Le réseau
de transport
d'électricité

ESIG GFM Workshop

ENERGY SYSTEMS
INTEGRATION GROUP

RTE Research and Development Update

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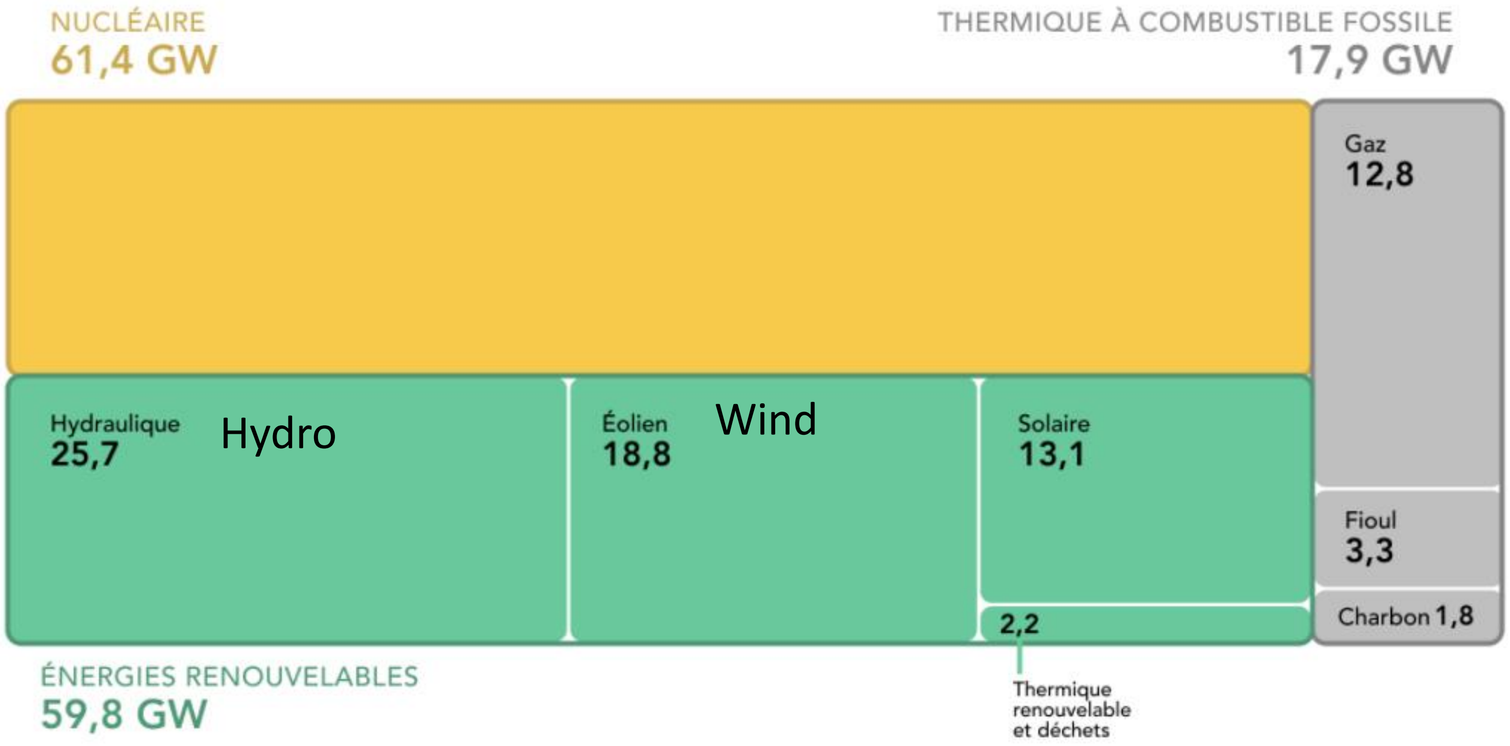
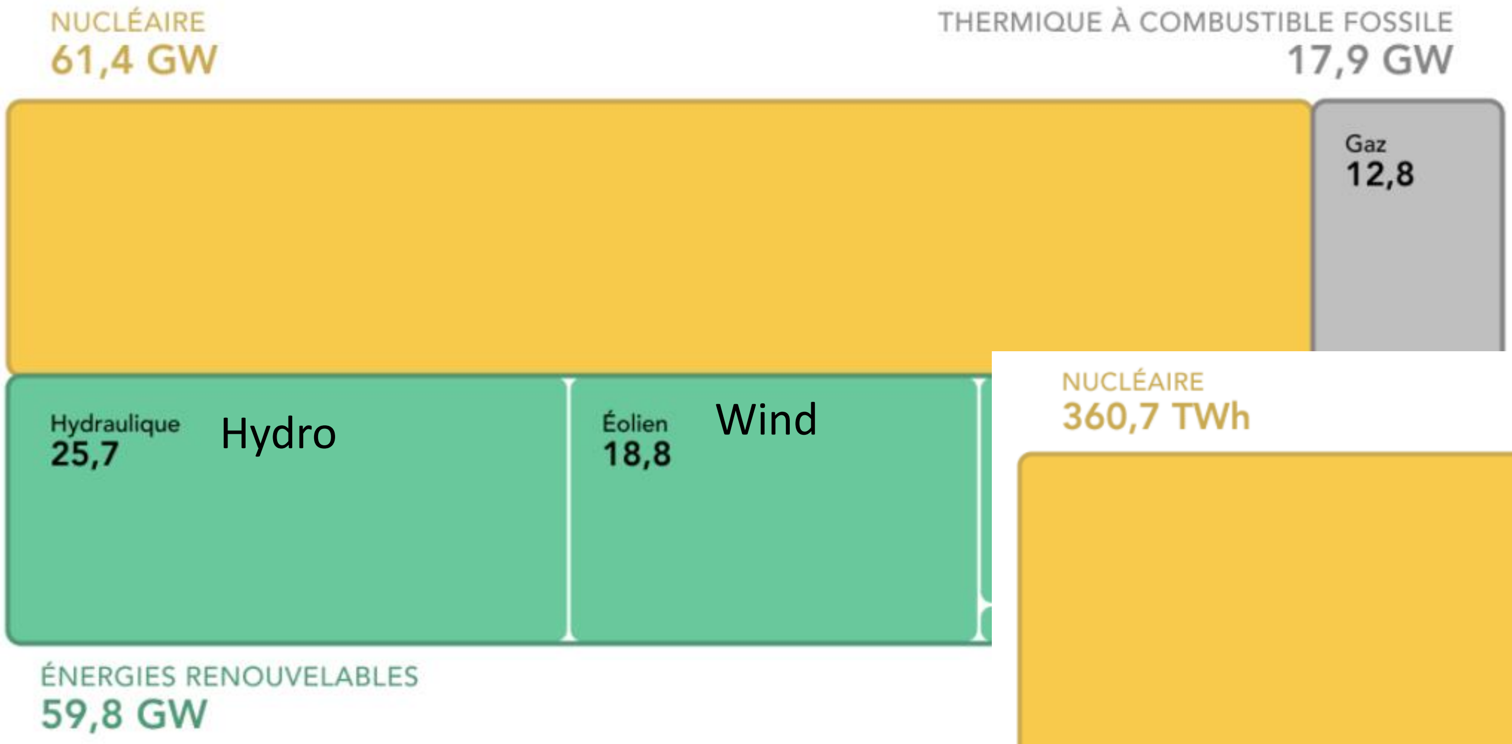
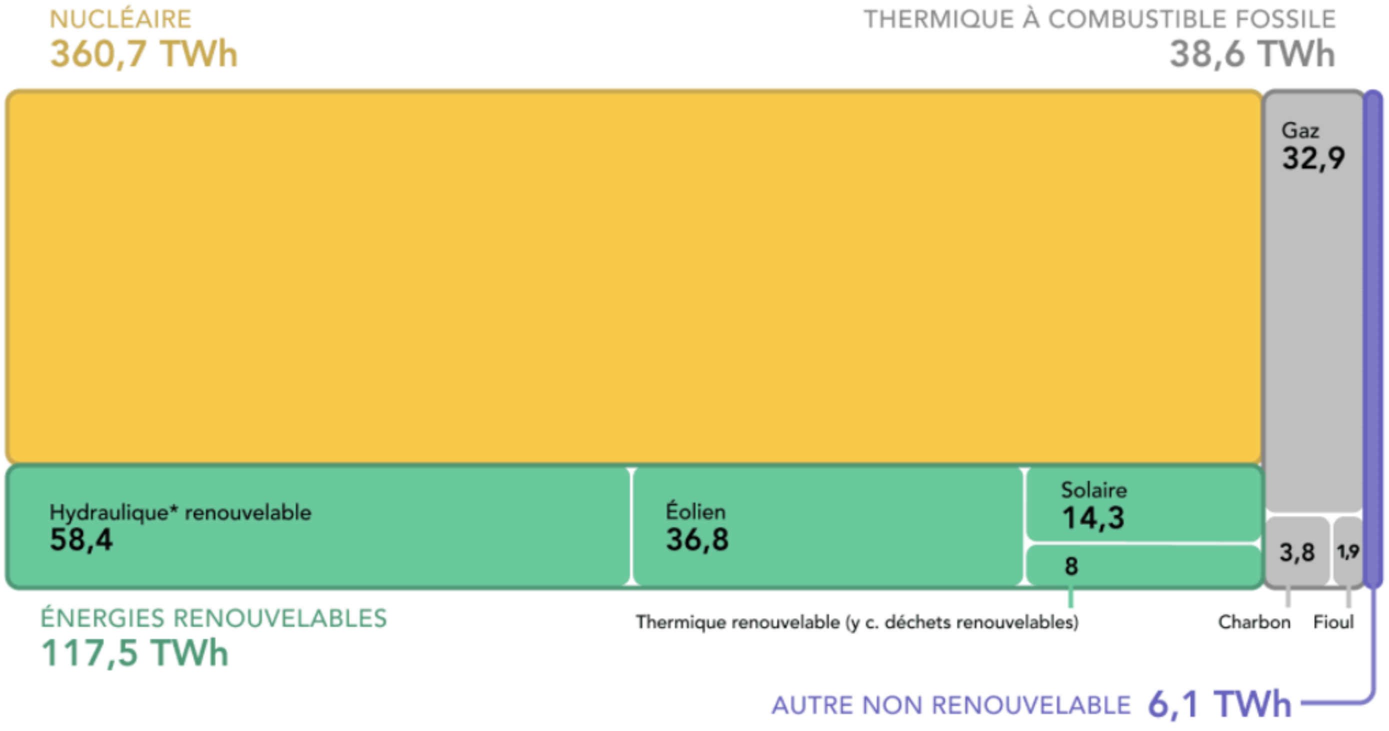
Context

Present situation and system evolution in France.



Present situation and system evolution in France.





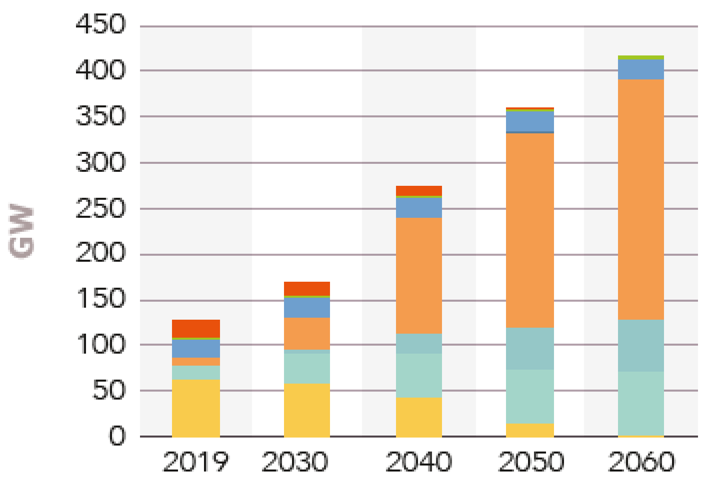
Present situation and system evolution in France.

Present situation and system evolution in France.

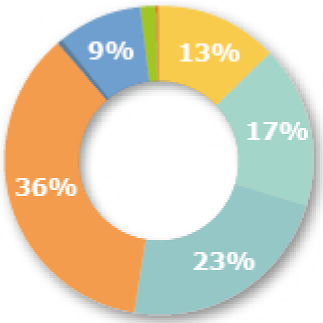
Scénario M1 : Répartition diffuse

Sources de production d'électricité

Capacités installées par filière



Bilan énergétique annuel en 2050



(capacités installées/production)

Filière	2050
Nucléaire existant	16 GW / 91 TWh
Nouveau nucléaire	-
Éolien terrestre	59 GW / 119 TWh
Éolien en mer	45 GW / 162 TWh
Photovoltaïque	214 GW / 255 TWh
Énergies marines	1 GW / 3 TWh
Hydraulique (hors STEP)	22 GW / 63 TWh
Bioénergies	2 GW / 12 TWh
Thermique existant*	0,5 GW / 0,5 TWh

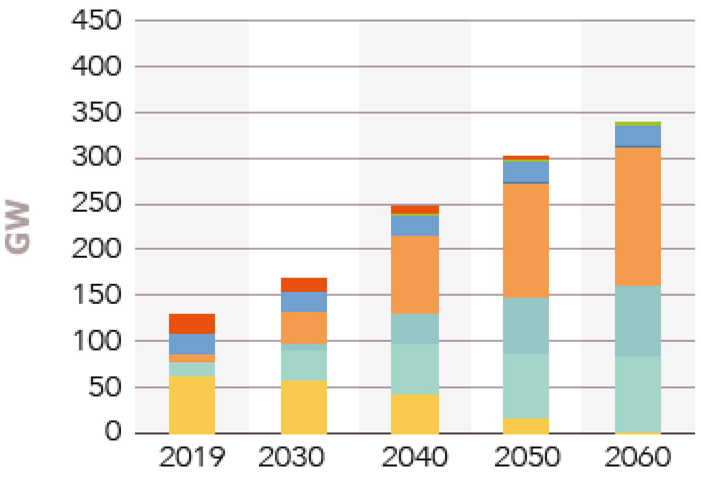
Present situation and system evolution in France.

Scénario M1 : Répartition diffuse

Scénario M23 : énergies renouvelables grands parcs

Sources de production d'électricité

Capacités installées par filière



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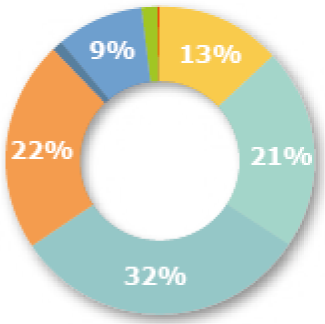


(capacités installées/production)

Filière	2050
Nucléaire existant	16 GW / 91 TWh
Nouveau nucléaire	-
Éolien terrestre	72 GW / 145 TWh
Éolien en mer	60 GW / 215 TWh
Photovoltaïque	125 GW / 153 TWh
Énergies marines	3 GW / 9 TWh
Hydraulique (hors STEP)	22 GW / 62 TWh
Bioénergies	2 GW / 12 TWh
Thermique existant*	0,5 GW / 0,5 TWh

Present situation and system evolution in France.

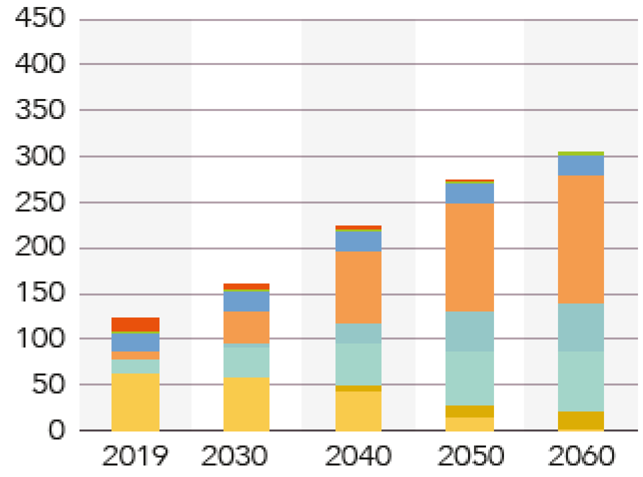
Scénario M1 : Répartition diffuse

Scénario M23 : énergies renouvelables grands parcs

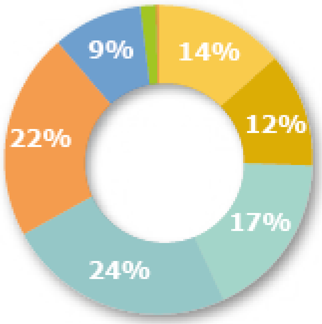
Scénario N1 : Énergies renouvelables + nouveau nucléaire 1

Sources de production d'électricité

Capacités installées par filière



Bilan énergétique annuel en 2050



(capacités installées/production)

Filière	2050
Nucléaire existant	16 GW / 92 TWh
Nouveau nucléaire	13 GW / 79 TWh
Éolien terrestre	58 GW / 117 TWh
Éolien en mer	45 GW / 160 TWh
Photovoltaïque	118 GW / 144 TWh
Énergies marines	-
Hydraulique (hors STEP)	22 GW / 63 TWh
Bioénergies	2 GW / 12 TWh
Thermique existant*	0,5 GW / 0,5 TWh

Present situation and system evolution in France.

Scénario M1 : Répartition diffuse

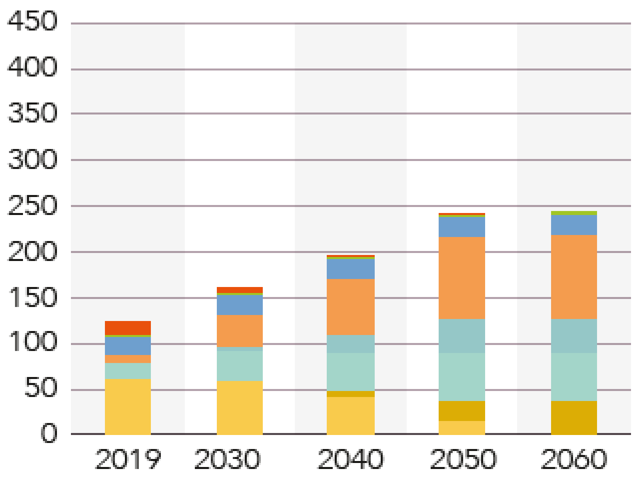
Scénario M23 : énergies renouvelables grands parcs

Scénario N1 : Énergies renouvelables + nouveau nucléaire 1

Scénario N2 : Énergies renouvelables + nouveau nucléaire 2

Sources de production d'électricité

Capacités installées par filière



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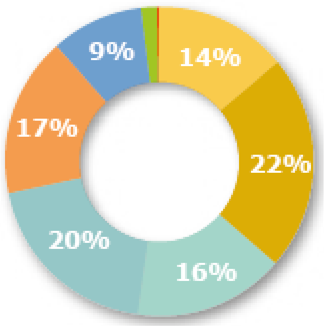


(capacités installées/production)

Filière	2050
Nucléaire existant	16 GW / 93 TWh
Nouveau nucléaire	23 GW / 148 TWh
Éolien terrestre	52 GW / 104 TWh
Éolien en mer	36 GW / 129 TWh
Photovoltaïque	90 GW / 110 TWh
Énergies marines	-
Hydraulique (hors STEP)	22 GW / 63 TWh
Bioénergies	2 GW / 12 TWh
Thermique existant*	0,5 GW / 0,5 TWh

Present situation and system evolution in France.

Scénario M1 : Répartition diffuse

Scénario M23 : énergies renouvelables grands parcs

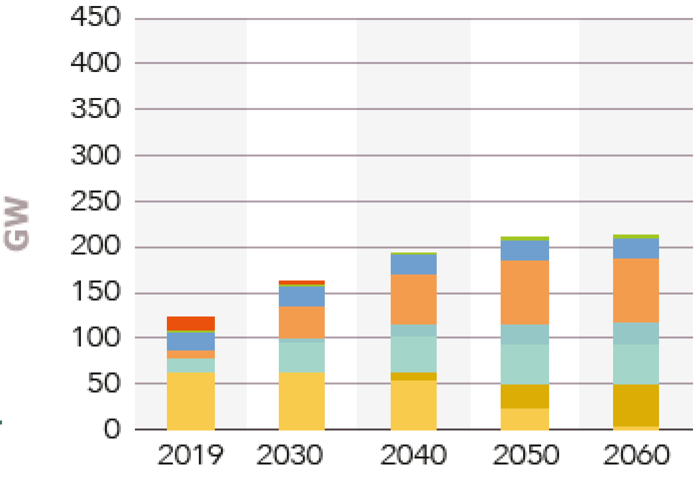
Scénario N1 : Énergies renouvelables + nouveau nucléaire 1

Scénario N2 : Énergies renouvelables + nouveau nucléaire 2

Scénario N03 : Énergies renouvelables + nouveau nucléaire 3

Sources de production d'électricité

Capacités installées par filière



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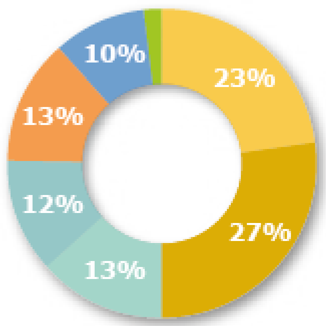


(capacités installées/production)

Filière	2050
Nucléaire existant	24 GW / 149 TWh
Nouveau nucléaire	27 GW / 179 TWh
Éolien terrestre	43 GW / 87 TWh
Éolien en mer	22 GW / 78 TWh
Photovoltaïque	70 GW / 86 TWh
Énergies marines	-
Hydraulique (hors STEP)	22 GW / 63 TWh
Bioénergies	2 GW / 12 TWh
Thermique existant*	-

Present situation and system evolution in Europe.

European scenario:
(assessed before the
Ukrainian War)

There will be hours / days
with very few synchronous
plants

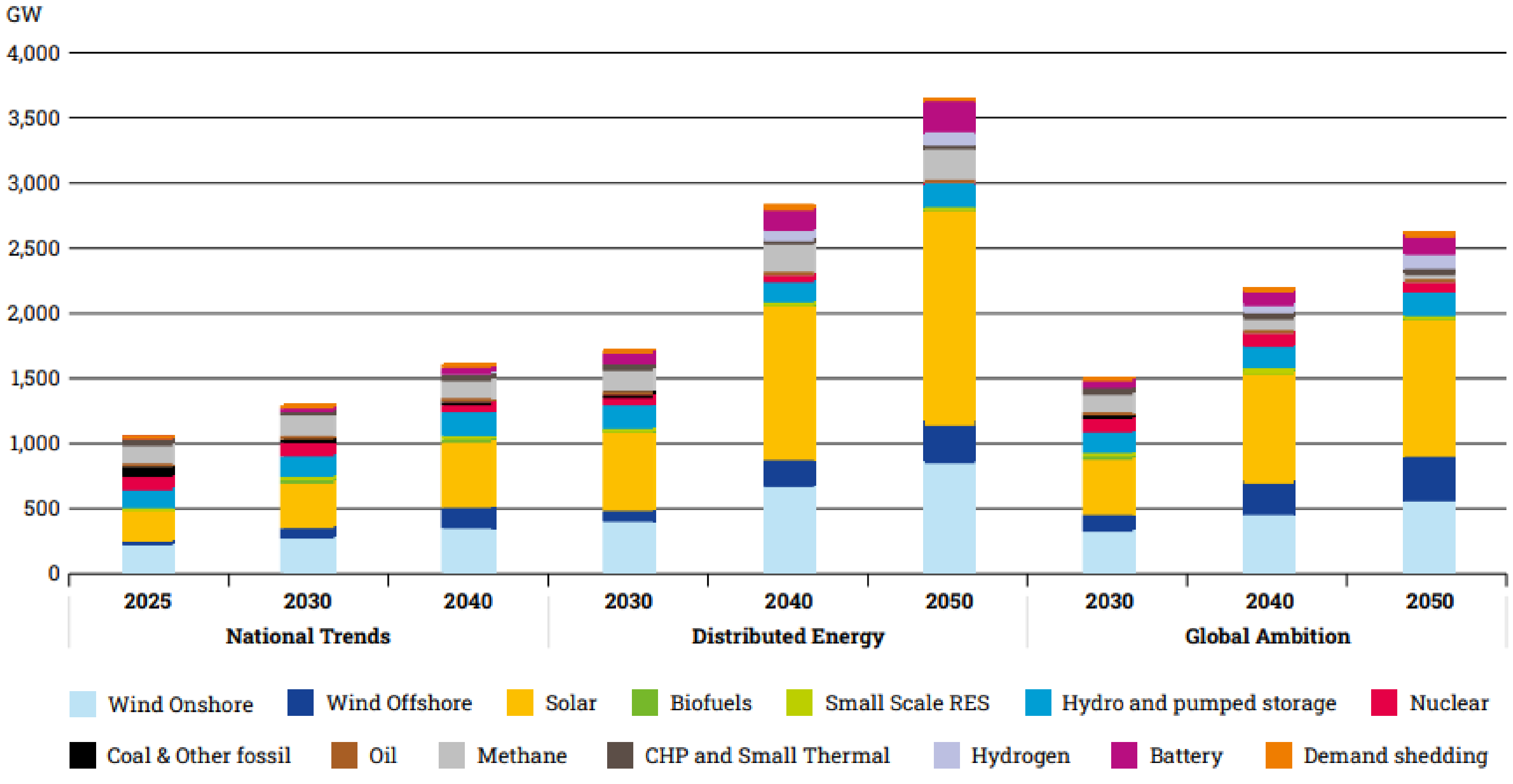


Figure 24: Capacity mix for EU27 (including prosumer PV, hybrid and dedicated RES for electrolysis)

Recent research

Grid forming projects

OSMOSE: WP3
2 demonstrators

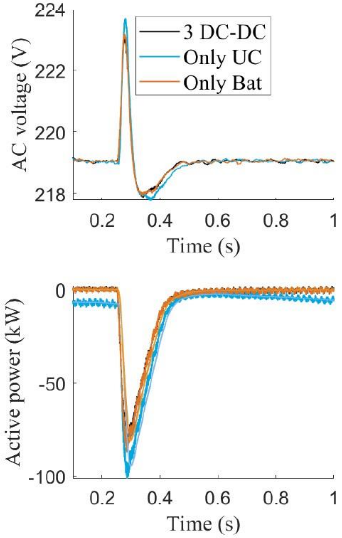
AC/DC	720 kVA
Battery Li-Titan	720 kW – 45 min
Transformer	300 V – 21 kV

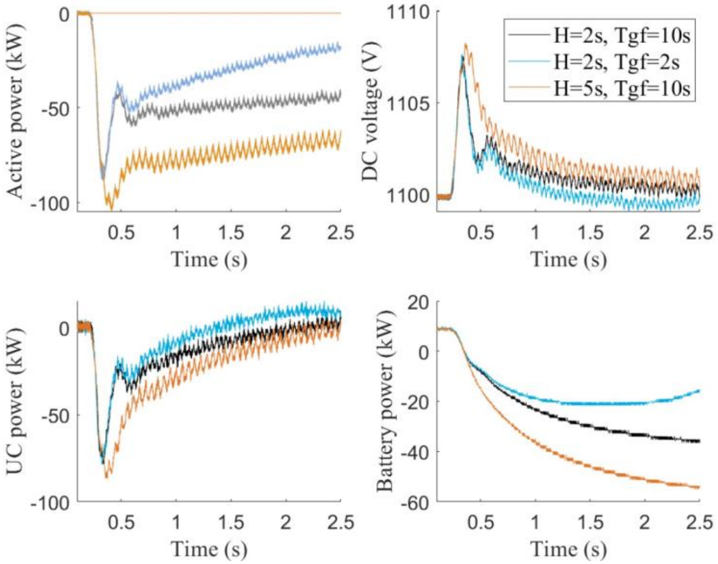
AC/DC	1000 kVA
Battery Li-ion	500 kW – 60 min
Supercapacitors	1000 kW – 10 s
Transformer	600 V – 20 kV

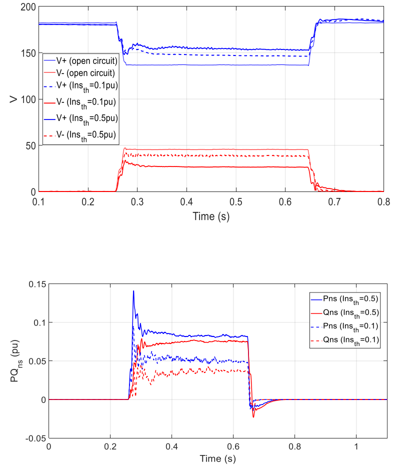
EPFL

Figure 2.1: The 720kVA/500 kWh grid-connected BESS installed at the EPFL campus

Many technicals results:







WP 3 proposed types of grid forming units

Depending on the provided subset of synchronisation services we propose 4 types of GFM units

Type 4 — Synchronous Machine

- Services provided: Type 3 + “High” fault current (more than 2 times Nominal)
- Criticality: if protections fail to detect faults
- Cost: high for converters since they have to be oversized, null for synchronous machines

Type 3 — VSC - ESS

- Services provided: Type 2 + Inertial response
- Criticality: When system inertia decreases globally
- Cost: limited due to the need of an energy buffer from a few seconds to 1min

Type 2

- Services provided: Type 1 + Synchronising power profile
- Criticality: When system inertia decreases locally
- Cost: very limited due to the need of an energy buffer <1 s.
- Other FFR resource are supposed to be available elsewhere to take over.

Type 1

- Service provided: Stand alone + System strength + “Low” fault current (within ratings, usually equal or close to nominal). Operate wide range of SCR
- Criticality: When system strength decreases locally
- Cost: null, only software

Making best use of capacity

- There is still work to be done on harmonisation on requirements and definitions. But grid forming is in fact a set of different capabilities.

- Separate definition of these capabilities, will allow to make best use of inverters existing capabilities.

- BESS / HVDC / STATCOM / PV / WIND can be “grid forming” even if they have very different characteristics (size, energy, available power)

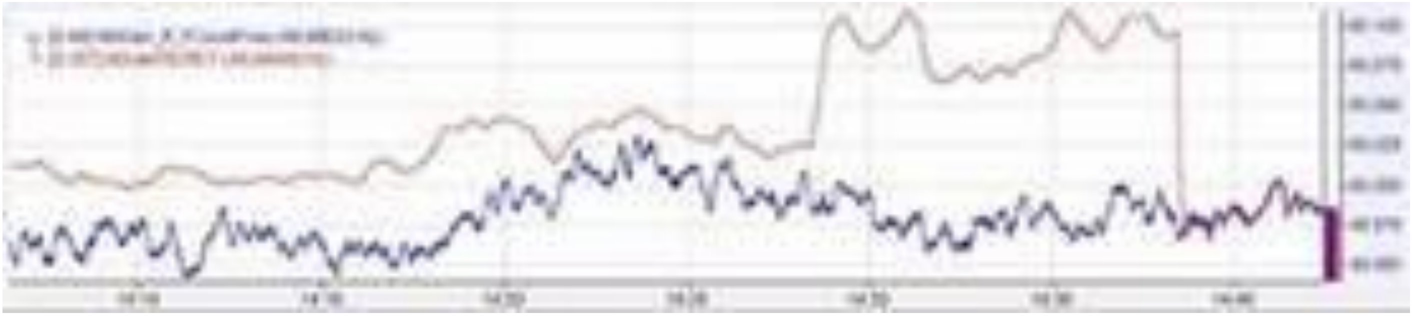
- Next version of European RfG will open the door for installation of GFM units.

Experimental result with batteries

Ringo project: 3 batteries in France to be used as virtual lines.

GFM experiment:

- The 12MW installation started in grid forming mode to energize a grid island (2 transformers, a small distance of 63kV cable and around 15km of 20 kV cable)
- connection of a 10MW wind farm
- operation as an island for 2 hours with wind farm charging the battery
- it seamlessly reconnected to the main grid and the battery then switched back to grid following mode.



Ongoing research

GFM from HVDC

Existing HVDC can provide GFM capability for black start
it can even be used in grid connected mode
but only transiently

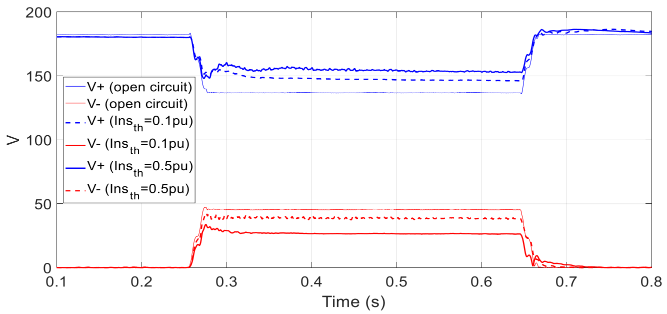
Research project to get the most out of HVDC
- HVDC pro (https://www.sintef.no/en/projects/2017/hvdc-inertia-provision/)
- PhD in KUL working on implementation of GFM on Bipolar HVDC in different configurations.

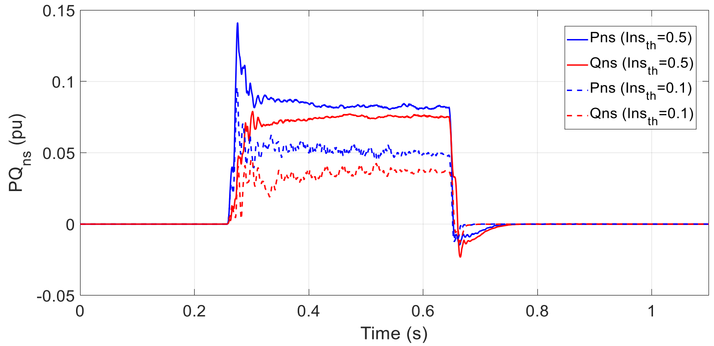
GFM and unbalanced

Many studies have been investigating GFM in balanced situation.

For the aim of the OSMOSE demonstrations,unbalanced during both normal operation and fault operation have been studied.
https://doi.org/10.3390/en14196168

⇒ Specification is a KEY.
- ⇒ Balanced voltage
- ⇒ Balanced current
- ⇒ Mixed solution??





PSERC project : S-95: Reliable fault-ride through and protection of converter-dominated power systems under unbalanced conditions

Where and when are they needed?

- Presently the assessment of need for grid forming requires detailed studies.

- Many indicators for screening have been developed for screening the needs
  - SCR / WSCR / SNSP / AFC / MSCR

- but don't yet accommodate the presence of GFM inverters

- Ongoing research with L2EP on criteria to assess where they are needed
  - **"Optimal placement of grid-forming and grid-following inverters to increase the stability of a transmission grid including a high proportion of power electronic converters"**

Ongoing work at ENTSOE level:

STABILITY MANAGEMENT IN POWER ELECTRONICS DOMINATED SYSTEMS

A common and comprehensive European roadmap should be released next year.

Is GFM exclusively for generation?

There is a priori no barriers to have a GFM inverter connecting DC load.

GFM capability on (big) PE connected loads would widen the pool of potential GFM inverters on the grid. => stronger and more resilient grid.

Capability vs use

Not having enough GFM capacity on the grid would endanger the viability of the grid.
The capacity of being grid forming should be required from any units up to its nominal capacities, even if the use might not always be necessary.

Should there be a market for GFM or should it be a requirement such as FRT?
Should the one that consume SCP pay for the one that produces it?

Explore new operation of the system

Distributed grid forming units may allow subsystems to be operated during partial blackout or system split.

=> Restarting the system bottom up? PhD with L2EP starting now to investigate this with DSO

=> Develop new defense plan ?

=> New operation for the distribution system

Thank you

Questions ?

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