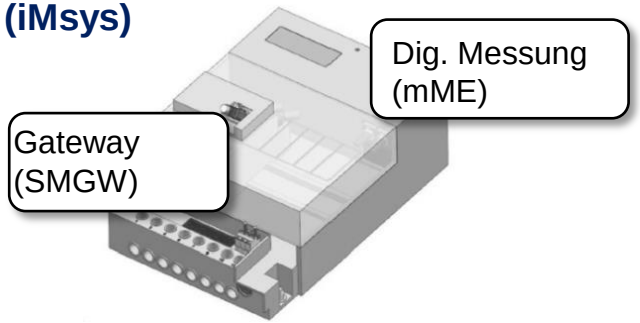
Backend

- Messstellenbetrieb
- Gateway Administration
- Meter-to-Cash
- Smart Grid
- …

EMTG

e.on

Frontend:
Intelligentes Messsystem (iMsys)



Stadtwerke

e.on

EMTG Smart Metering - “end to end” service solution

Preparation
- Framework Contracts
- Consulting
- Contract Management

Installation
- Scheduling
- Installation
- Commissioning

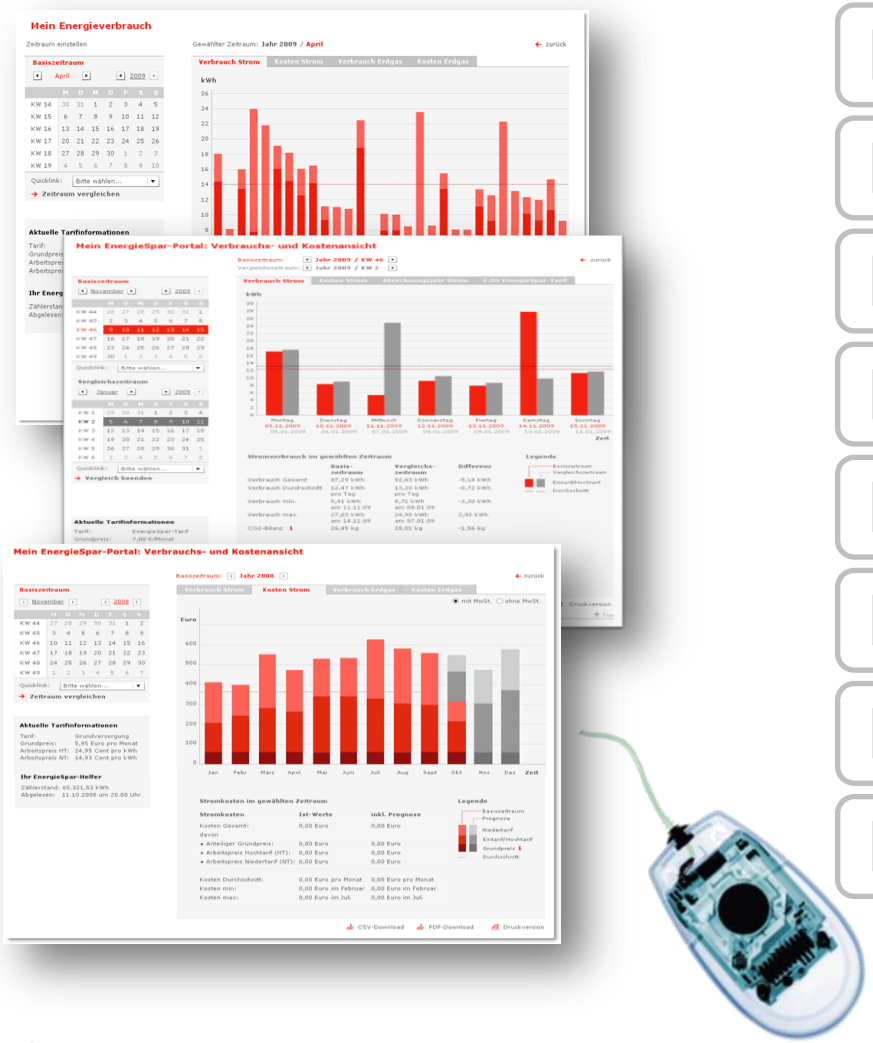
Operation & Maintenance
- Performance Management
- Reporting and incident management
- Replacement

Data Collection & Data Processing
- Multiple comms options
- Reading Frequency
- Commissioning & Validation
- Enhanced meter data – frequency, reactive, event logs etc

Data Management
- Secure data storage
- Analysis & Integration
- Exception & performance reporting

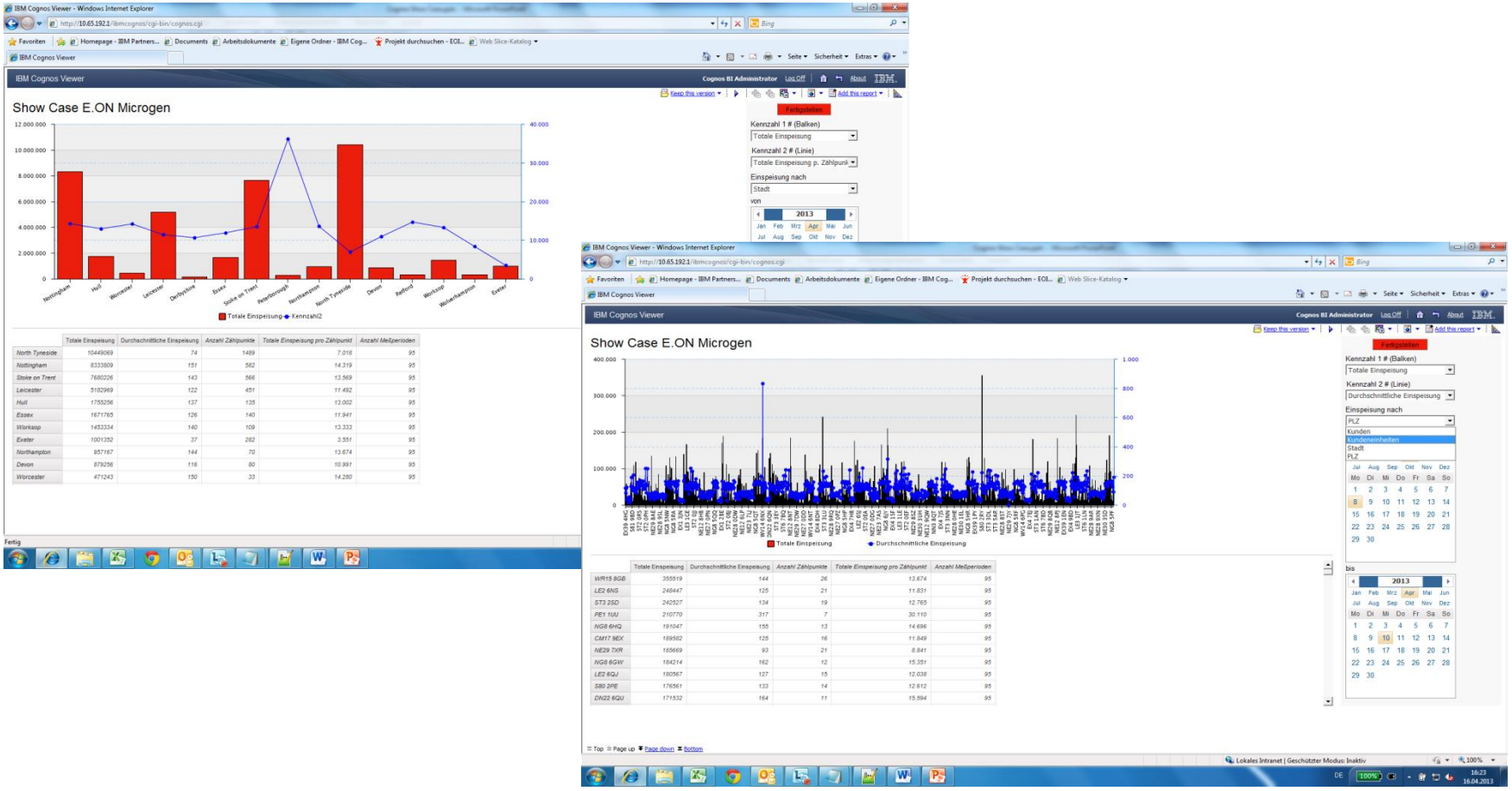
Business Support
- Customised portal solutions
- Training and advice
- Technical Support

More transparency - more control for customers



- Visualisation of consumption including costs as well as ¼ or ½ hourly values
- Representation at different levels of aggregation (eg, day, month, year)
- Additional information (eg, maximum, minimum and average values)
- Instantaneous meter reading
- Display historical values
- Compare and benchmark consumption in different periods
- Comparison of consumption across multiple sites
- Download the consumption data for further analysis as MS Excel

Data Analysis & Reporting - examples



- Detailed analysis and trend reporting
- Flexible presentation styles