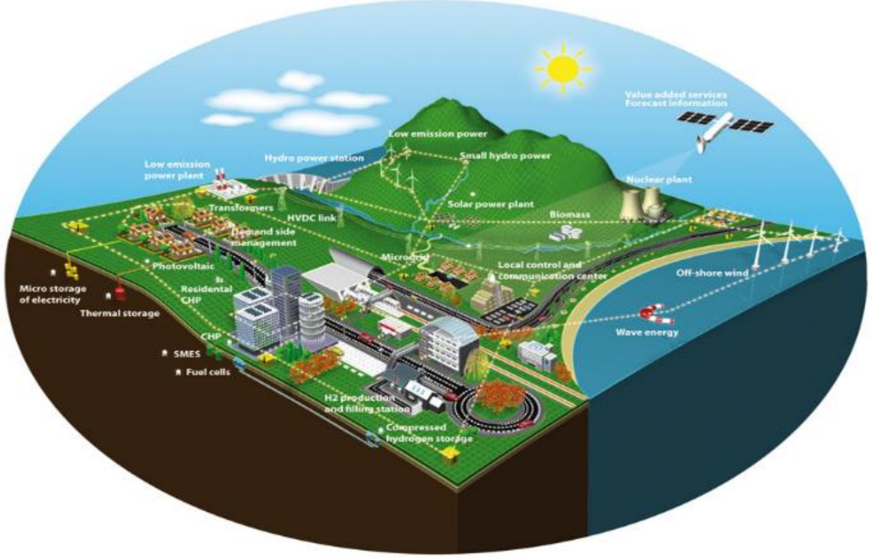
Smart Grid Development in Norway



Kjell Sand
Professor at Department of Electric Power Engineering, NTNU
Scientific manager The Norwegian Smart Grid Centre

The Norwegian University of Science and Technology, NTNU

- 8 faculties and 55 departments and divisions
- 40.000 students
- Full time eq.: 6900, of which 4200 are in teaching, research and outreach positions (39 % female).
- 366 PhD finished in 2016
- 6800 bachelors and masters finished in 2016

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STRATEGIC RESEARCH AREAS 2014–2023

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Norwegian University of Science and Technology

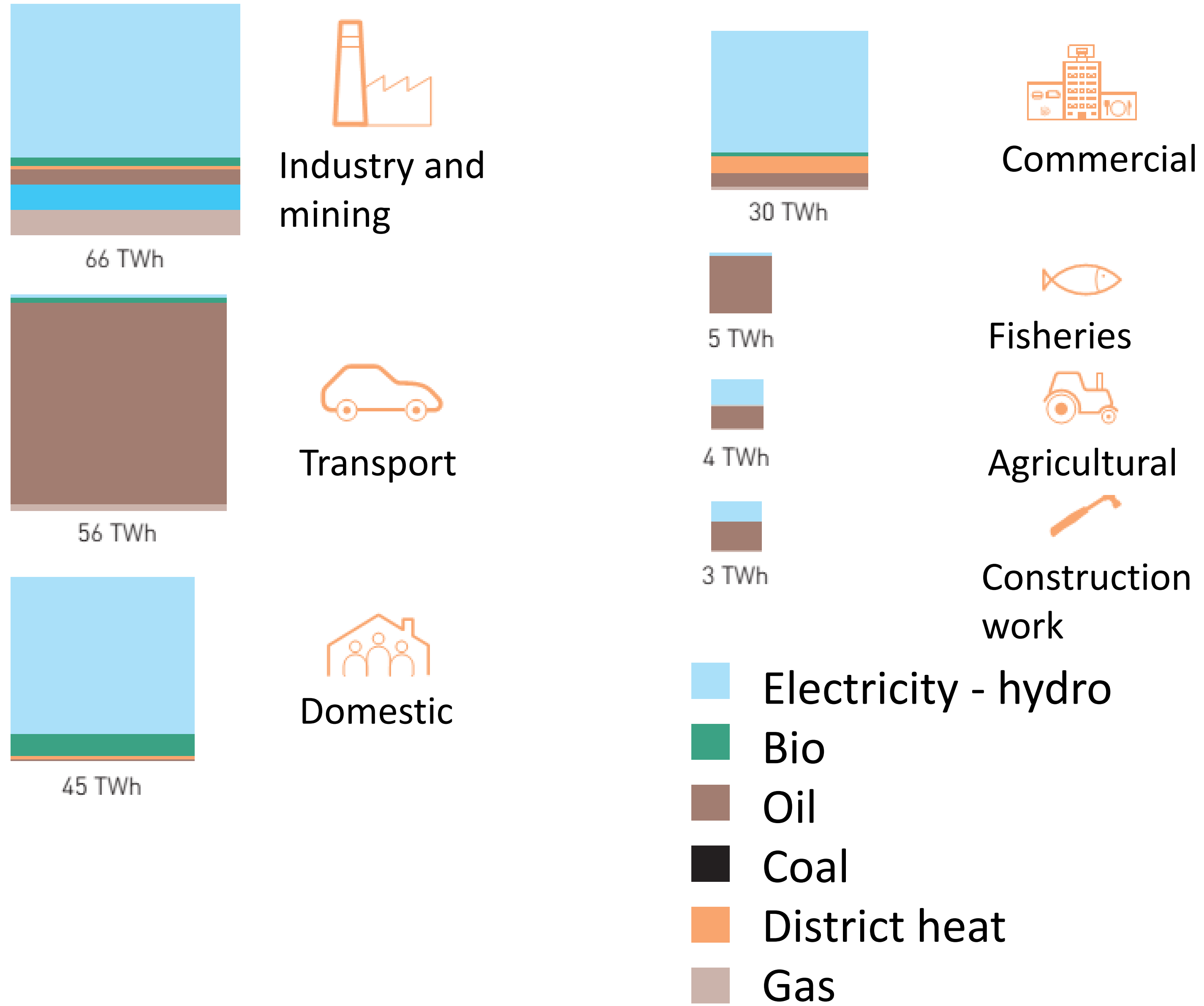
ENERGY

HEALTH

OCEANS

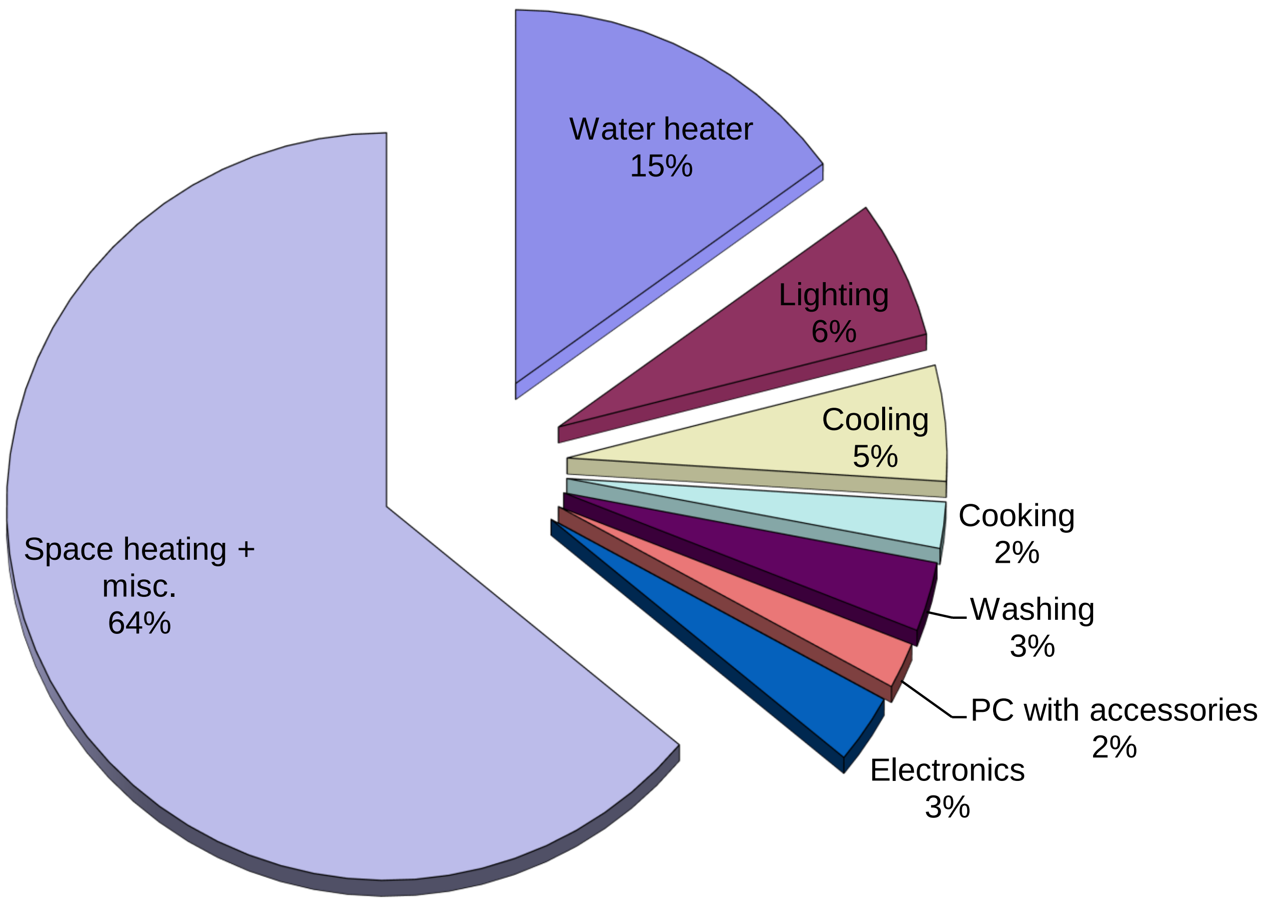
SUSTAINABILITY

Norway mainland energy use 2014
Mainly hydropower and oil – 67% renewables



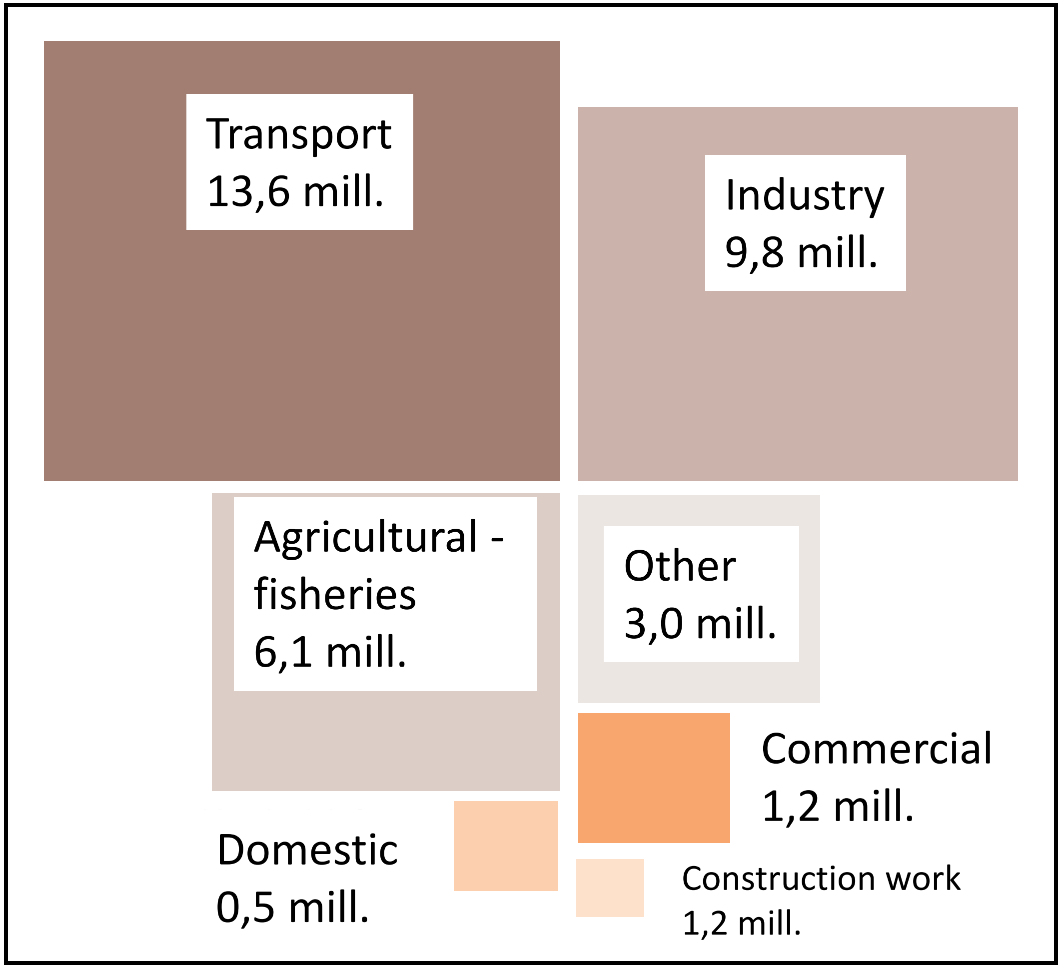
Electric Energy Usage in Norwegian Households.

16 000 kWh per household (average)



Thermal loads (heating/cooling) offer flexibility

Norway mainland climate gas emissions 2014 per sector : 34,9 mill. ton CO_2 equivalents.



Smart Grid Status Norway

Transmission/sub-transmission

"Smart"

MV Distribution

Not so "smart"

LV distribution/ supply terminal

Becoming "smarter"

Smart metering by 2019-01-01

Grid characteristics

- Low customer density, but high electricity use per customer
- High amount of cabines/cottages connected to the power system
- Long distances between power plants and load centers
- Significant amount of MV and LV distribution as overhead lines
- Approx. 70 % of LV distribution 230 Volts - 30% 400 Volts
- Weak grids with approx. 40% of the supply terminals weaker than the standardized EMC reference impedance (IEC TR 60725)
- Demanding environment – especially for overhead lines (wind, ice, snow, salt, moisture, vegetation...)

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Requirements for smart meters in Norway

- Full roll out by the end of 2018
- Responsible party: DSOs
- Functional requirements
  - Register and store with a sampling frequency of 60 min (with options for 15 min sampling)
  - Standardized interface for communication with external equipment – Moe Area Network (HAN port)
  - Connectable to other smart meters: Gas, heat, water
  - Secure storage of data in case of voltage interruption
  - Disconnect or limit customer power consumption
  - Exchange spot price and tariff information
  - Exchange control and earth fault signals
  - Data security and tampering measures
  - Measure active and reactive power (input and output) i.e. 4-quadrant measurements

HAN port requirements

- Data streaming of OBIS codes (IEC 62056-6-1 DLMS/COSEM)
- MBUS (EN 13757-2)
- RJ-45 connection (ISO/IEC 8877)

- Data:
  - Active power (import/export) - 2,5 sec interval
  - Reactive power and direction - 10 sec
  - Currents (L1, L2 og L3) - 10 sec
  - Voltages (L1, L2 og L3) - 10 sec
  - Energy (import/export) - Hourly
  - Reactive energy (import/export) - Hourly
  - Time stamp - Hourly

Might support e.g. display, demand side management, demand response

Plan and status for smart meter rollout in Norway

- In total approx. 2.9 mill. smart electricity meters to be installed
  - 2.5 mill. smart meters in households and cottages
- Meters are installed inside buildings
- Average installation costs per metering point: 3500 NOK (including software)
- Total costs: approx. 10 Bill. NOK
- Increased grid tariff per household: 300 NOK/year

1 US$ = 8 NOK

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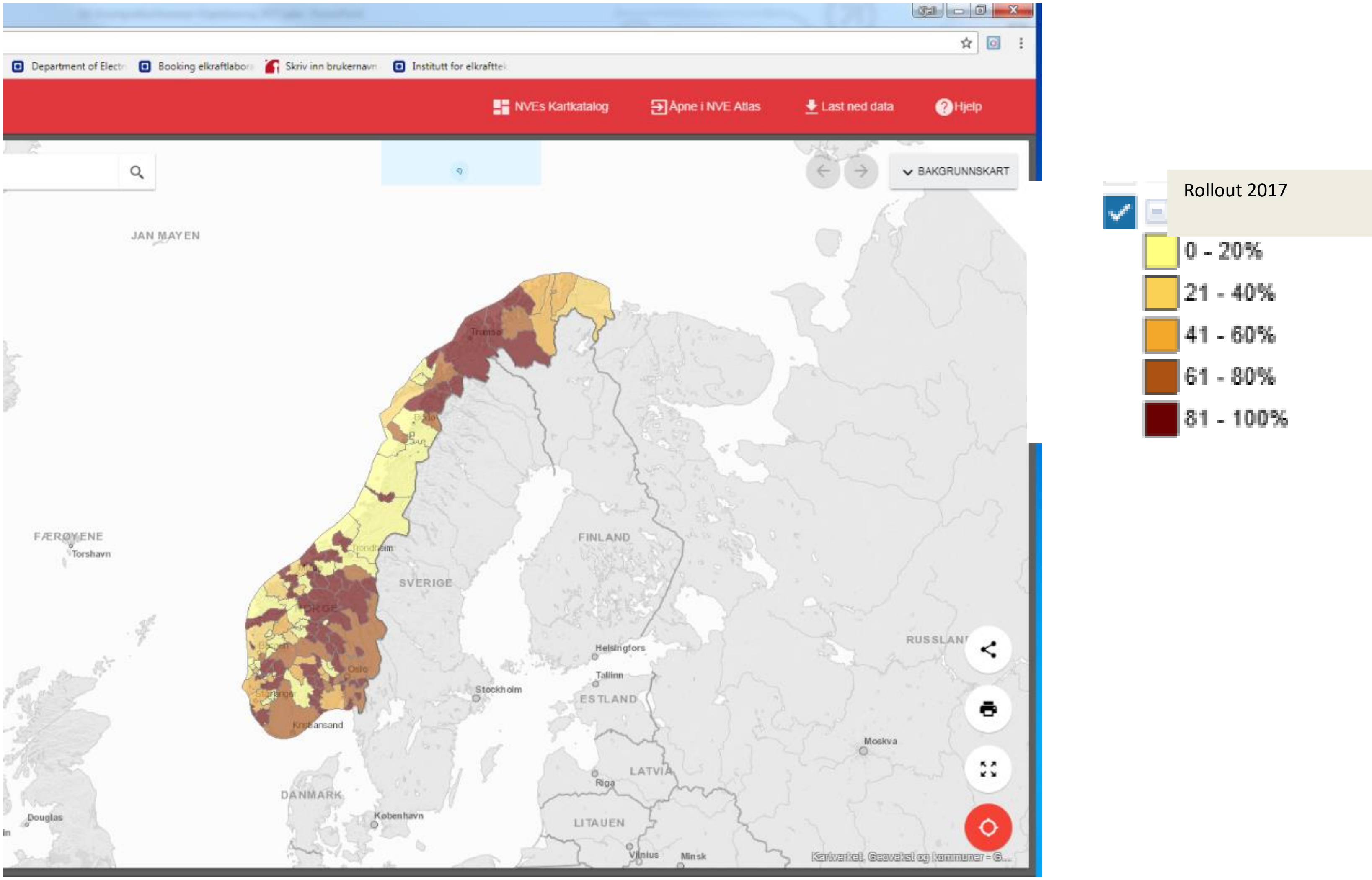
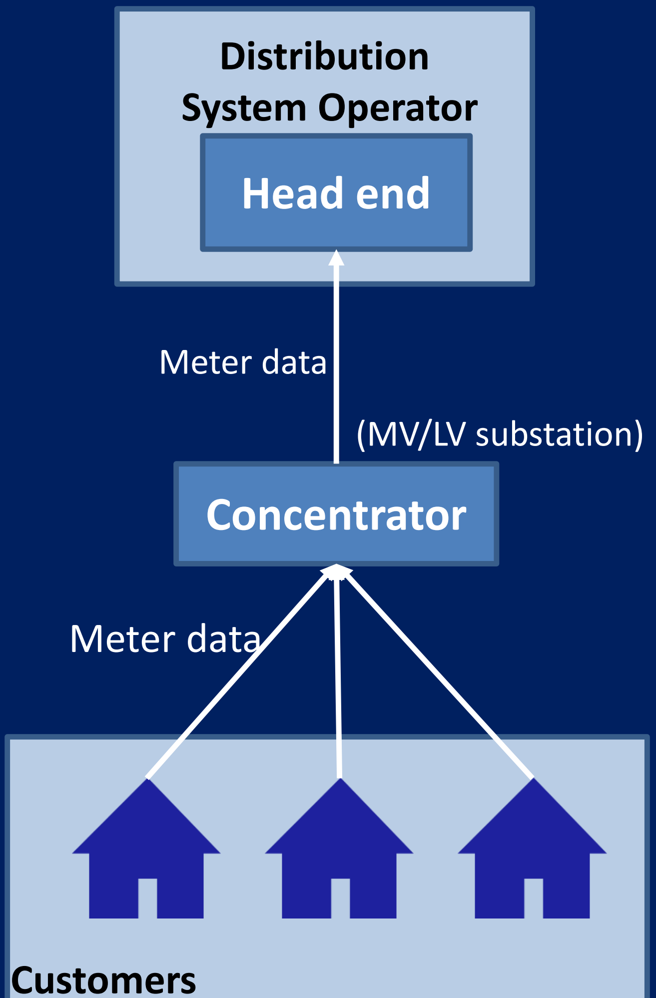
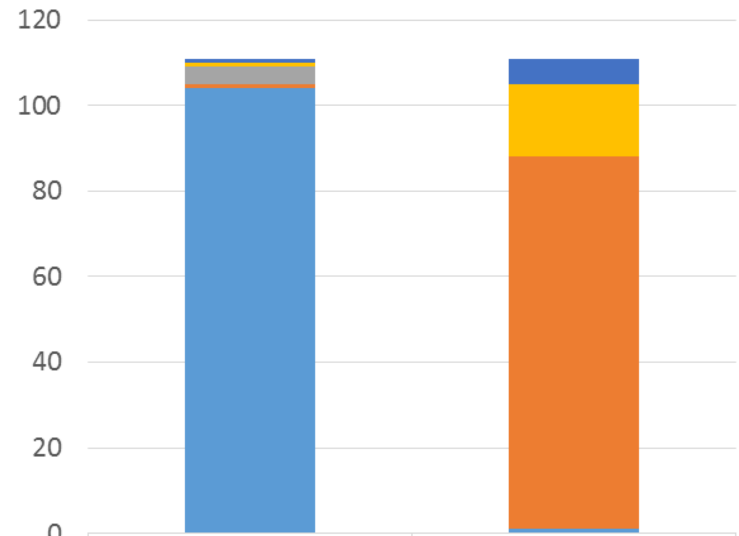
The development is monitored closely by the regulator based on mandatory DSO reports



Source: www.nve.no (Regulator’s web site)

Smart meters – Communication solutions





	Meter - Concentrator	Concentrator - Head end
Other/Not decided	1	6
Fiber	1	17
PLC	4	0
Mobil (GPRS, 4G, 3G, 2G)	1	87
Radio/Radiomesh	104	1

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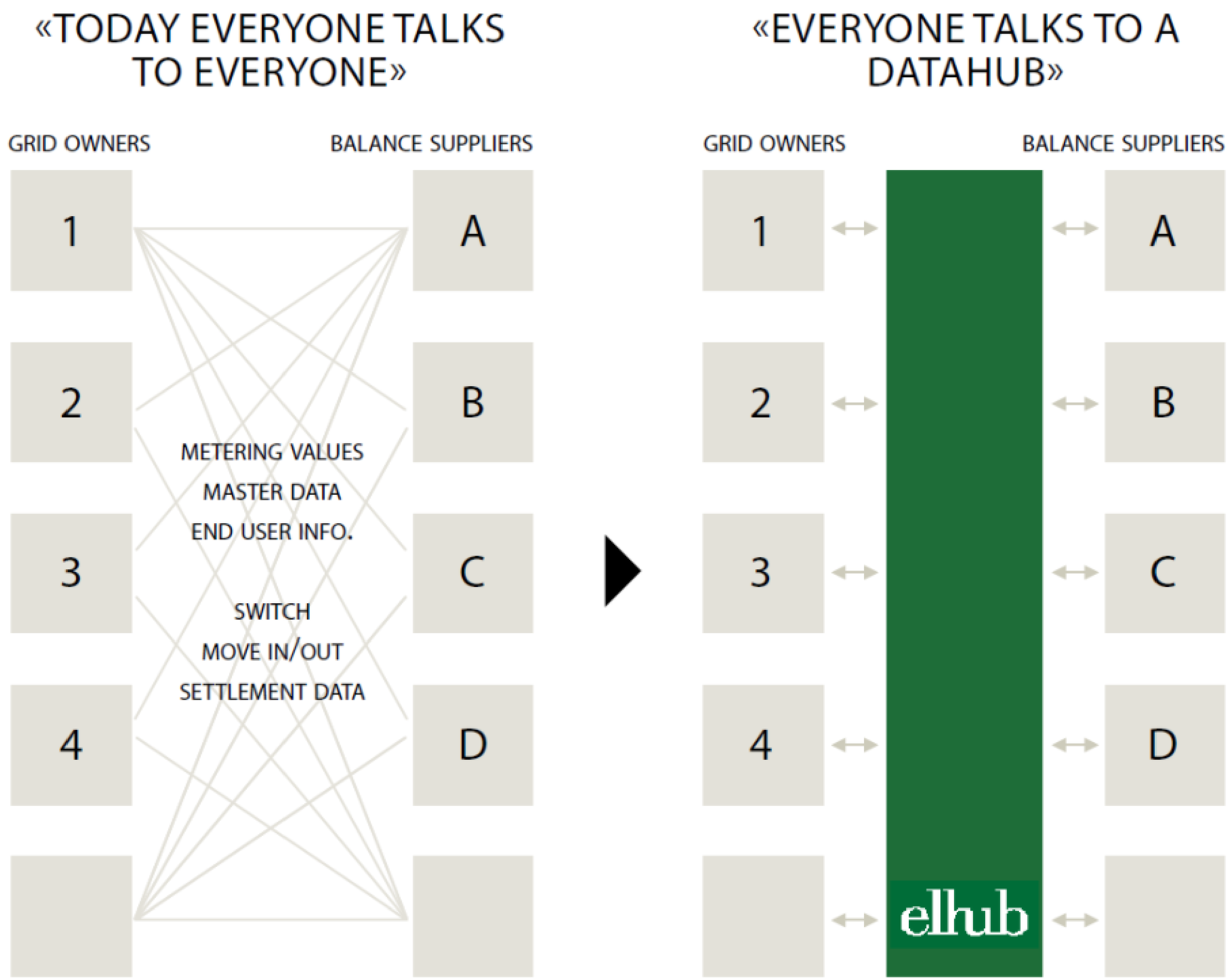
Who owns the metered data?

- Use of meter data is regulated by the Personal Data Protection Act
- DSOs and power retailers can use the data necessary to invoice the customer
- The customer decides who should have access to their data
- The DSOs can only store the customer data for 3 years

National datahub for meter data and customer data exchange – operated by the Norwegian TSO: Statnett



Demand will become more flexible

- Industry level

- Home level

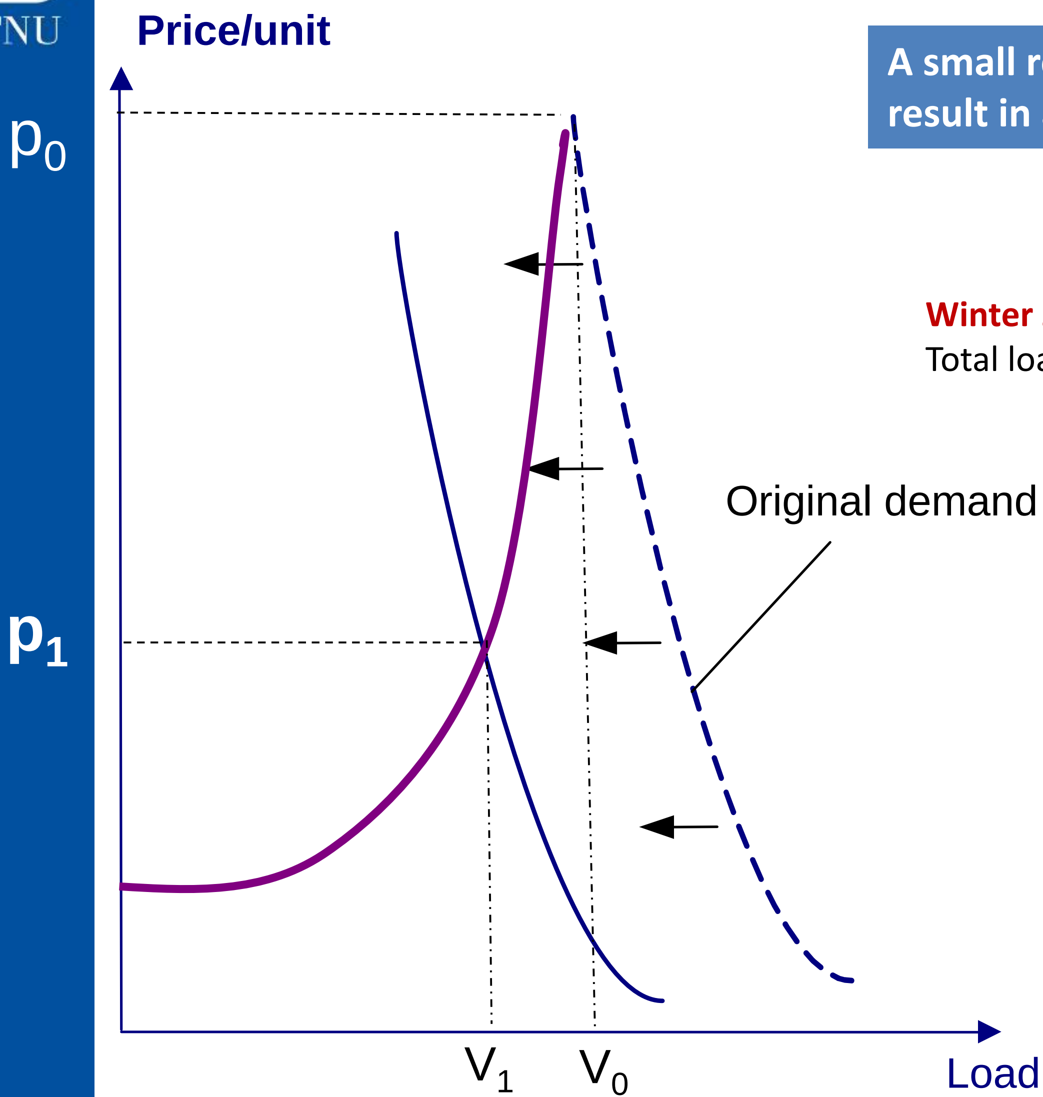
- Apparatus level

- EVs

Flexibility potential today:

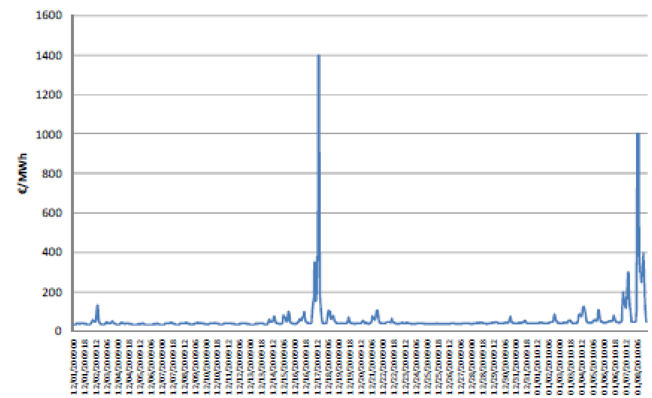
- Industry 3000 MW
- Buildings 2000 MW
- i.e. 20% of system hourly peak load

Value of demand side price elasticity



A small reduction in volume (from V_0 to V_1) will result in a large reduction in price (from p_0 to p_1)

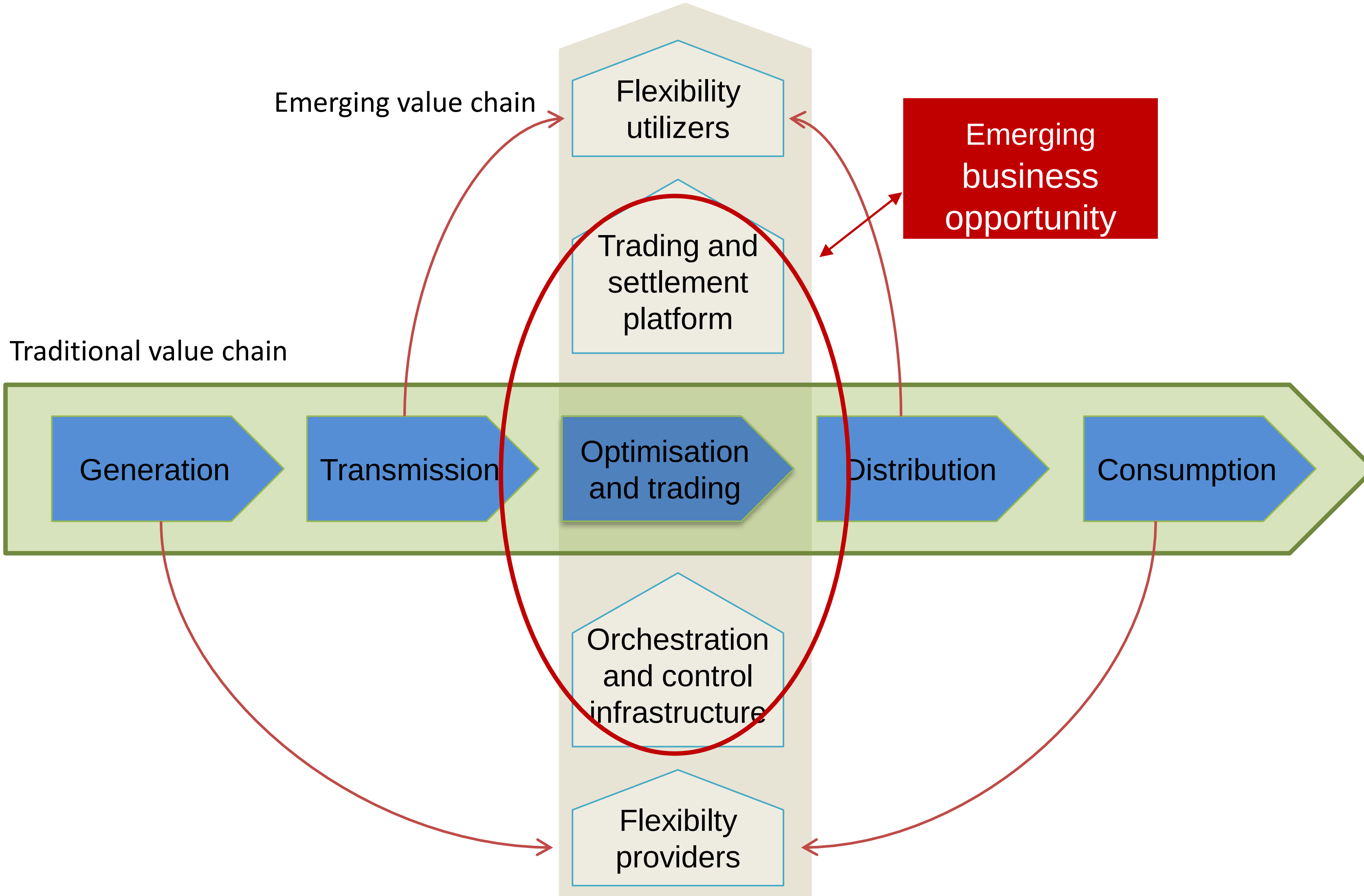
Winter 2009/2010 – extreme prices in the Nordic market:
Total load in system: 40 000 MW



Less than100 MW load reduction would have reduced the price from 13 NOK/kWh to 1 NOK/kWh

(1 US$ = 8 NOK)

Aggregators are harvesting flexibility



Household offers - three different technical products tested with different customer messages

eWave. Display

Home control

AMI Price signal response

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Energy savings winter 2014 vs 2013

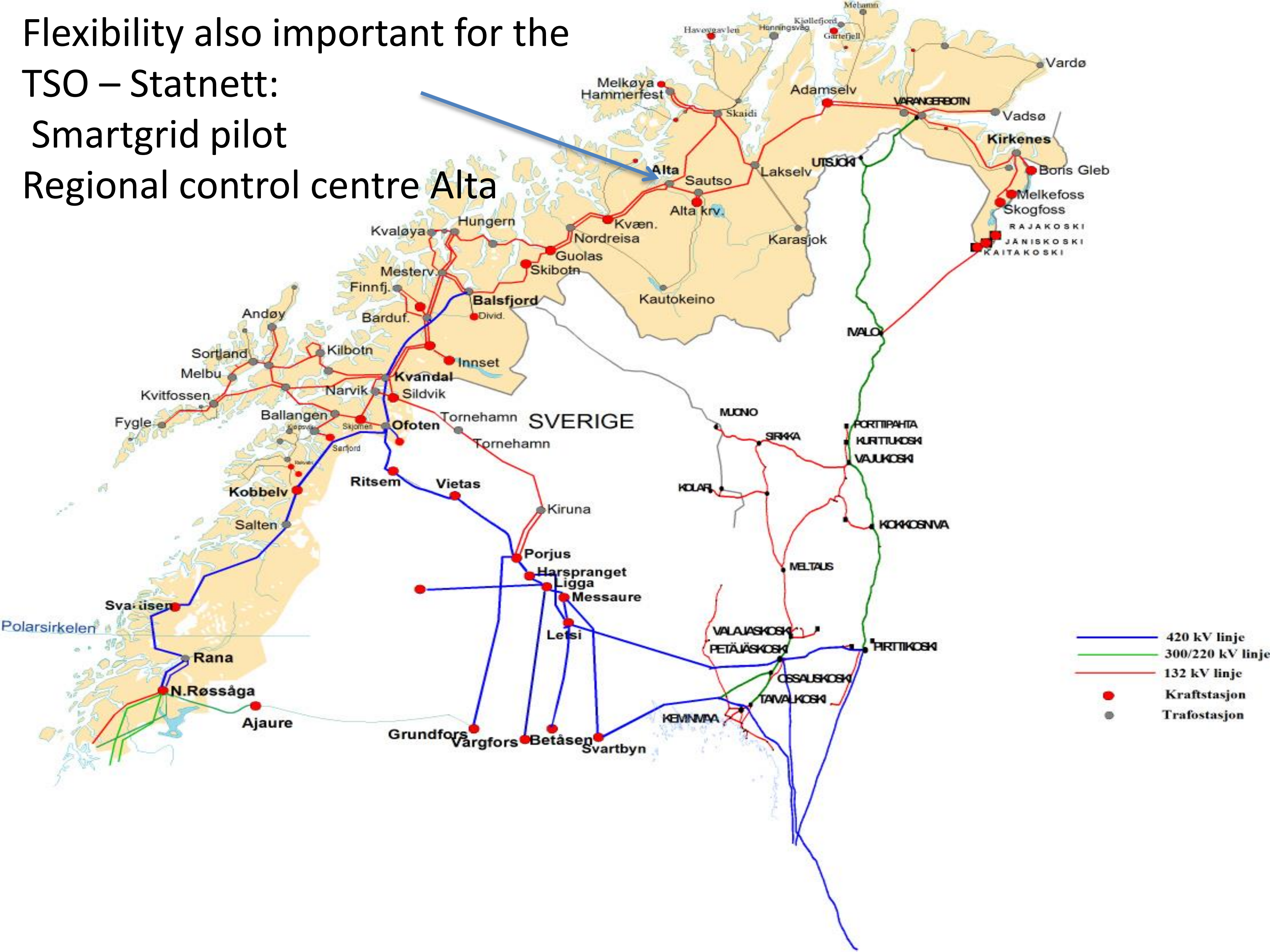
- Site 1 (rural)
  - Test group – net reduction (temp. corr) -16,3%
  - Control group net reduction (temp. corr) +0,1%

- Site 2 (urban)
  - Test group –net reduction (temp. corr) -5,3%
  - Control group – net reduction (temp. corr) 0,0%

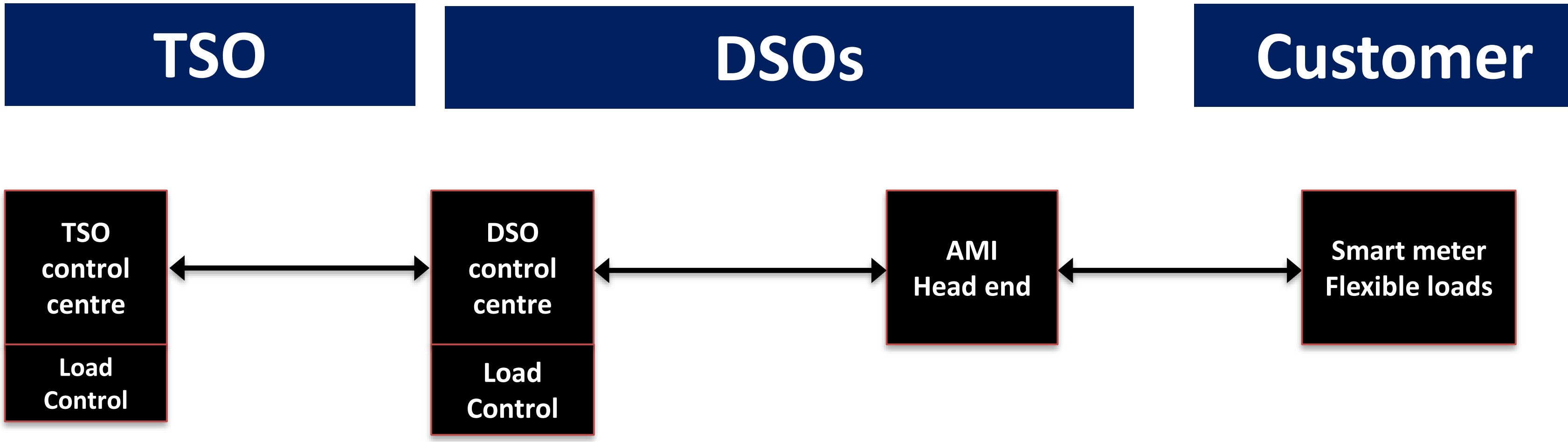
Flexibility also important for the TSO – Statnett:

Smartgrid pilot

Regional control centre Alta



Statnetts demand response pilot



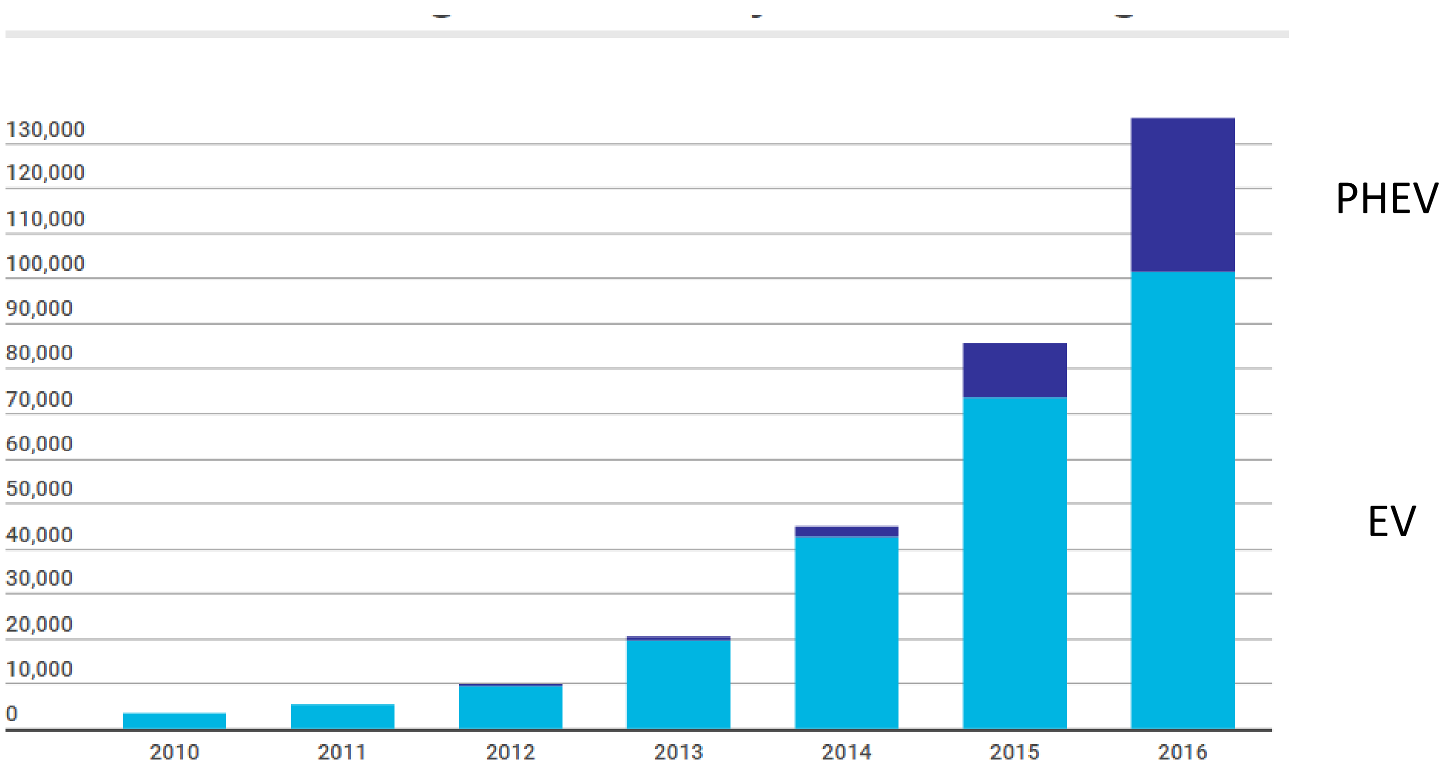
Standards/ protocols

ELCOM	XML / CIM (IEC 61968-9)	DLMS / COSEM
	HTTPS (TLS)	
TCP / IP	TCP / IP	TCP / IP
Fibre	Ethernet	GPRS

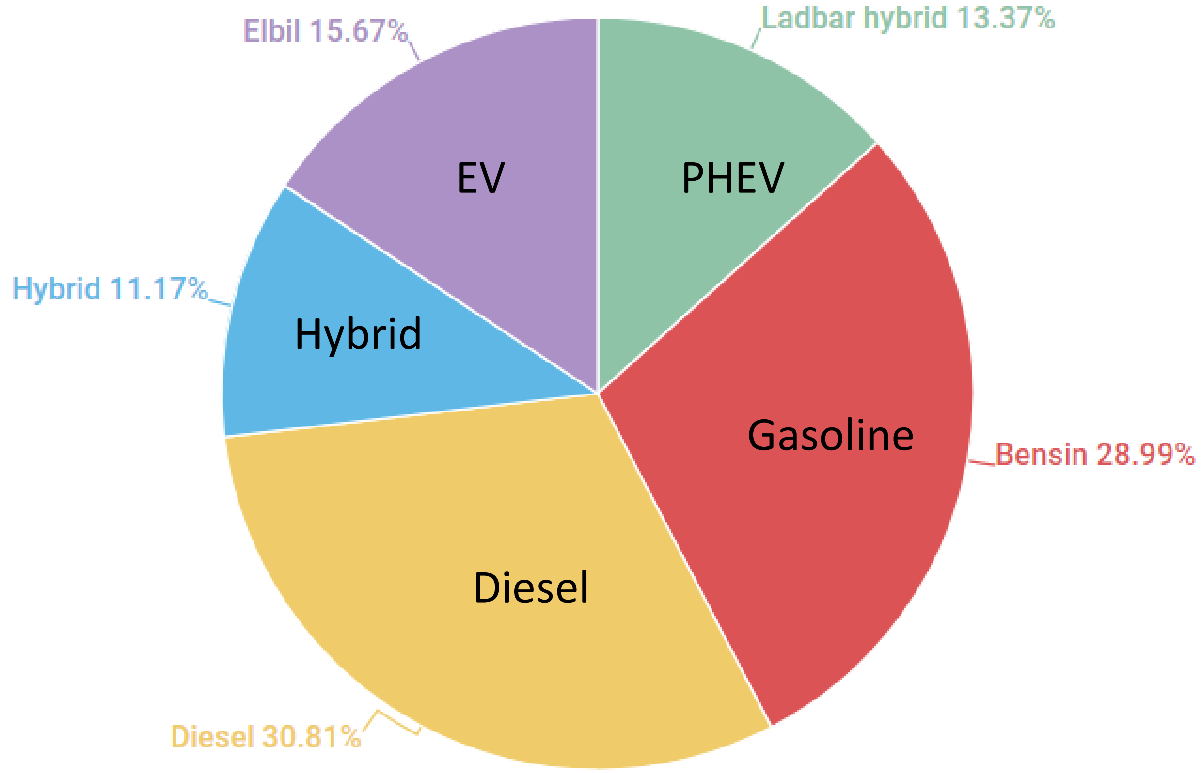
Disconnection time : 5 sec.

EV/PHEV development

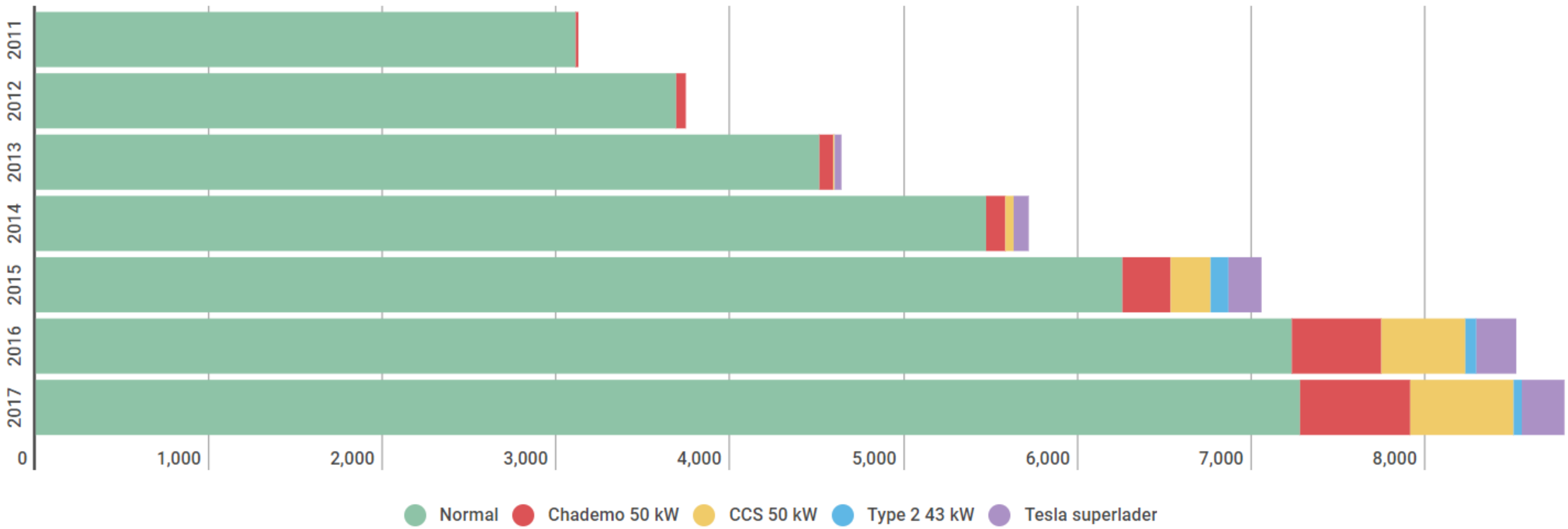
Population	5,2 mill.
Private cars:	2,4 mill.
Trucks, lorries, buses:	0,4 mill.
PHEVs/EVs (August 2017):	175.000



Private car sales 2016- market shares



No. of public charging stations
(Many have private charging at home)



Initial benefits/incentives electric vehicles in Norway – from 2008/2009

- No import tax (High import tax for fossil fuel vehicles)
- No value added tax (VAT in Norway: 25%)
- Low annual road tax (between 10 and 20 % of fossil fuel vehicles)
- Free parking in public parking places
- Free charging at public charging stations
- No toll when driving on toll roads
- Possible to drive in the bus lane
- No charge for the car on national ferries (must pay passenger rate for driver)
- 50 % discount on company car taxation
- Fuel economy (1 l gasoline : 2,2 US$ - 1 kWh: 0,13 US$)

Tax example medium sized gasoline fueled car

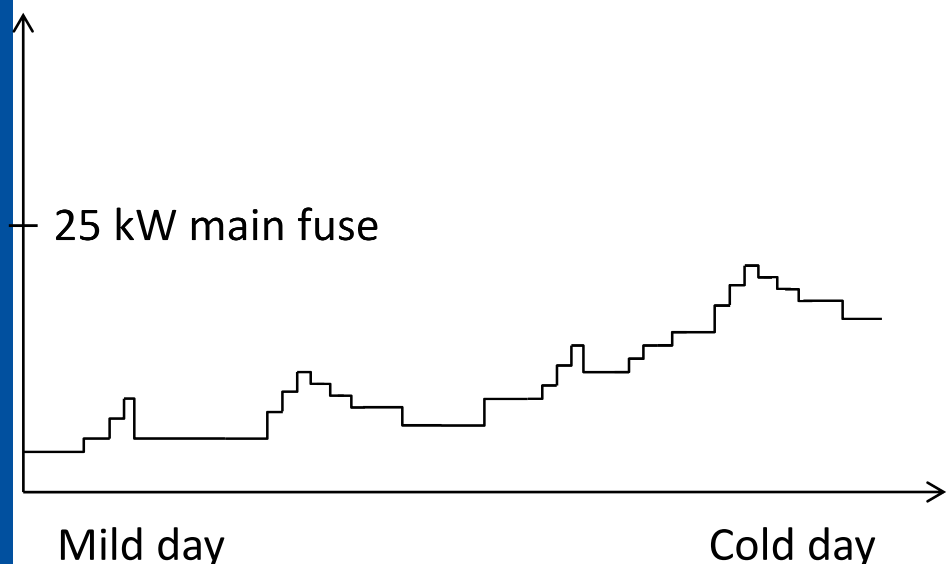
• Price without tax		:	25 000 US$
• CO_2	- 140 g/km	:	4 000 US$
• Weight	- 1400 kg	:	10 500 US$
• Motor	- 180 Hk	:	7 000 US$
• NO_x	- 30 mg/km	:	200 US$
• VAT (25%)		:	6 250 US$
• ***Total***		***:***	***52 950 US$***

EV energy consumption - not a challenge

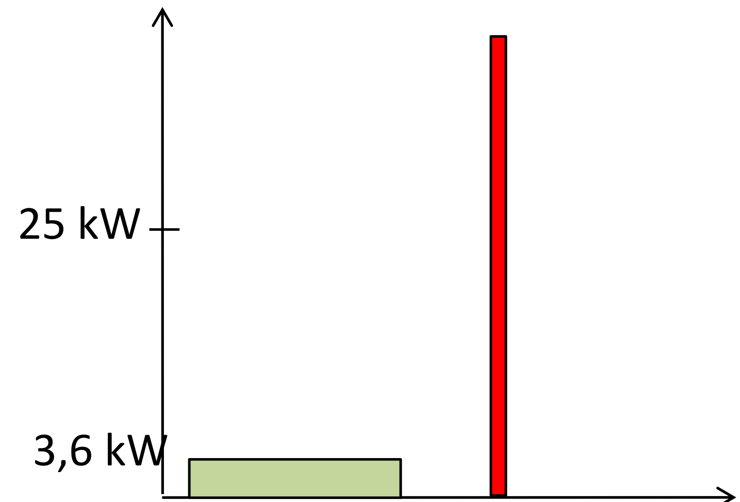
- Average driving distance 15.000 km per/yr
- EV electricity use 5,3 - 7,1 TWh/yr (all cars EVs)
- Hydro power generation: 139 TWh/yr (last two last years)

Distribution system challenges might be expected - especially in weak grids

Residential house

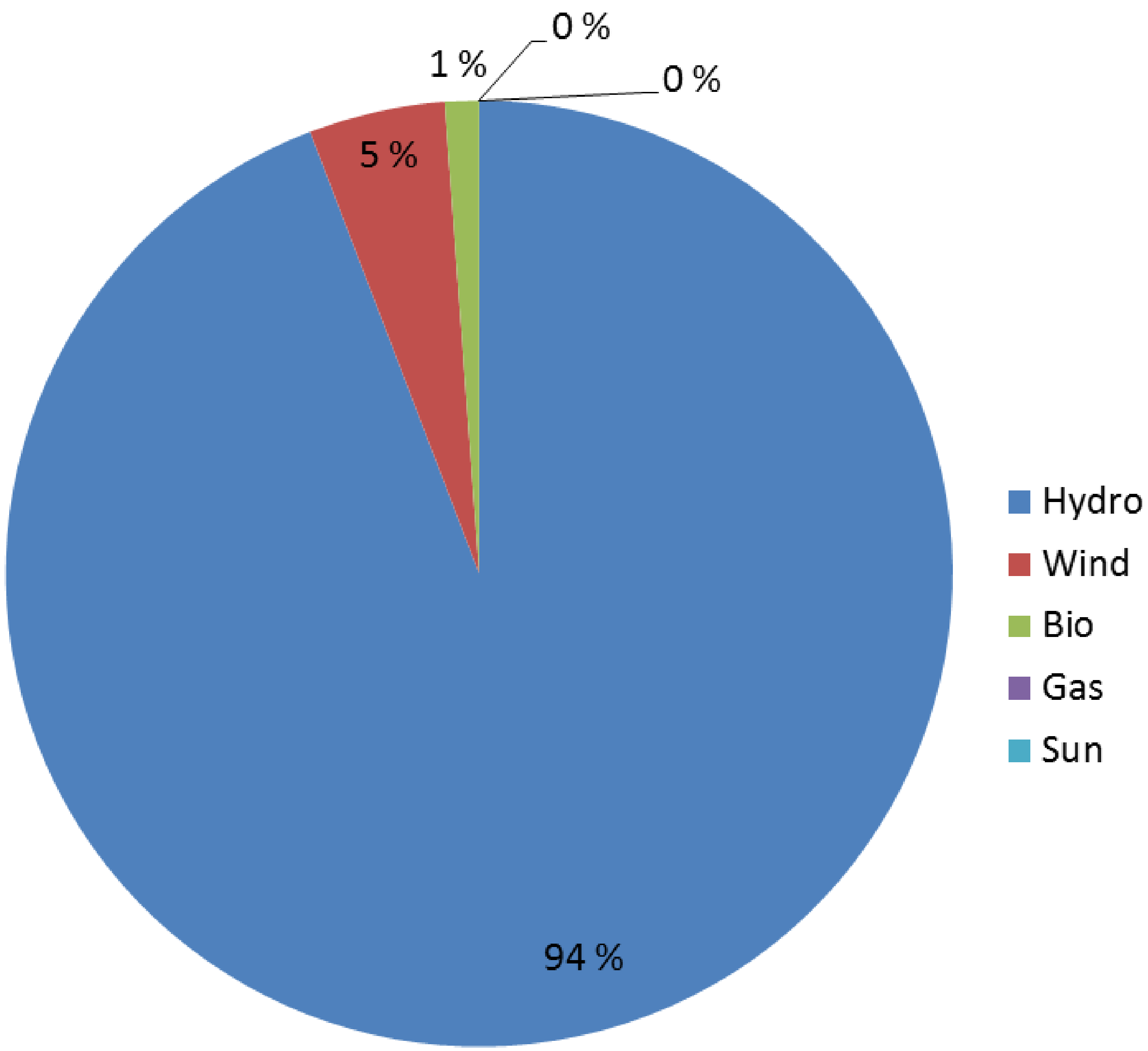


Electric vehicle



Fast charging
Slow/normal charging

DG (<10 MW) in Norway today- by energy source



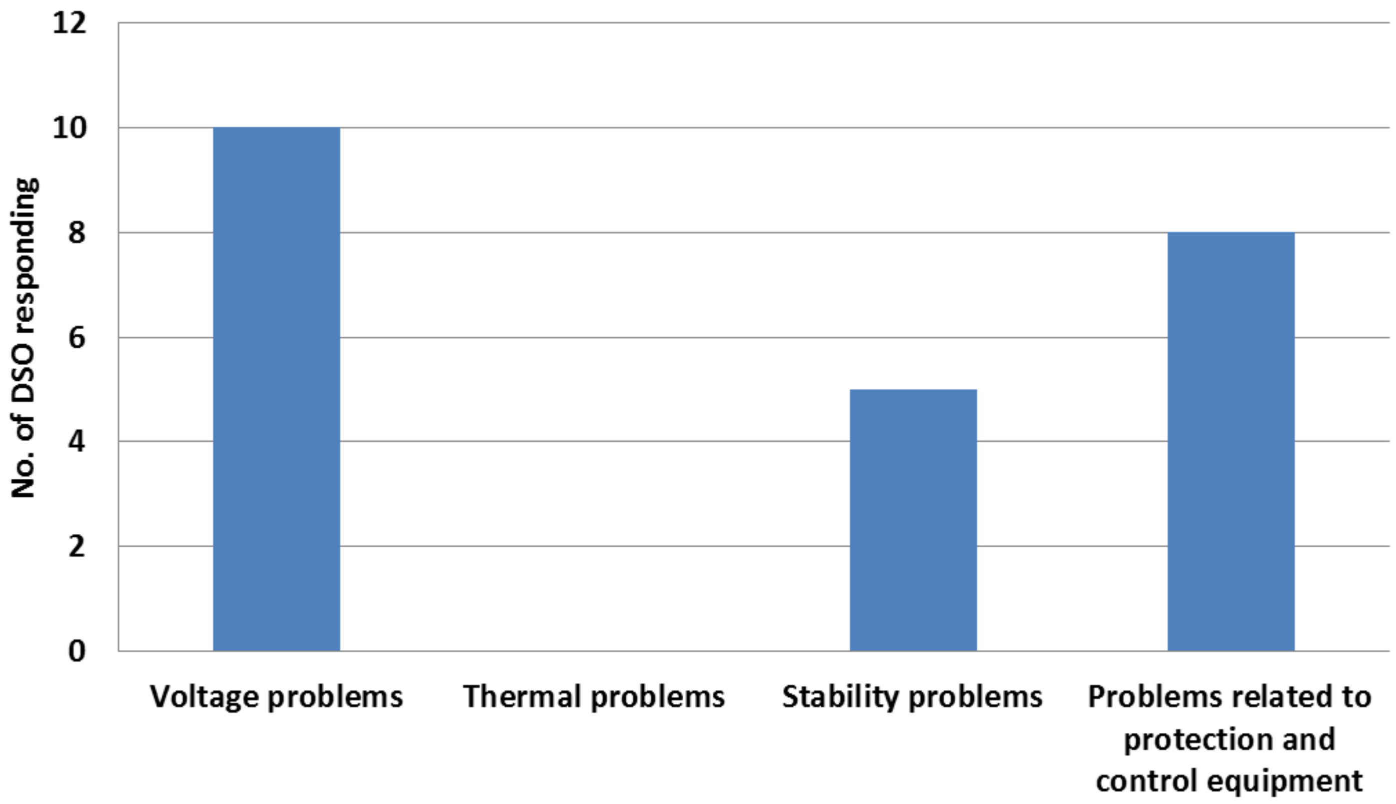
Common DG situation in Norway

Small hydro power plants (1 - 10 MVA)

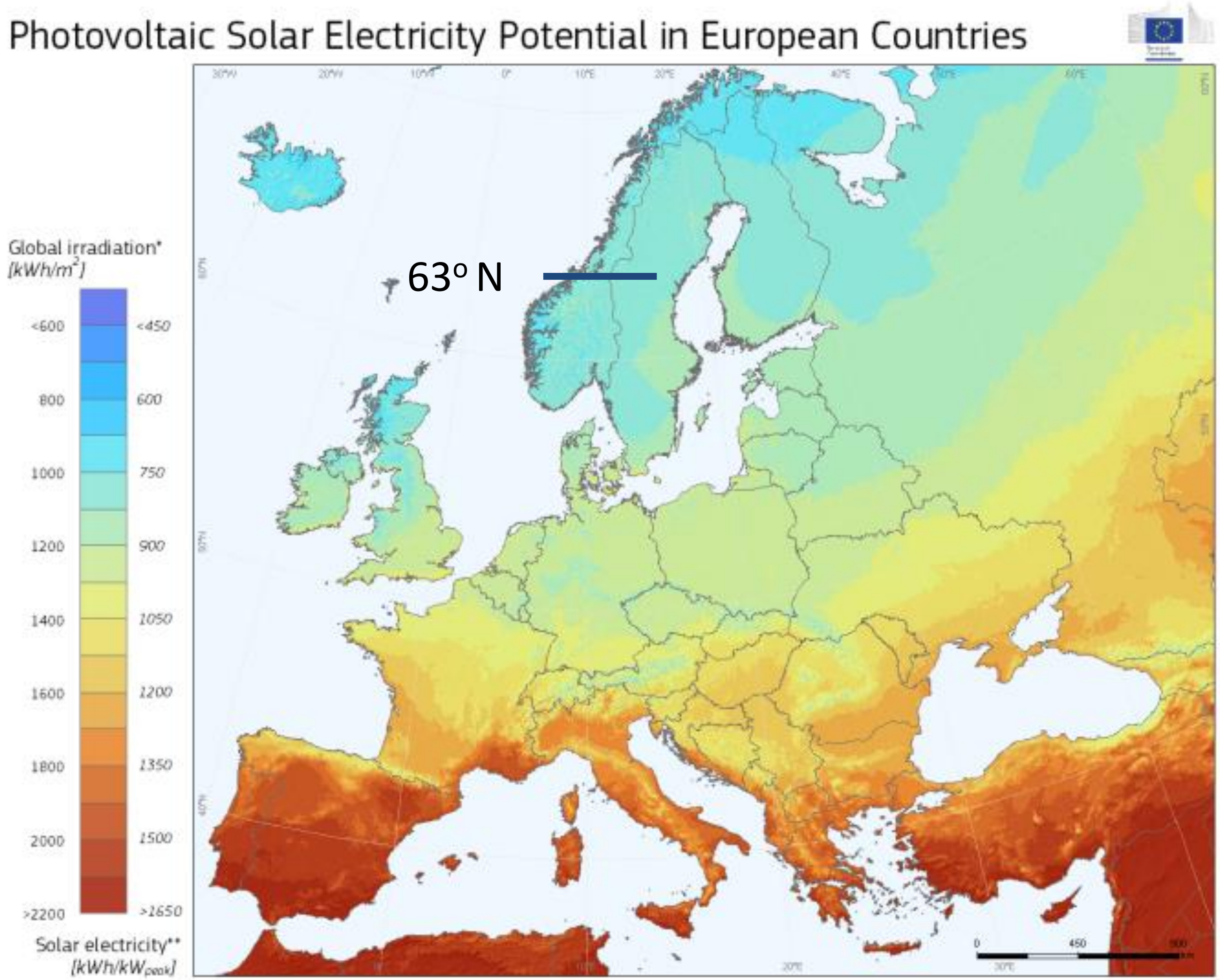
in areas with low consumption and weak grids

- Generation much higher than local consumption
- Strongly varying generation (river plants without reservoir capacity)
- Long feeders and **high voltage levels** when the generation is high

Some challenges for DG integration



What about PV?



PVGIS © European Union, 2001-2012

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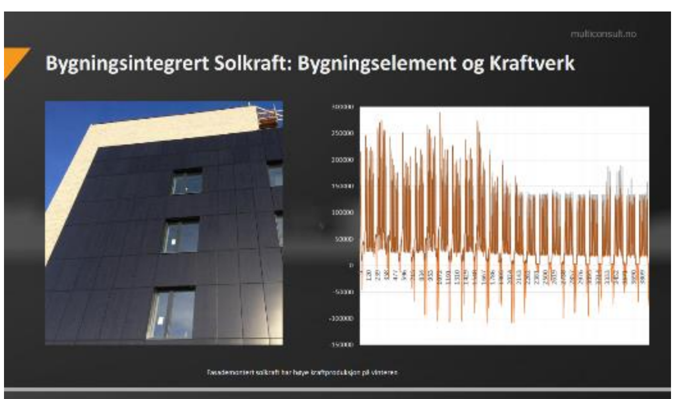
Increased interest for PV in Norway

- New building codes (Zero Energy Buildings)
- Cost development of PV



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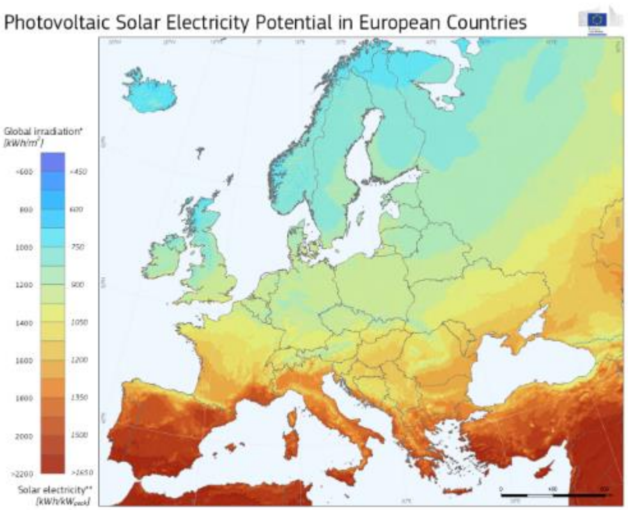
Potential better than earlier estimated due to
cold climate, clean air, reflection from snow parts of the year

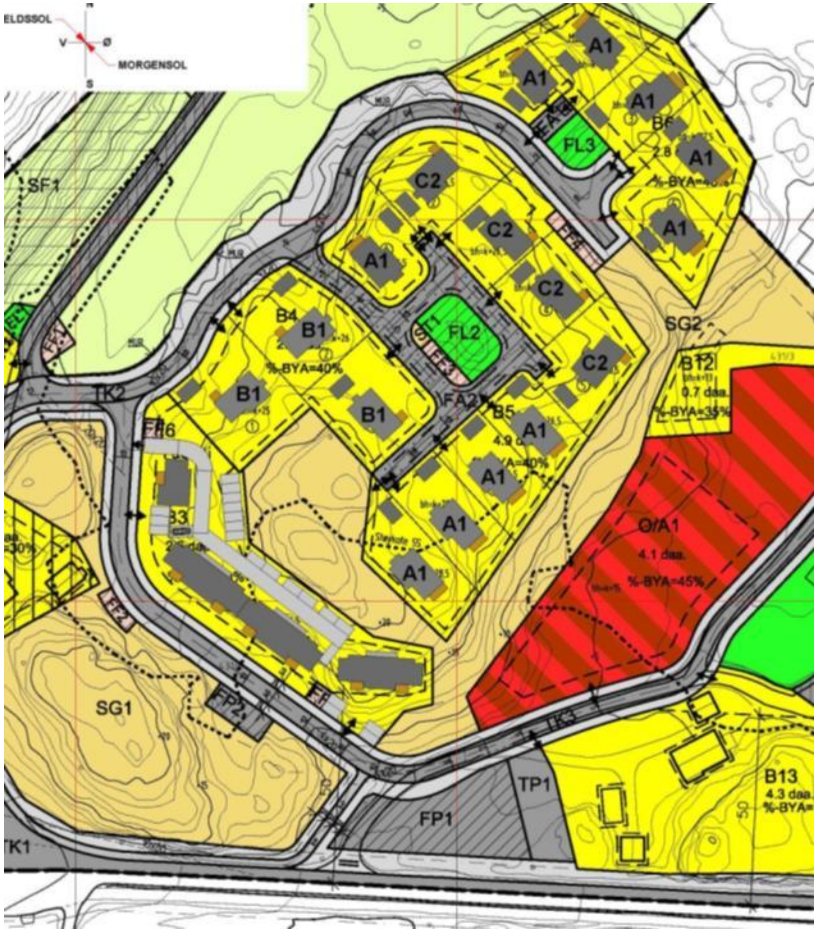
City	Irradiance [kWh/m²]
München	1330
Berlin	1260
Oslo	1300
Bergen	901
Trondheim	1020



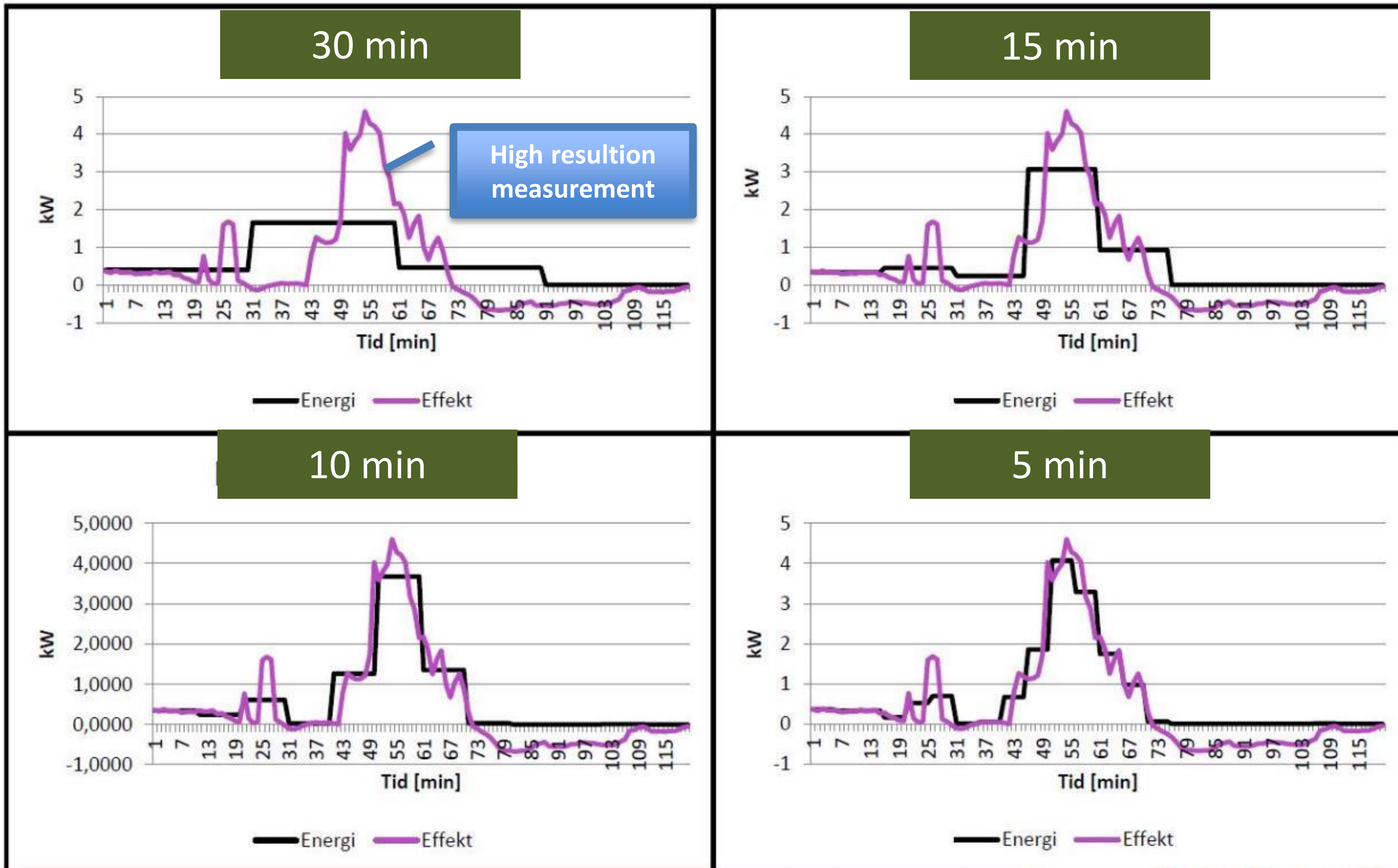
Example – Skarpnes project

- Norway's first zero-energy housing area
- 21 buildings
- 17 family houses

- Energy System:
  - Heat Pumps
  - ***PV (~ 200 kWp)***

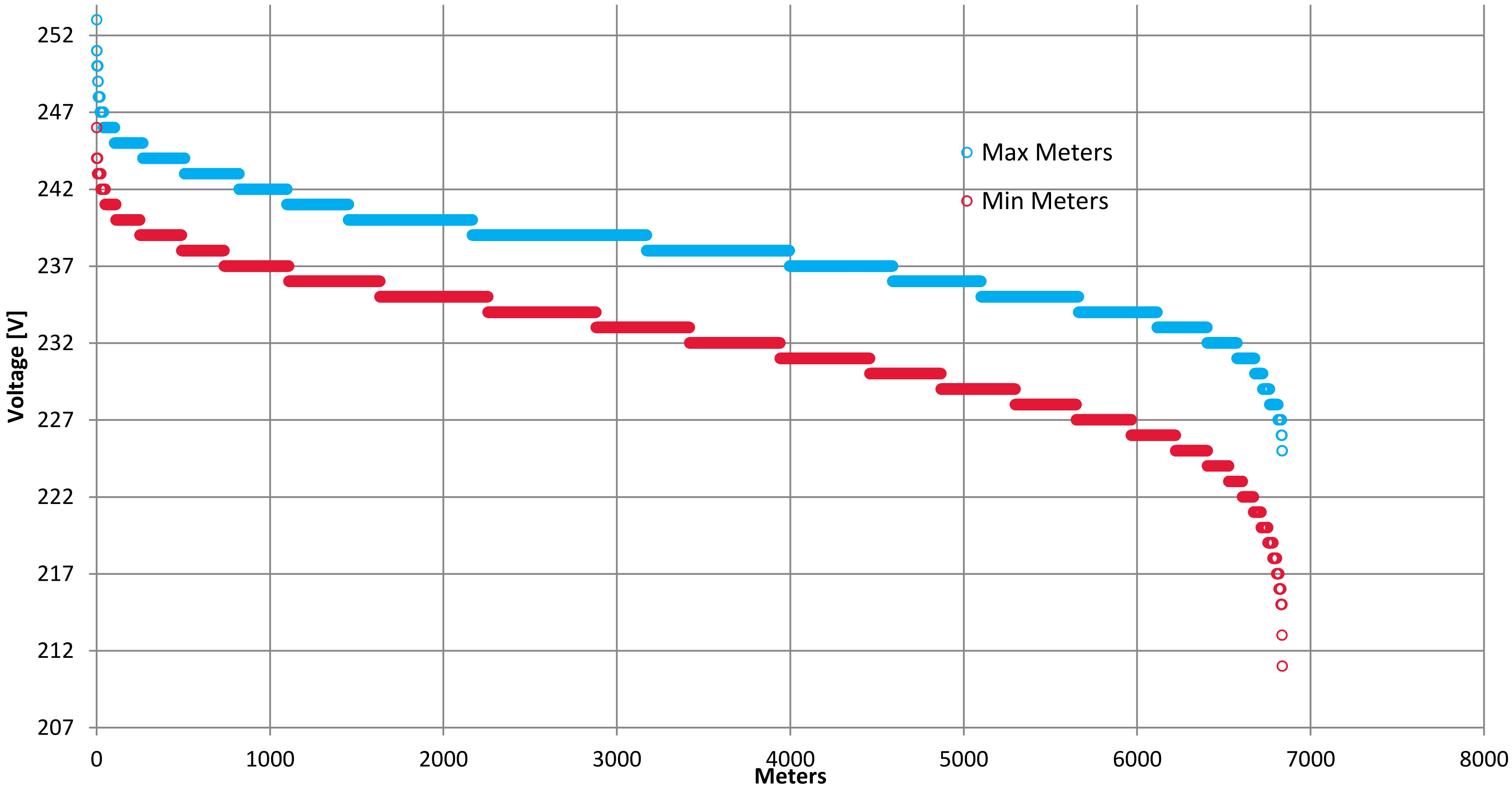


Need for better AMI resolution than hourly averages to manage voltage quality



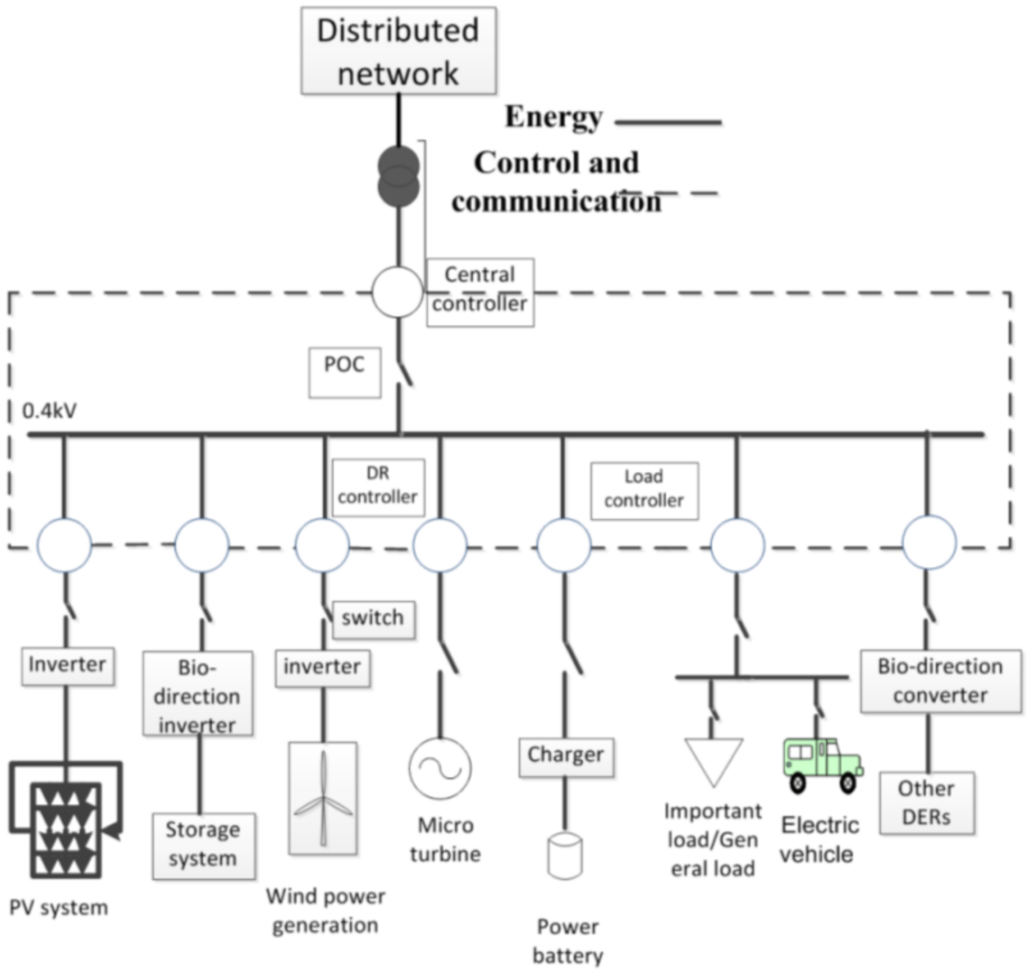
To provide grid and market benefits from the smart meter roll-out is high on the agenda

Example_ Use case voltage quality monitoring



Data from one day measurements – 6900 smart meters

Micro grids in Norway



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Drivers

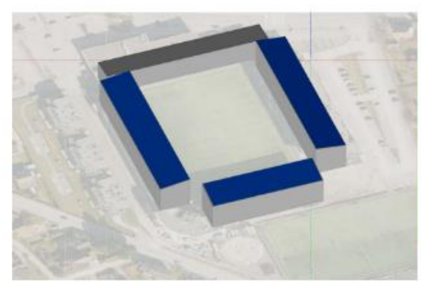
	Europe	North America	Latin America	Asia Pacific	Africa
Commercial and industrial	Cost, Reliable & secure power supply	Cost, Reliable & secure power supply		Reliable & secure power supply	
Government institutions and campuses	Environment	Cost, Reliable & secure power supply		Reliable & secure power supply	
Community	Environment, Cost	Cost, Reliable & secure power supply		Cost, Reliable & secure power supply	
Remote villages	Cost	Cost	Cost	Electrification, Cost	Electrification, Cost
Islands	Environment, Cost	Environment, Cost	Cost	Cost	
Remote mines and constructions	Cost, Reliable & secure power supply	Cost, Reliable & secure power supply	Cost, Reliable & secure power supply	Cost, Reliable & secure power supply	Cost, Reliable & secure power supply
Military		Cost, Reliable & secure power supply			

Electrification   Environment   Cost   Reliable & secure power supply

Pilot studies/projects

- Islands – replace diesel generation with renewables
- Islands supplied by old submarine cables – micro grids an alternative to traditional reinvestments
- Urban micro grids – lighthouse projects with PV
- Cottage and cabin areas without grid connection

Stadium roof top PV with battery



Nøkkeltall	
Solcelleanlegg	
Areal:	5330 m^2
Antall moduler	3230
Installert effekt:	840 kWp
Produksjon normalår:	660 MWh
Spesifikk ytelse:	786 kWh/kWp
Energilager	
Kapasitet:	1 MWh
Effekt:	800 kW

Skagerak Energi

Mountain cafe – Weak grid
Battery for 24h island mode

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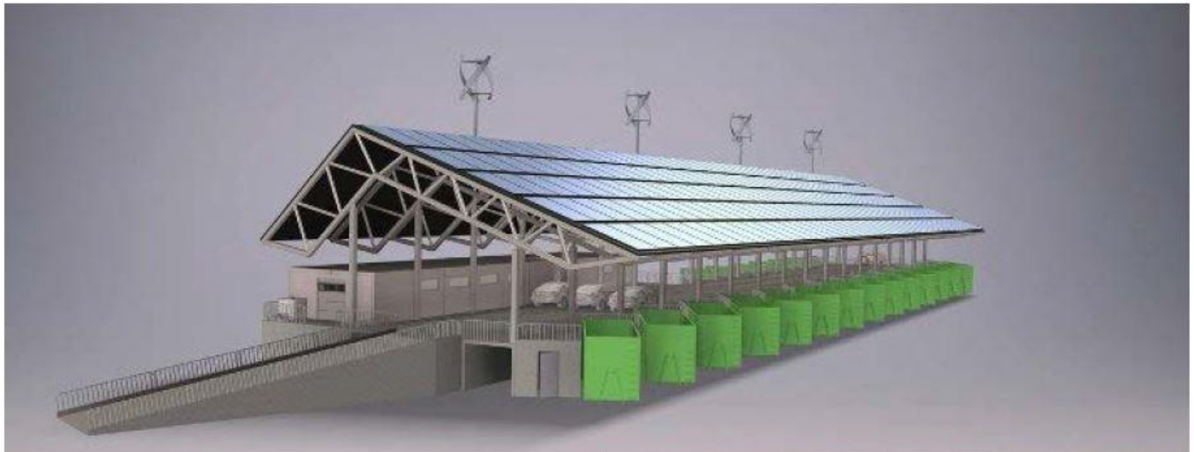
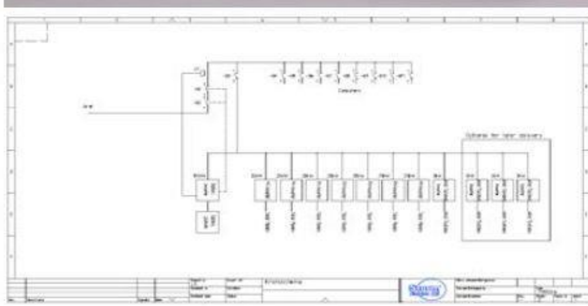
Sub-Pilot #2: Sandbakken





Transformer capacity:	800 kVA	Generation:	PV (1200m2, 184kWp)
Supply Voltage:	400V TN		Wind (4 mills, 12kWp)
Battery Storage:	240 kWh	Annual production:	est. 169 MWh
EV Charging:	6 Terminals	Consumption:	est. 200 MWh
Customers:	1	Peak Load:	est. 300 kW

Motivation – self sufficiency

Last slide:
EV fuel Norway: Hydro power