NTNU – Trondheim
Norwegian University of
Science and Technology

The Norwegian Move to Smart Grid – Opportunities and Challenges in a European Context

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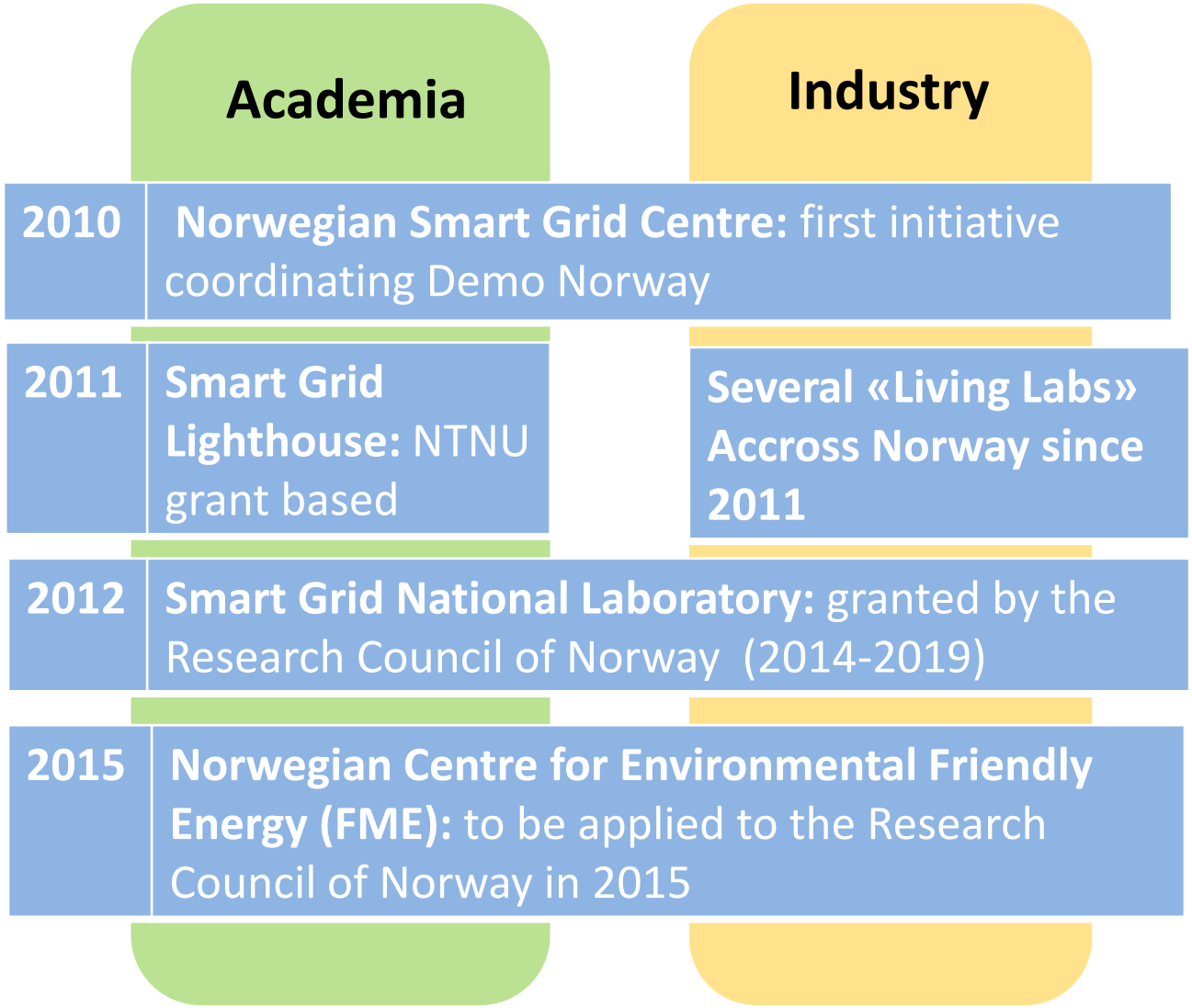
Content

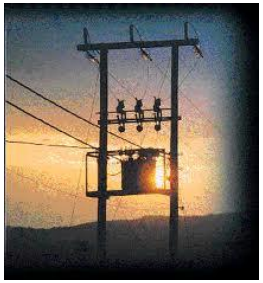
- **Smart Grid in Norway**
  - Driving forces: Norwegian peculiarities
- **The Norwegian Smart Grid Center**
- **Demo Norway**
- **The Smart Grid National Laboratory**

The steps toward the Smart Grid



Norwegian System Peculiarities

- Large part of the LV distribution system is of type **230 Volt line to line system** different from the 400 Volt line to line voltage systems in most of Europe
- **Weak grids** with approx. 40% of the supply terminals weaker than the standardized EMC reference impedance giving larger voltage quality problems when connecting EVs, PVs etc. than many countries



- High flexibility for **demand response and demand side management** schemes due to large part of electricity consumption in the domestic sector used **for space and water heating**

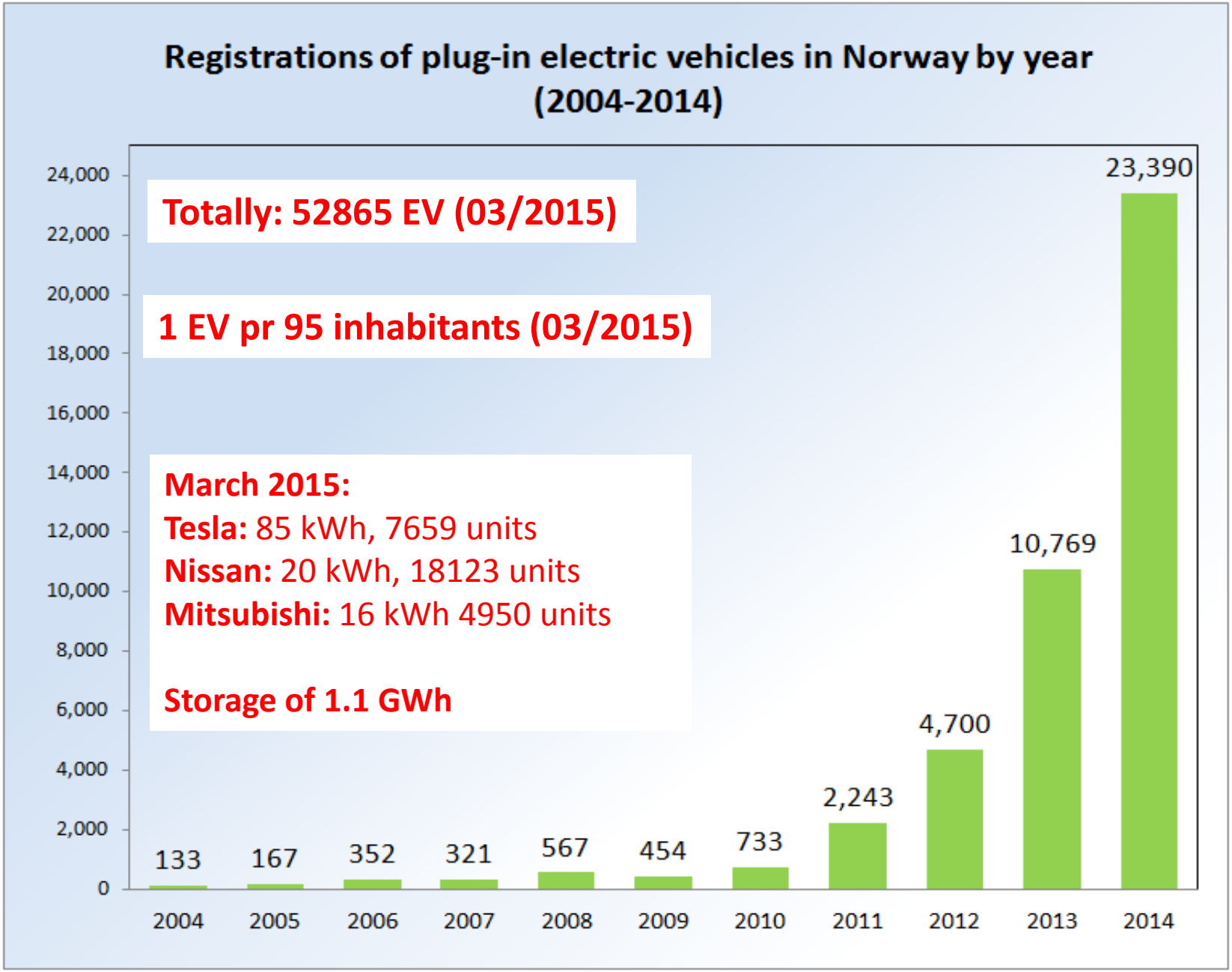
- Well developed **broadband communication** to homes and increased use of fiber-to-home communication provided by power utilities

The Norwegian Power System

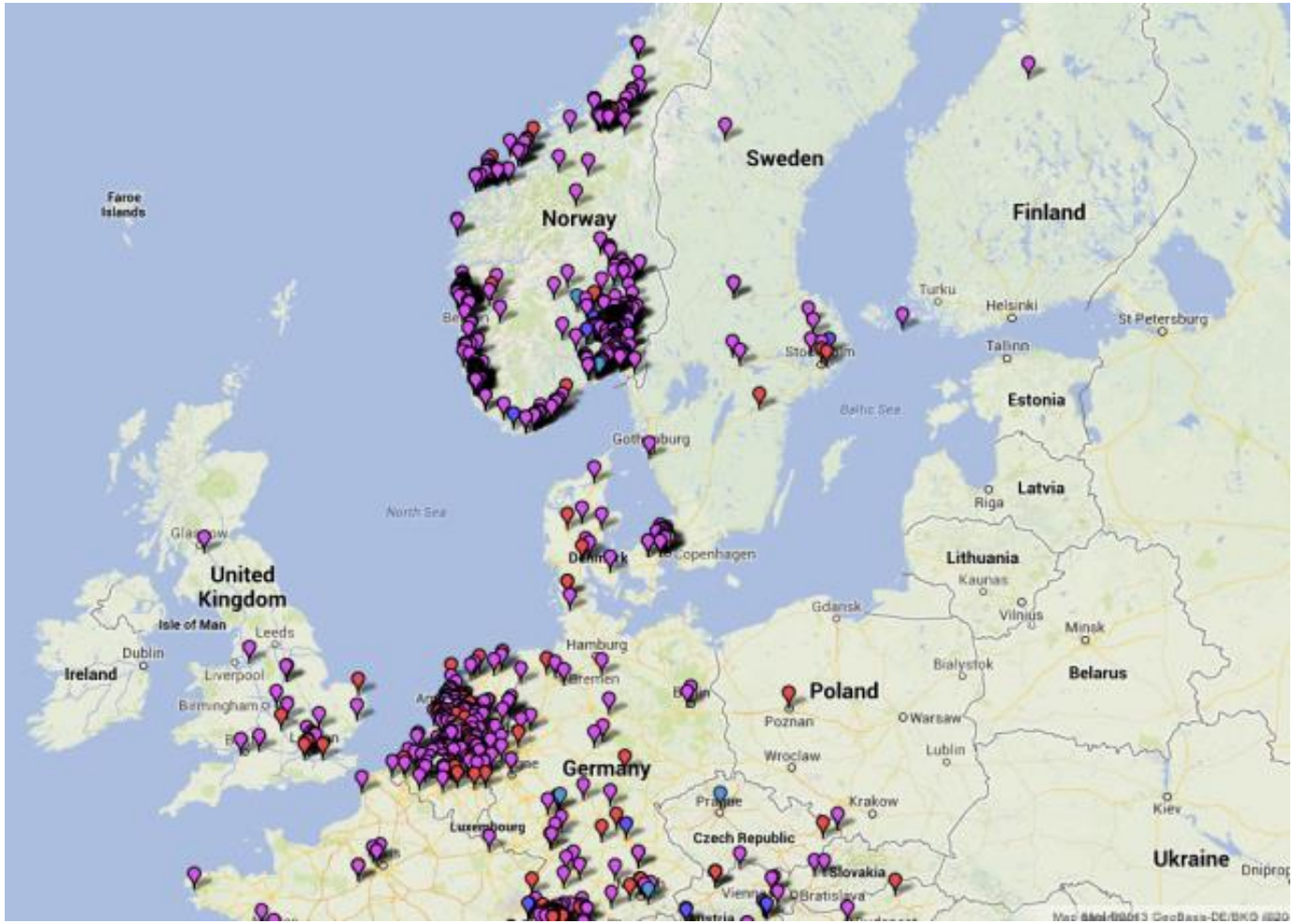
- **Large availability of hydropower plants** with reservoirs are fast and easy to control: **low-cost balancing services**
- Quick growing use of **purely battery based electric vehicles** due to very good incentives (tax exempt, free parking, free use of toll roads and bus lanes etc.)
- Increasing **penetration of distributed generation** (much small hydro so far)
- Trend of less **annually energy consumption but larger peaks** in periods
- **Distribution grids** need significantly upgrading
- **Well-developed electricity markets.** There are multi-national markets with significant volumes for day-ahead, intra-day and balancing with participation of producers and consumers

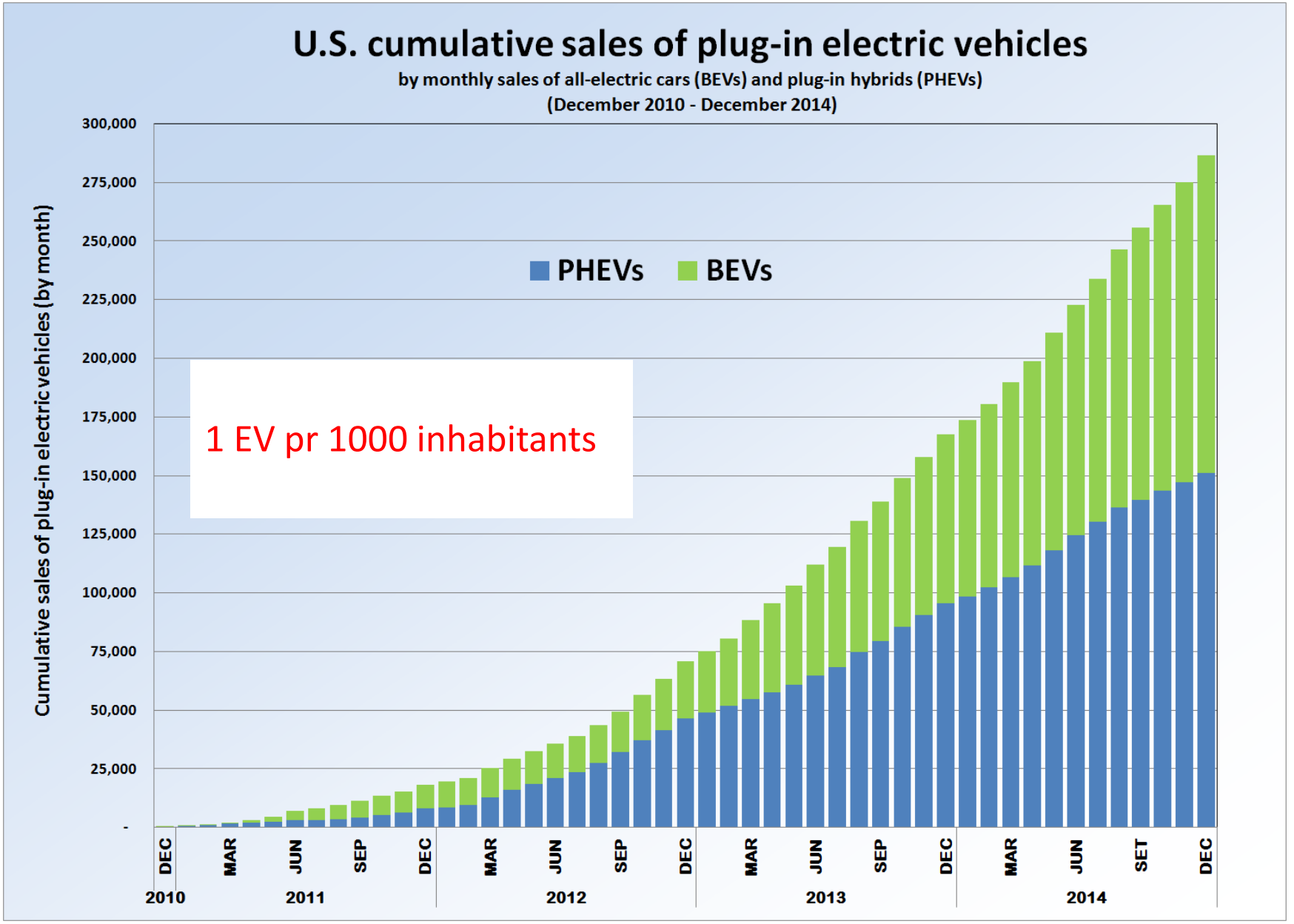
Our possible role in a sustainable power system?

Registrations of plug-in electric vehicles in Norway by year (2004-2014)



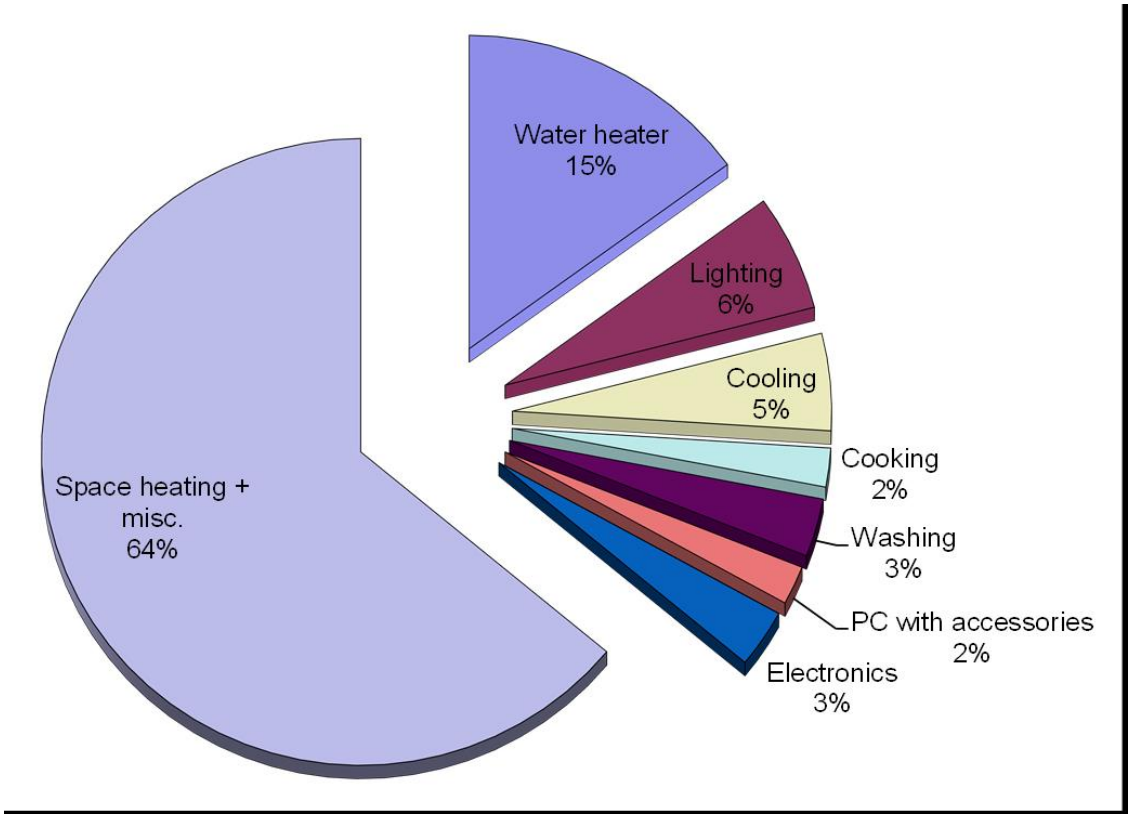
Crowd sourced orders of Tesla




U.S. cumulative sales of plug-in electric vehicles
by monthly sales of all-electric cars (BEVs) and plug-in hybrids (PHEVs)
(December 2010 - December 2014)
Cumulative sales of plug-in electric vehicles (by month)
300,000
275,000
250,000
225,000
200,000
175,000
150,000
125,000
100,000
75,000
50,000
25,000
-
PHEVs
BEVs
1 EV pr 1000 inhabitants
DEC
MAR
JUN
SEP
DEC
MAR
JUN
SEP
DEC
MAR
JUN
SEP
DEC
MAR
JUN
SET
DEC
2010
2011
2012
2013
2014

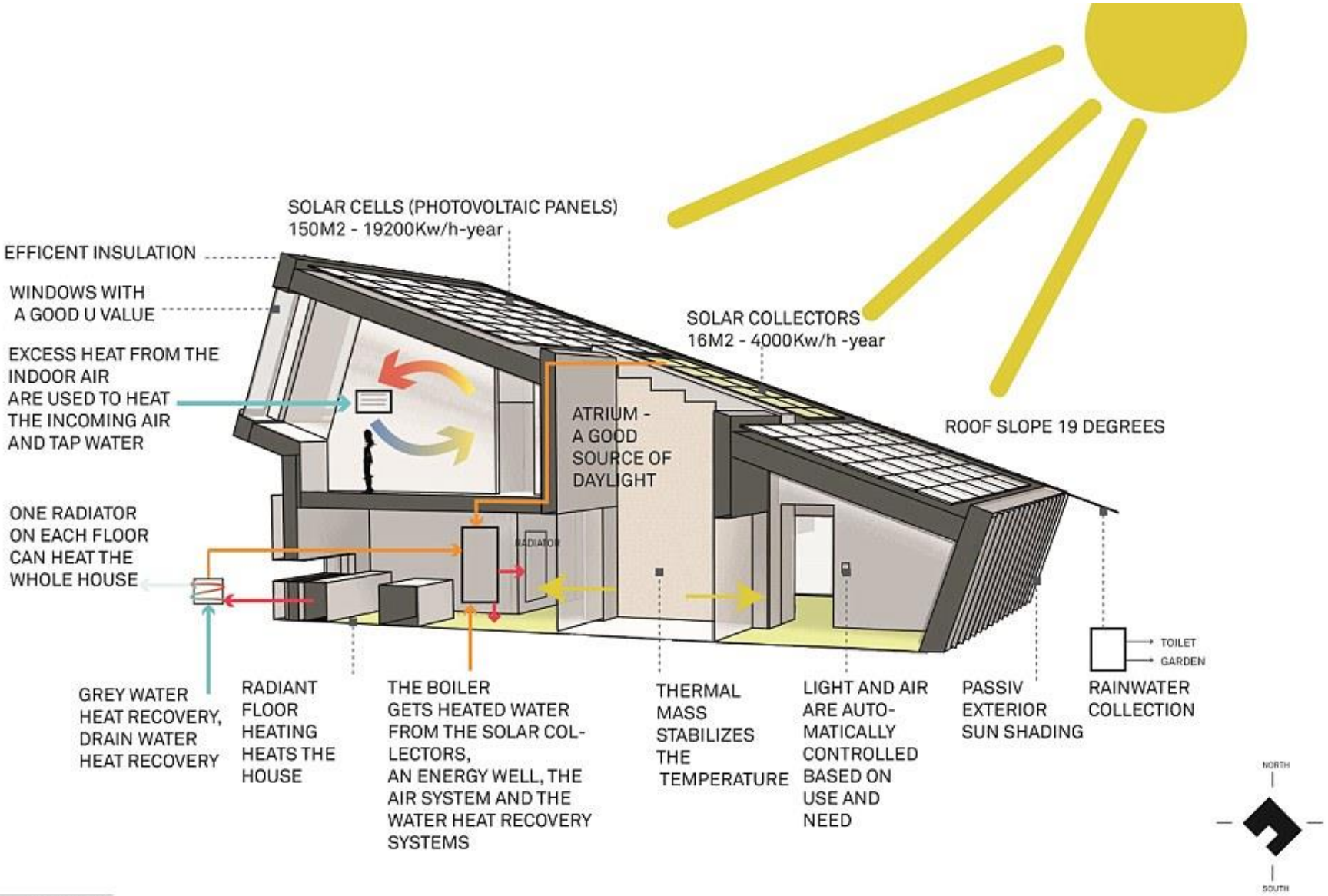
A lot of electricity used for heating

16 000 kWh per household (average)



ECO HOME

Real Power House: produces 23,200kWh a year - requires just 7,272kW to run



The Norwegian Smart Grid Center

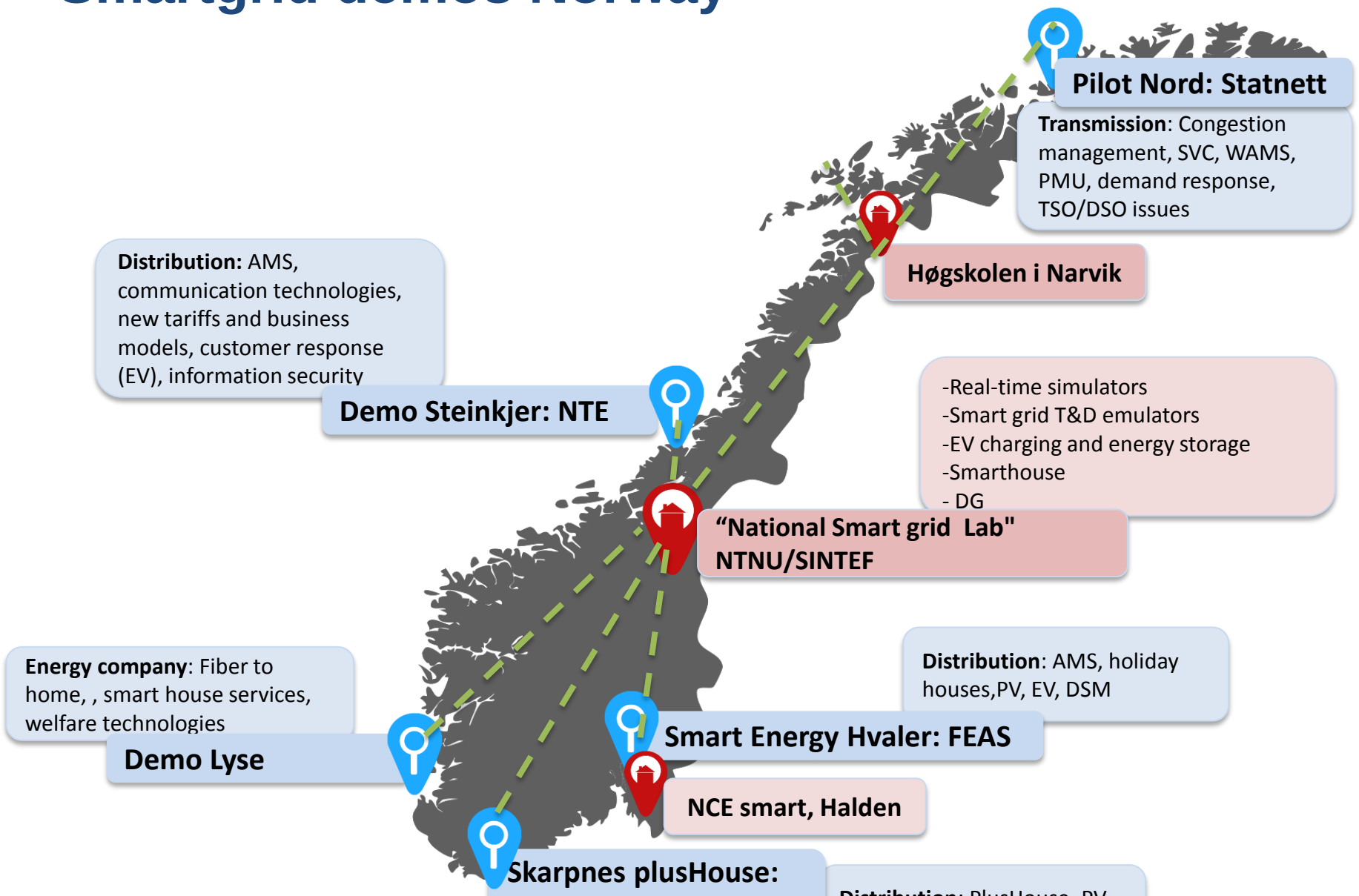
- Established in 2010 recommended by Ministry of Petroleum and Energy in its national strategy process for defining future Energy R&D in Norway.
- NTNU and SINTEF answered the challenge and became the locus of coordinating national research, demonstration, laboratory, education, standardisation and information activities to optimise the use of resources and avoid uncoordinated parallel activities.
- Currently 47 members from universities, research bodies, supply industry, transmission and distribution companies as well as infra-structure providers within telecommunication.

The Norwegian Smartgrid Centre - A National team for technological cooperation

Goals of the Smart Grid Center

- Establish a national **roadmap of Smart Grid** in Norway
- Coordinate the **national demo sites** run by network operators
- **Standardization and interoperability** for a successful implementation of smart grid solutions
- **Contribute to the competiveness** of the emerging Norwegian Smart Grid industry

Smartgrid demos Norway



The Smart Grid National Lab

- The new SG-lab was created to supplement the national "living labs/Demos" by:
  - Testing **immature use case** and **use case technologies** first in the laboratory before they are tested / verified in real power grids that supply households, businesses, etc.
  - Testing the use case / technologies **under harsh conditions in a controlled laboratory environment**:
    - Faults (short circuits),
    - High levels of harmonic distortions
    - Electromagnetic interference (EMC)
    - Etc.

Smart Grid-Lab Subprojects

Subproject 1
Smart House Demonstration

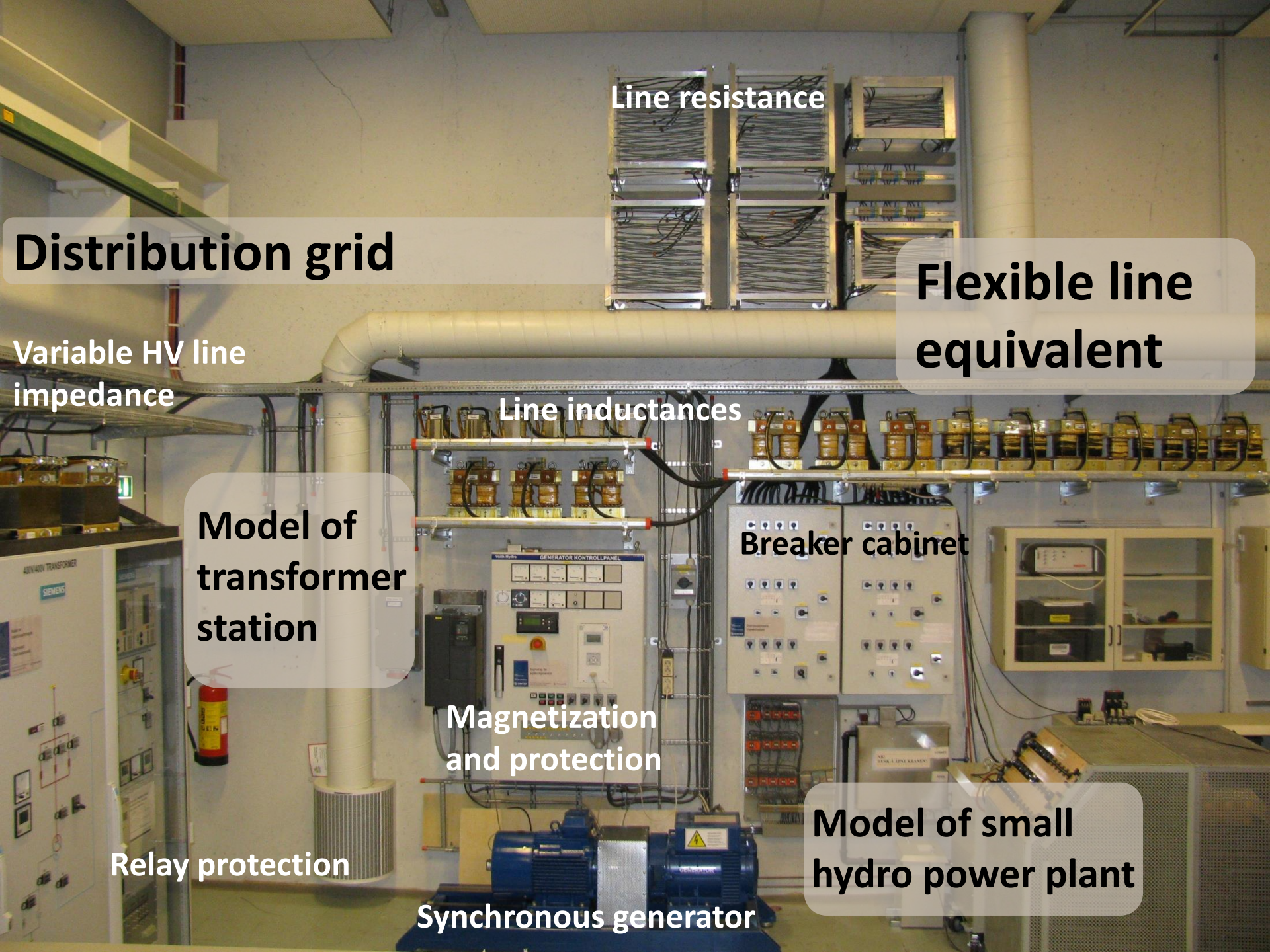
Subproject 2
EV charging & distributed storage

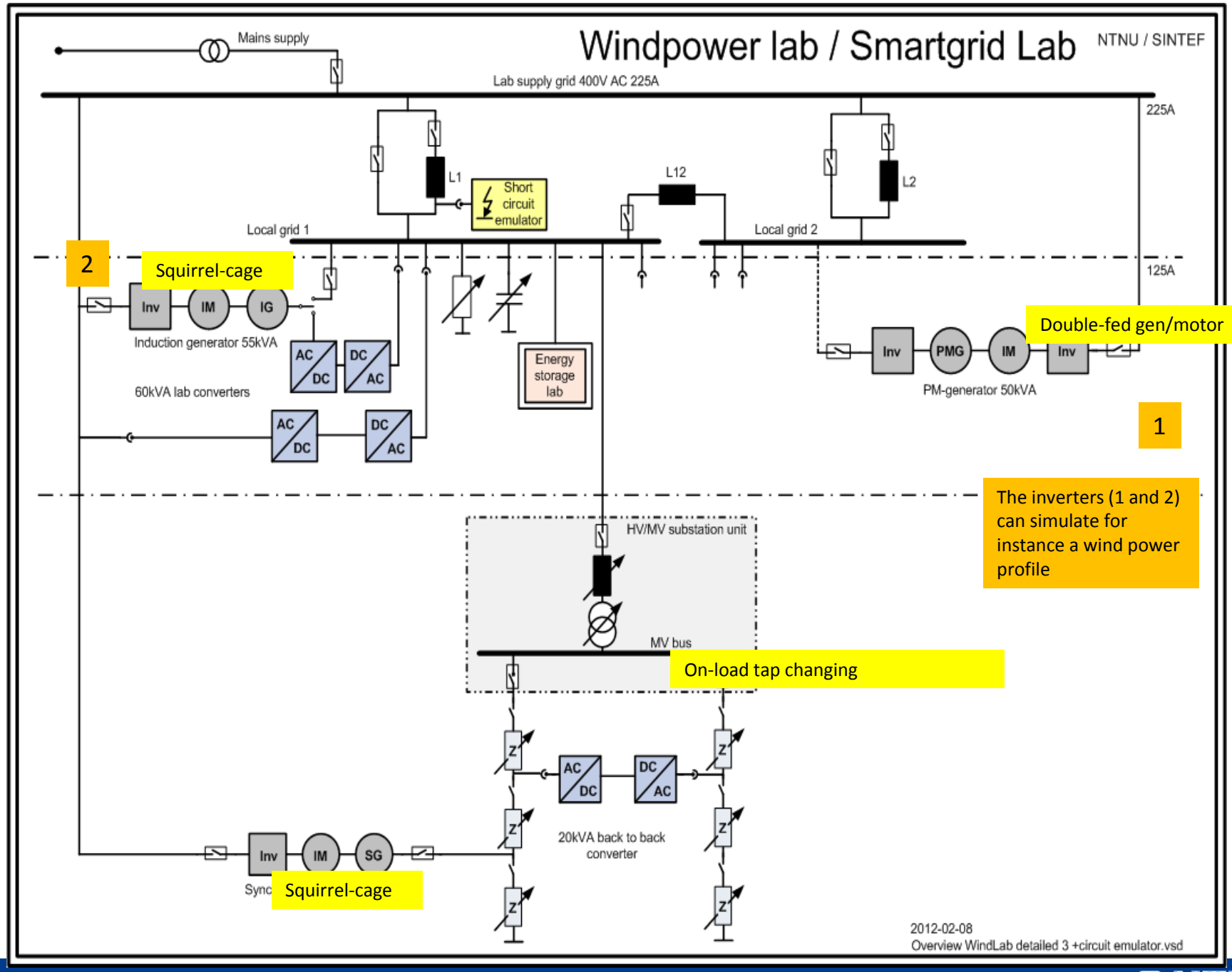
Subproject 3
Real Time simulator OPAL-RT

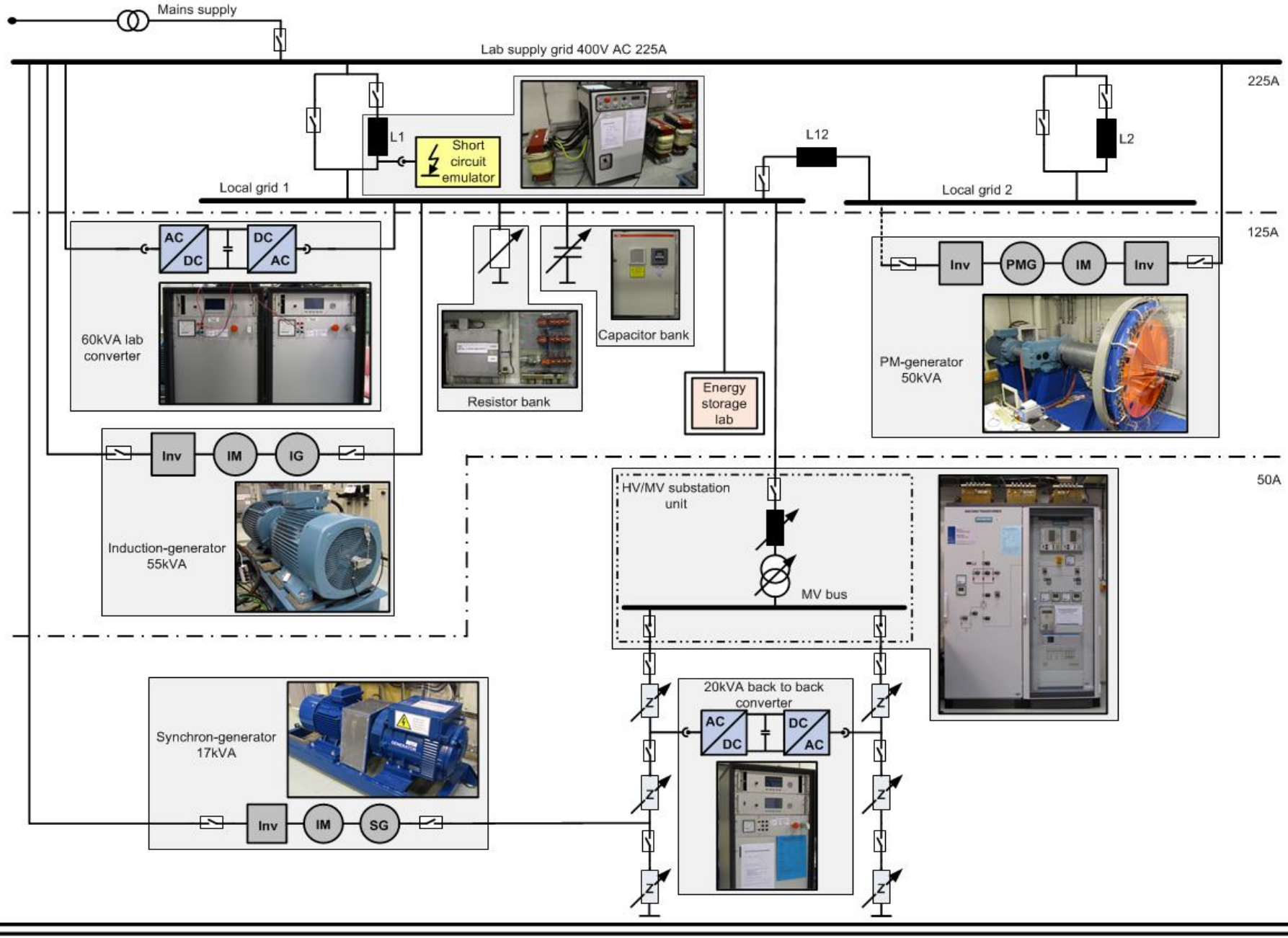
Subproject 4
Grid Emulation & Network Interactions

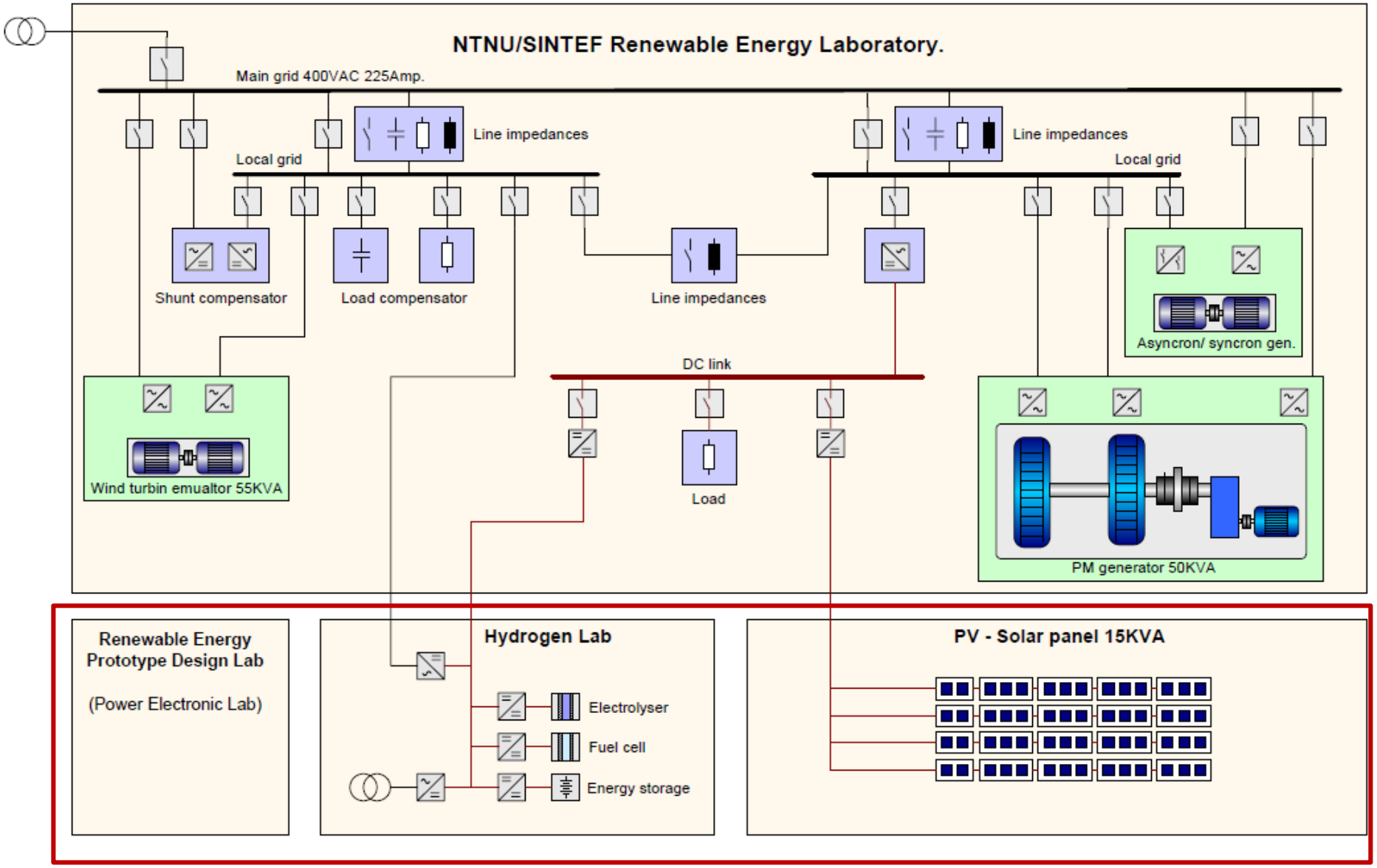
Subproject 5
Physical Extension & Software Infrastructure

Subproject 6
Remote Access & Database Design

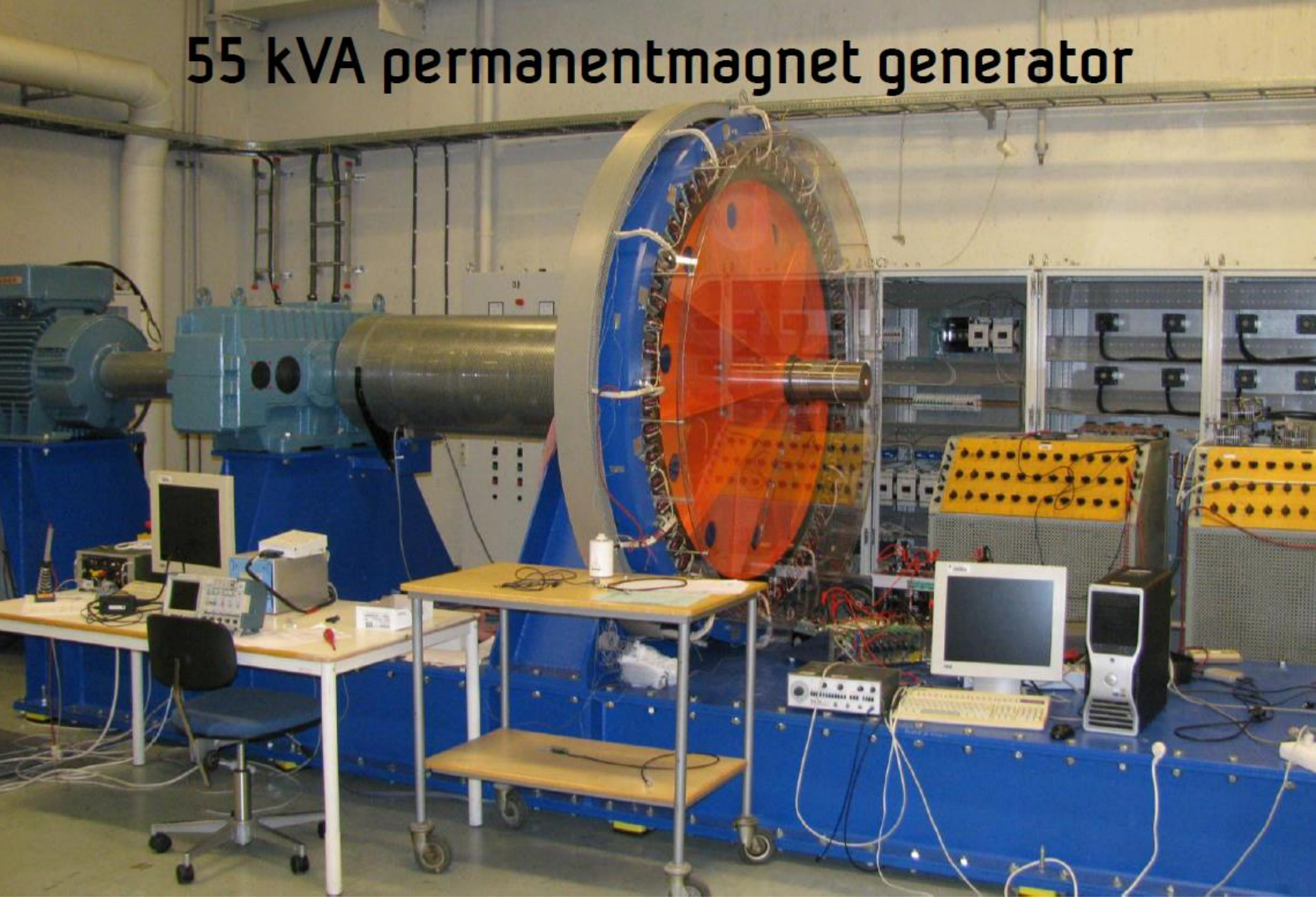

Line resistance
Distribution grid
Flexible line equivalent
Variable HV line impedance
Line inductances
Model of transformer station
Breaker cabinet
Magnetization and protection
Model of small hydro power plant
Relay protection
Synchronous generator


Windpower lab / Smartgrid Lab
NTNU / SINTEF
Mains supply
Lab supply grid 400V AC 225A
225A
125A
L1
Short circuit emulator
L12
L2
Local grid 1
Local grid 2
2
Squirrel-cage
Inv
IM
IG
Induction generator 55kVA
AC DC
DC AC
60kVA lab converters
Energy storage lab
Double-fed gen/motor
Inv
PMG
IM
Inv
PM-generator 50kVA
1
The inverters (1 and 2) can simulate for instance a wind power profile
HV/MV substation unit
MV bus
On-load tap changing
Z
AC DC
DC AC
20kVA back to back converter
Inv
IM
SG
Sync
Squirrel-cage
2012-02-08
Overview WindLab detailed 3 +circuit emulator.vsd


Mains supply
Lab supply grid 400V AC 225A
225A
L1
Short circuit emulator
L12
L2
Local grid 1
Local grid 2
125A
AC
DC
DC
AC
60kVA lab converter
Capacitor bank
Resistor bank
Energy storage lab
Inv
PMG
IM
Inv
PM-generator 50kVA
50A
Inv
IM
IG
Induction-generator 55kVA
HV/MV substation unit
MV bus
20kVA back to back converter
AC
DC
DC
AC
Synchron-generator 17kVA
Inv
IM
SG


NTNU/SINTEF Renewable Energy Laboratory.
Main grid 400VAC 225Amp.
Line impedances
Local grid
Line impedances
Local grid
Shunt compensator
Load compensator
Line impedances
Asyncron/ syncron gen.
DC link
Wind turbin emualtor 55KVA
Load
PM generator 50KVA
Renewable Energy Prototype Design Lab
(Power Electronic Lab)
Hydrogen Lab
Electrolyser
Fuel cell
Energy storage
PV - Solar panel 15KVA

55 kVA permanentmagnet generator



Thanks
for your attention

Pilots/demos

- Demo Steinkjer (NTE)
  - 4500 Network users
- Smart Energy Hvaler (Fredrikstad Energinett)
  - 6700 Network users
- Demo Lyse (Lyse Energy)
  - Few thousand Network users
  - 20- 100 Smart houses
- Smart grid pilot – Transmission (Statnett)
- Demo Skarpnes (Skanska, Agder Energy)
  - 40 energy neutral houses/flats