SUPEERA

Support to the coordination of national research and innovation programmes in areas of activity of the European Energy Research Alliance

SUPEERA workshop

Bringing research and industry closer: accelerating innovation and uptake of new technologies

⟶*The workshop is in hybrid mode (**recorded)***

⟶***Do not turn on your microphone and camera during the event;** you **only** might be requested to do so during the Q&A session*

⟶*Please **send your questions via chat** to all organisers*

⟶*The **recording** of the webinar and the **PPT** will be **circulated shortly after***

Padova, Italy, 10.05.2022

AGENDA (speakers) 1/2

09:00	Welcome and greetings	Alberto Bertucco, Head of the Interdepartmental Levi Cases, University of Padova
09:05	Keynote speech:	Vito Di Noto, Professor, Department of Industrial Engineering, University of Padova
09:25	Intro to the workhop Presnetaion of two pathways	Ivan Matejak, SUPEERA coordinator, EERA Maria Oksa, Senior Sceintist, Project Partner, VTT
09:20	Collaboration between research and industry: best practices, barriers and replicability potential	
	Introduction of the speakers - EERA Joint Programme Energy Storage - EERA Joint Programme FCH - ENI, Italy - ENEL Green Power	- Myriam Gil Bardaji, JP Manager, KIT - Stephen Mc Phail, former JP Coordinator - Andrea Bernardi, Head of Solar Storage & Bio-Energy Technologies - Paolo Prevedello, Hydrogen Innovation Project Engineer
11:00	Panel discussion	All Moderator: Ivan Matejak
11:30	Coffee break	

AGENDA (speakers) 2/2

11:45	Cross-sectorial dialogue for system solutions towards the CET objectives	
	- Systemic and cross-sectorial issues pertaining to the Clean Energy Transition - SNAM - StoRIES project - Batteries Europe - SIMBA project	- Spyridon Pantelis, Project manager, EERA - Dina Lanzi, Head of Technical Business Unit H2 - Stefano Passerini, Project Coordinator, KIT - Alessandro Romanello, ETIP Coordinator, Innoenergy - Maider Zarrabeitia Ipina, Postdoc researcher, KIT
13:00	Panel Discussion and Q&I	All Moderator: Spyridon Pantelis
13:30	Lunch break	

Welcome and objective of the workshop

Ivan Matejak, EERA,
Project Coordinator

SUPEERA supports the SET-Plan and the Clean Energy Transition

We...

- Facilitate the coordination of the research community
- Accelerate innovation and uptake by industry
- Provide recommendations on policy
- Promote the SET-Plan and the Clean Energy Transition

We connect the dots.

EERA European Energy Research Alliance

cea DTU

KIT Karlsruhe Institute of Technology SINTEF VTT

OBJECTIVES of the

PROJECT ACTIVITY:

- Promoting and establishing a **dialogue between industry and energy experts** (including IWGs, European industrial organisations & related platforms);
- **Analysing** the proposed energy measures in the **NECPs** and LTSs;
- **Defining pathways** covering different realities in terms of maturity & regional coverage;
- Delivering sectorial, cross-sectorial and systemic **recommendations on R&I priorities**; supporting uptake of new technologies by the industry

WORKSHOP:

- Update on selected pathways: **energy storage & FC;**
- Present and **discuss key findings** of initial analysis of NECPs and national & EU initiatives;
- Focus on **relevant cooperation practices/experiences** (esp. research-industry) to facilitate innovation & market uptake;
- Consider **preliminary recommendations** we can draw from them; their possible replicability in other contexts/countries;
- Follow up on **series of workshops**

The SET Plan & NECPs as tools for EU-wide collaboration on R&I priorities of low carbon technologies

Ivan Matejak,
SUPEERA Coordinator

Dynamism of R&I in the energy transition

- Integrated SET Plan (2008; 2015; *2022*)
- European Green Deal (2019)
- Recovery Plans (2021)
- REPowerEU (2022)
- What next?(2022, 2023…)

Methodology on analysis of the NECPs

→ ***27 NECPs and the EC assessments (Oct 2020)***

→ Criteria for selection:
- Increase regional coverage
- Matching regions with best practices
- Strong European competitive areas
- Pathways with needs of cross-sectorial and systemic activities
- Planned measures maturity

(yellow)	Policy/ies for pathways have been described
(green)	Research plan and/or funding scheme exists
(grey)	Not described / excluded from NECP country plan

→ “Traffic lights”

Selection of most relevant six pathways (wind, hydrogen, **storage**, **bio**, energy systems integration and solar)

<u>**Analysis of the pathways**</u>

→ Focus on NECP chapter 2.5 Research, innovation and competitiveness

→ Solutions, best practices and gaps

Framework for transnational cooperation

Enabling framework crucial to deliver transformation

Key aspects:

- Mature and less mature topics: Technologies
- Cooperation and knowledge: industrial alliances, EERA JPs…
- Strong European competitive areas
- Transferable best practices in MS/AS

Key enablers and cross-cutting factors:

- Smart and innovative materials
- Enhancing grid integration and security
- Social acceptance, societal awareness and engagement
- Enabling policies and regulatory measures
- Financing

Dialogue between R&D&I and IND

- Wind energy
- **Hydrogen**
- **Energy storage**
- Bioenergy
- Energy systems integration
- Solar energy

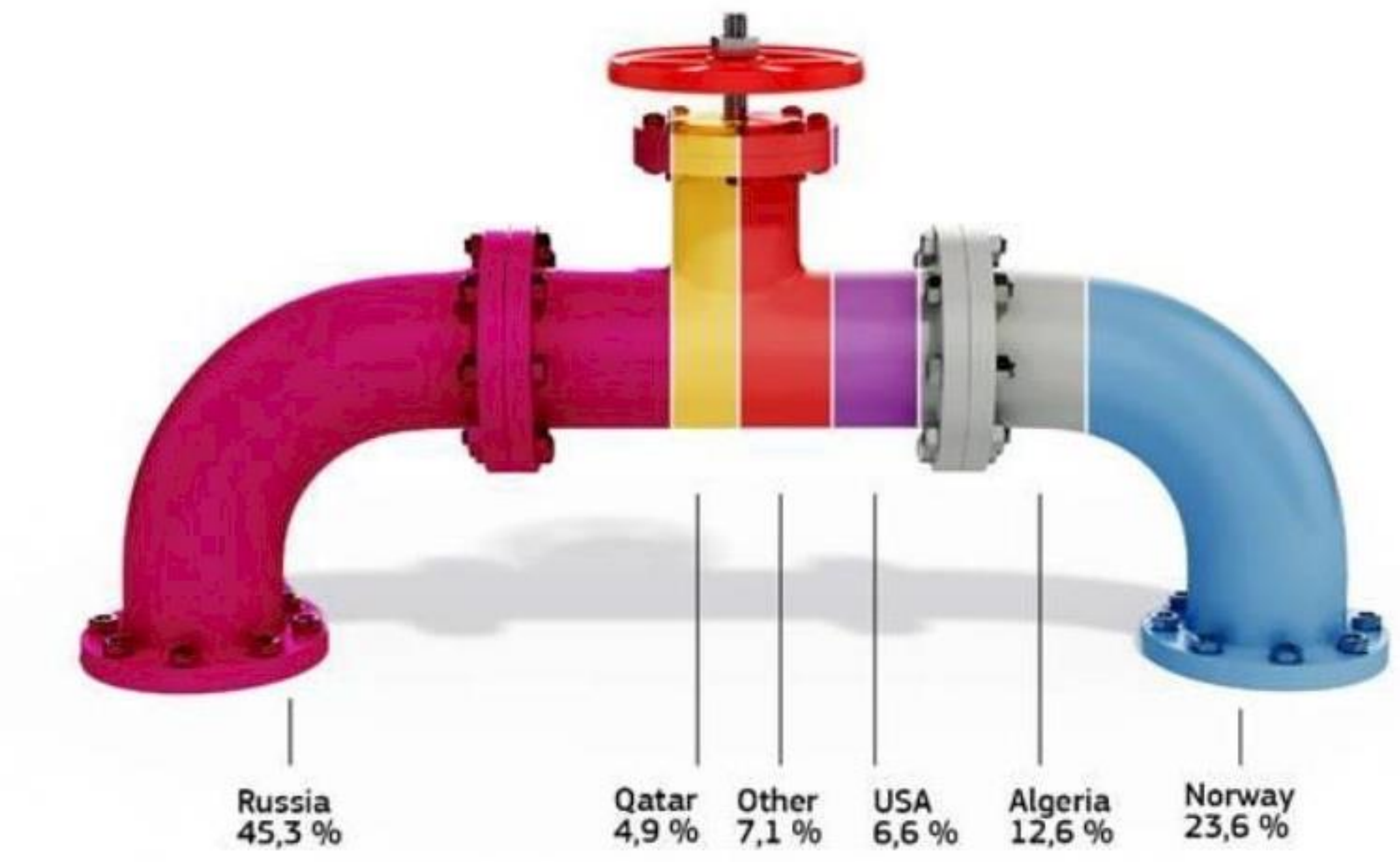
REPowerEU - Objectives

Versailles Declaration, 10-11/03/2022

EU leaders agreed to phase out the EU dependency on Russian gas, oil and coal imports ASAP and invited the EC to put forward a plan to ensure security of supply and affordable energy prices during the next winter season by end of March.

- Joint European action for more affordable, secure and sustainable energy
- Get rid of Russian dependency – gas, oil, coal - well before 2030, starting with gas
  EU Dependency:
  - Gas: 40%
  - Oil: 27%
  - Coal 46%
- Get rid of 2/3 (100 bcm) of current gas imports from Russia by 2023

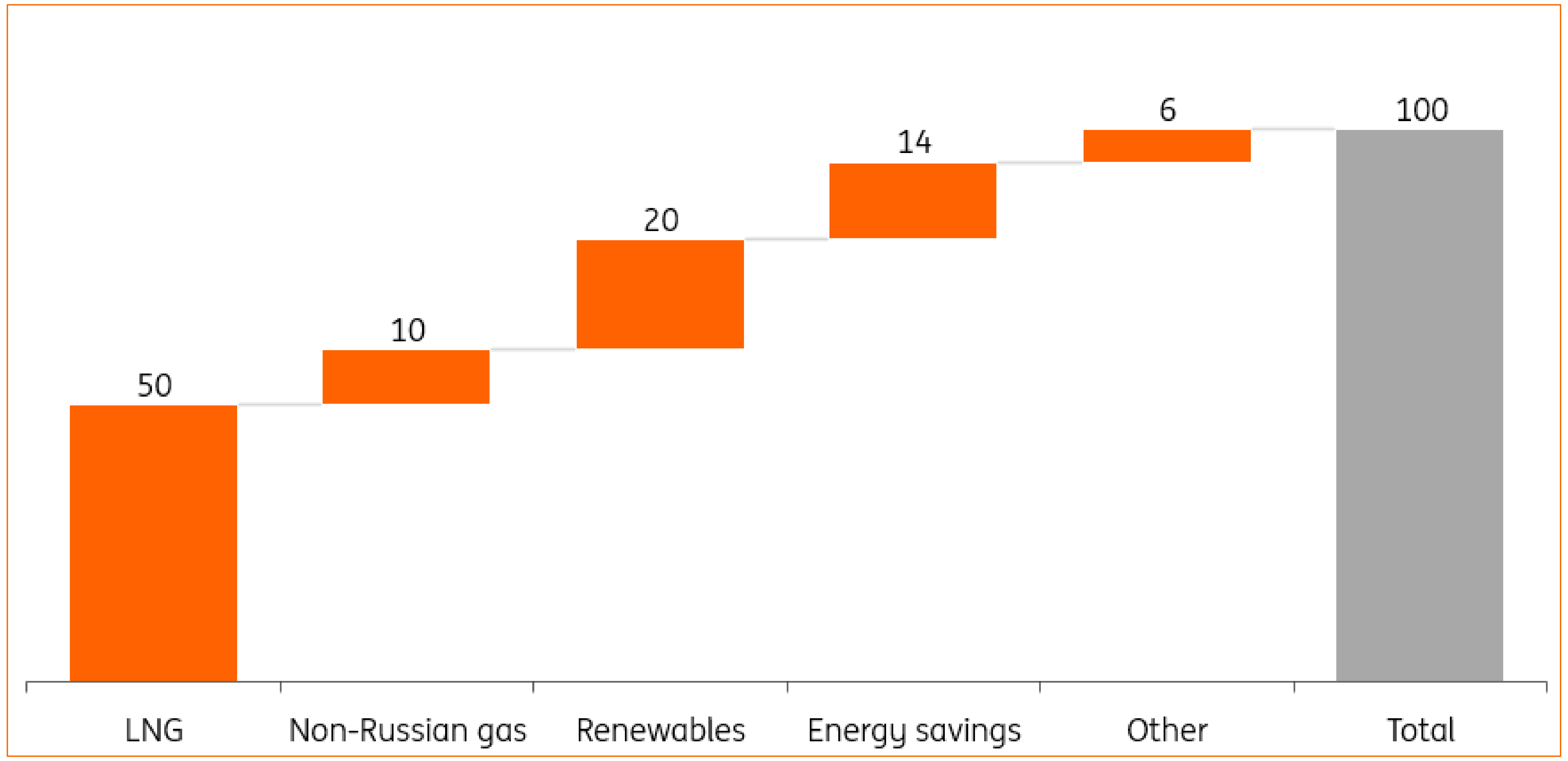
Share in EU natural gas imports, 2021



Source: European Commission

REPower EU – Cut Russian Gas dependency - CET

1. **Boosting RES** deployment, grid and permitting
   1. Solar PV
   2. Wind
   3. Heat-pumps x2 :10 M installations in 5 Y
2. **Energy Efficiency**
   1. Buildings
   2. Industrial Processes
3. **Diversifying Gas supply**
   1. Suppliers
   2. LNG infrastructure
4. **Double 2030 Biomethane** targets: 35 bcm by 2030
5. **Accelerate Hydrogen**
   1. Infrastructure : ports, transport, storage
   2. Import 9-18 Mt, produce 5-6 Mt by 2030



SET Plan as a tool for EU-wide collaboration on R&I priorities of low-carbon technologies

SET Plan evolution

Since 2007 :

- the SET Plan has been **instrumental in fostering collaboration** between SET Plan countries, industry and research institutes
- successful in **coordinating national R&I agendas** on low-carbon energy
- **14 SET Plan IWGs** have established ambitious research and innovation targets
- **Cross-sectorial** collaboration has increased

Revamping process 2022:

- Deliver on the goals of the **Green Deal**, the **Energy Union** and **Recovery Plans** and the **ERA Policy Agenda**
- Strengthen EU's strategic energy **value chains** to increase our energy and technology independence and security of **energy supply**
- Adapt the **governance of the SET Plan** to ensure the delivery on issues of strategic importance while keeping an optimal flexibility and agility
- Promote synergies between different programmes and **leverage national financing**

PANEL SESSION Collaboration between research and industry: best practices, barriers and replicability potential

Moderator: Ivan Matejak

EERA Joint Programme Energy Storage — Stefano Passerini, JP Coordinator, KIT

EERA Joint Programme FCH — Stephen Mc Phail, former JP Coordinator

ENI — Andrea Bernardi, Head of Solar Storage & Bio-Energy Technologies

ENEL Green Power — Paolo Prevedello, Hydrogen Innovation Project Engineer www.supeera.eu

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Presentation of two pathways: key findings on energy storage and fuel cells and hydrogen

Maria Oksa, VTT, Project Partner
Suvisanna Correia, VTT
Mónica de Juan, EERA

REPowerEU

→ On Energy storage and on Hydrogen – to cut the dependence on Russian gas

- Designating **gas storage** as critical infrastructure, and allowing incentives for refilling.
- Decarbonising Industry by accelerating the switch to electrification and **renewable hydrogen** and enhancing our low-carbon manufacturing capabilities.
- A **Hydrogen Accelerator** to develop infrastructure, **storage facilities** and ports, and replace demand for Russian gas with additional 10 mt of **imported renewable hydrogen** from diverse sources and additional 5 mt of **domestic renewable hydrogen**.

Energy storage - overview

→Relevant European Policy

Clean energy for all Europeans package

- Energy storage addresses several central principles of package

A comprehensive European Approach to Energy Storage. The report:

- Was adopted by the European Parliament in July 2020;
- Calls on the Member States to fully explore their energy storage potential;
- Underlines the need for flexibility that arises from intermittent RES electricity generation;
- States that increasing amounts of storage capacity needed for excess electricity;
- Feasible technologies vary by country.

→Technology recap from the NECPs

Electricity storage technologies

- Pumped hydro storage plant has largest capacity (Europe, global)

- Battery storage for mobility and stationary uses, European priority
  - Scale from house to transmission substation battery banks

- *Islands and other remote areas with limited interconnections, storages especially valuable; range of feasible technologies limited*

Heat storage technologies

- Time scale from daily to long-term seasonal storage

- Primary needs in buildings and industry

- Store excess RES electricity as heat in liquid or solid matter

- Utilise currently wasted heat streams via heat pumps

Overview of NECP best practises and gaps in energy storage

Topics	AT	BE	BG	CY	CZ	DE	DK	EE	EL	ES	FI	FR	HR
Storage emphasis	1	1	1	1	3	3	3	3	1	1	3	3	1
Reasearch Policies	2	2	1	1	2	2	2	1	2	2	2	2	1
Funding	1	1	1	3	3	1	1	3	3	1	1	1	1
Regional cooperation	1	1	1	3	3	1	1	1	3	3	1	1	3
Regulation	1	1	1	1	1	1	1	1	1	1	1	1	1
Projected capacity	1	3	1	3	3	3	3	3	3	1	3	3	3

Topics	HU	IE	IT	LT	LU	LV	MT	NL	PL	PT	RO	SE	SI	SK
Storage emphasis	3	3	1	1	1	1	1	3	3	3	1	3	1	3
Research policy	2	1	2	2	1	1	2	2	2	2	2	2	2	2
Funding	3	3	1	1	3	1	1	1	1	1	1	1	3	1
Regional cooperation	3	3	3	1	1	1	3	3	1	3	3	1	3	3
Regulation	3	3	1	3	1	1	1	1	1	1	1	1	1	1
Projected capacity	3	3	1	3	3	3	3	3	3	3	3	3	3	3

Code colours

1	Described in NECP
2	Research plan exists
3	Not described in NECP

Market-driven development of storage capacity is indicated in the Nordic energy market area (DK, FI, SE) and NL.

Missing link with hydrogen – NL, PT, FR and DE having strong plans on hydrogen.

Best practises in energy storage actions

→Regional cooperation in research and funding

- **France and Germany** launched 2018 bilateral funding of €20 million on energy storage and distribution. Funded projects create knowledge about energy storage conditions and operation in cross-border distribution system.
- **Nordic Energy Research**: seven key areas for joint Nordic research efforts, incl. Energy Storage, to be granted up to 4 million NOK to each key area

→Regulation

- **In Finland** the power reserve system ensures electricity supply in situations in which market-driven electricity does not cover demand, e.g. low RE generation
- Power plants, demand-side flexibility and storage can participate in the power reserve. The system has been in use since 2007.

→Projected storage capacity

- Planned capacity expressed in MW in **Austria, Bulgaria, Italy and Spain**

→Remote areas

- **Greece** plans to promote solar powered desalination plants with battery storage to produce water for drinking or irrigation on islands and in remote areas.
- RE and energy storage systems will supply stable power for these desalination plants.

→Circular economy

- Retiring the two last coal-fired power plants of **Portugal** in 2023 will involve studies for recycling and reusing the equipment
- Thermoelectric solar capacity with storage to produce renewable steam for existing turbines
- Direct use of green hydrogen as a fuel to substitute coal

The revised EU Batteries Regulation

- The Council of the EU and the EP have agreed on their positions on the **proposed batteries regulation**, originally published by the EC in December 2020
- **Main change** → **scope of the regulation**: batteries for light means of transport were not covered under the previous regulation
- **Materials** play a key role in this development. The new regulation looks at making batteries more "renewables" by introducing:
  - Improved requirements for circular design in the production phase
  - Better recovering processes of important materials, such as cobalt, lead, lithium and nickel
  - Reduced greenhouse gas emission linked to the use of the mentioned materials by introducing alternative and renewable raw materials (definition not included)

Why Hydrogen as pathway?

→Key priority for the European Green Deal and Europe's clean energy transition

→RES electricity to decarbonize large share of the EU energy by 2050, not all

→Replace fossil fuels in some carbon intensive processes, e.g. steel or chemical sectors

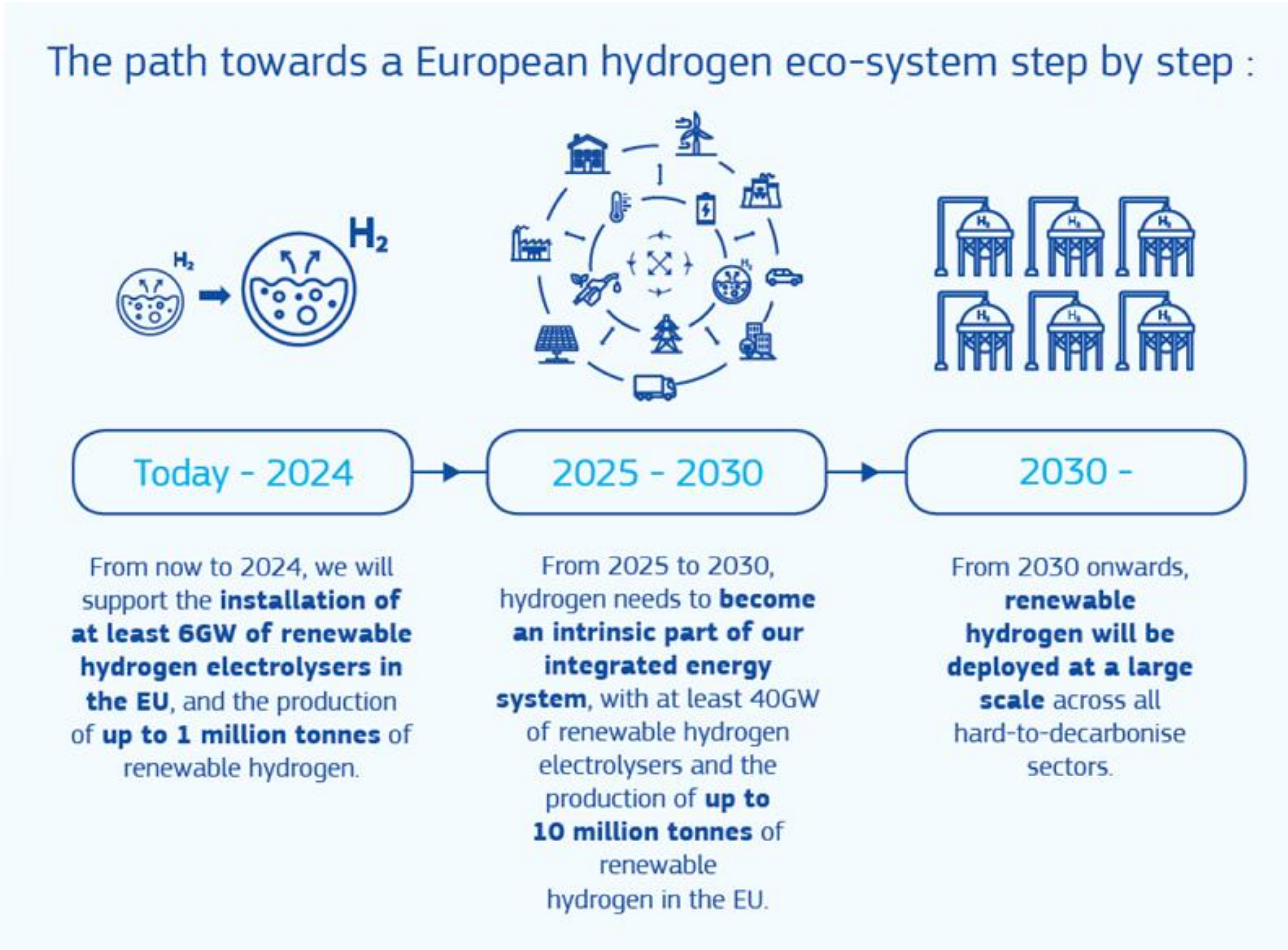
→Solutions for hard to abate parts of the transport system, in addition to electrification and other renewable and low-carbon fuels

→Potential for repurposing or re-using parts of the existing gas grid

→Investment will foster sustainable growth and jobs, critical for recovery from the COVID-19 crisis

source: www.flickr.com

European Hydrogen Strategy



European Hydrogen strategy – main areas for analysis

→ *Renewable hydrogen*, produced mainly via wind and solar energy, is the strategy's priority

→ *Infrastructure*

- Key action: start the planning of H2 infrastructure, including long-term network plans and fuelling stations
- Infrastructure needs are complex, depend on the pattern of H2 production, demand and transportation costs

→ *Demand*

- Lead markets are industrial applications and mobility
- Boosting demand and supply of H2 likely to require various forms of support

→ *Collaboration*

- European Clean Hydrogen Alliance (viable investment projects, a forum to coordinate investment by all stakeholders and engage civil society)

National hydrogen strategies

→**Published**:

- Germany (planned electrolyzer capacity 2 GW)
- Netherlands (3-4 GW by 2030)
- France (6.5 GW by 2030)
- Portugal (2 GW by 2030, 5 GW by 2050)
- Spain (4 GW by 2030)
- Poland: creating hydrogen economy
- Finland: National Hydrogen Roadmap

EU Clean Hydrogen Partnership

- **The EU CHP has launched the first batch of calls for proposals under its scope, with these among the main topics:**

  - Hydrogen production processes
  - The efficiency of solar thermochemical water splitting
  - Low temperature water electrolysers for highly pressurised hydrogen production
  - Use of hydrogen in transport (and mainly, heavy-duty transport), heating and power
  - Cross-cutting projects
  - “Hydrogen valleys” → A Hydrogen Valley is a defined geographical area, city, region or industrial area where several hydrogen applications are combined together and integrated within an FCH ecosystem

- While the total mobilisation of public funds will amount to €1 billion over the course of the partnership, this first call for proposals will channel €300 million that shall be equalised by private sector participants, aiming to reach a total of €600 million in funds.

Findings from NECPs in Hydrogen

→**European industry** needs clarity and investors need certainty in the transition, a clear understanding across the Union on

(i) the hydrogen production technologies that need to be developed in Europe, as well as

(ii) what can be considered as renewable and low-carbon hydrogen.

→The **end goal for the EU** is clear: climate-neutral energy system integration with renewable hydrogen and renewable electricity at its core.

→A challenge of a **long period**; the EU will need to plan the transition carefully, given that starting points and infrastructure differ across Member States.

→All current plans are not announced in NECPs

Best practice examples

H2 production

- **Bulgaria**: A Power to X pilot for a 20 MW hydrogen plant → further development of hydrogen power plants after 2030 will be analysed
- **Denmark**: 2019, 2 Power-to-X-projects to establish large scale production and storage of green hydrogen

Infrastructure

- **Czech Republic**: building 3–5 H2 filling stations by 2025, with plan to update this number to at least 12 stations
- **Italy**: Development of power-to-gas storage systems for storage of excess RES production, and secure and reliable storage of H2

Creation of market demand

- **Germany**: support the purchase of heavy goods vehicles with hydrogen technologies and passenger cars with hydrogen / fuel cell drive
- **Italy**: A national strategic framework for the transport sector promotes alternative fuels, in particular electricity, natural gas and hydrogen

Collaboration

- **Baltic States**: Regional cooperation in the transport sector with regard to the production and use of biomethane, future technologies (energy storage, CCU, hydrogen, etc.)
- **Penta countries**: Hydrogen can play a role in flexibility of the internal electricity market

European and regional collaboration

- European Clean Hydrogen Alliance – & the Commission's New Industrial Strategy
- European Clean Hydrogen Partnership
- North Baltic Sea hydrogen strategy: https://ec.europa.eu/regional_policy/en/projects/united-kingdom/hytrec-a-unified-hydrogen-strategy-for-the-north-baltic-sea-region

- More information on EC pages:
  https://ec.europa.eu/growth/content/powering-climate-neutral-economy-commission-sets-out-plans-energy-system-future-and-clean_en

Research - Industrial collaboration

→ The **Horizon Europe** Framework Programme: launch of new public-private partnership on Clean Hydrogen with an increased budget

- New partnership will support joint R&I activities with industry on supply, storage, transport and transformation of clean hydrogen for the whole economy
- Will aim at establishing hydrogen's competitiveness and viability as an energy source in place of fossil fuels

→ Source: https://ec.europa.eu/info/sites/info/files/research_and_innovation/research_by_area/documents/ec_rtd_hydrogen-factsheet.pdf www.supeera.eu

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EERA Joint Programme Energy Storage

Myriam Gil Bardají (KIT) on Behalf of JP ES
JP ES Manager
StoRIES project depity coordinator

EERA Joint Programme on Energy Storage

Established in **2011**

40 ROs and Universities dedicated to low-carbon technology research

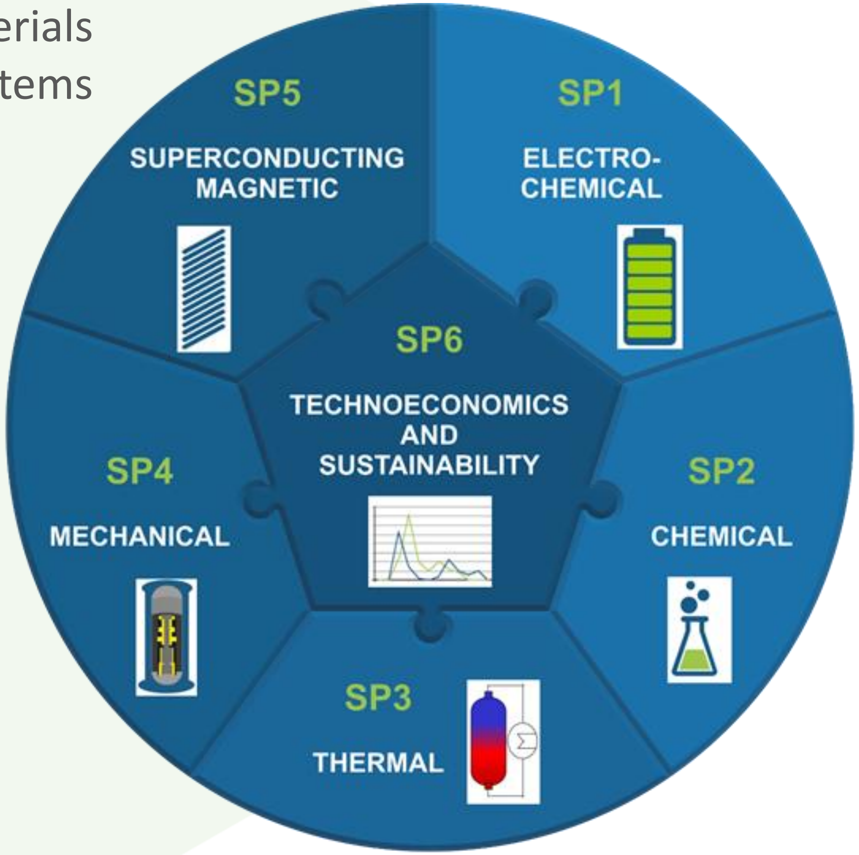
15 Member States /Associated countries collaborating through JP ES

EERA European Energy Research Alliance Energy Storage

SUB-PROGRAMMES: ES TECHNOLOGIES

HTS materials
SMES systems

Li-ion batteries
Post Li-ion batteries
Redox Flow batteries
Supercapacitors



Hydropower
Flywheels
Compressed Air
Liquid Air

P2X
Hydrogen
Direct Air Capture

Latent heat storage
Sensible heat storage
Thermochemical storage

Sub-Programmes Coordinators

Stefano Passerini, KIT
JP coordinator

Margherita Moreno, ENEA
SP1 -Electrochemical

Adelbert Goede, DIFFER
SP2 -Chemical

Salvatore Vasta, CNR
SP3 - Thermal

Atle Harby, SINTEF
SP4 - Mechanical

Xavier Granados, CSIC
SP5 - SMES

Manuel Baumann, KIT
SP6 – Techno-economics

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European Energy Research Alliance
Energy Storage

Mission and Vision

- developing **common research** and coordinating the scientific community
- establishing a dialogue at European level among all stakeholders involved in energy storage R&D
- facilitating **knowledge transfer** by communication with industry and stakeholders
- **advising policy makers** by identification of regulatory barriers and providing policy recommendations
- establishing **best practices** by developing new technologies and pave the way to market introduction

JP ES Activities 2021-2022

- **Mobility Scheme:** up to €4,000 per exchange including special Covid-19 expenses
- **Online PhD Days:** to stimulate exchange and discussion on the topic with young scientist
- **JPES Award:** to support activities in the field of energy storage
- **JPES @EUSEW:** to networking with other initiatives and establish a dialogue with EC
- **Policy and Stakeholder Workshops:** facilitating knowledge transfer
- **Industry Advisory Board:** to take into account current industry needs

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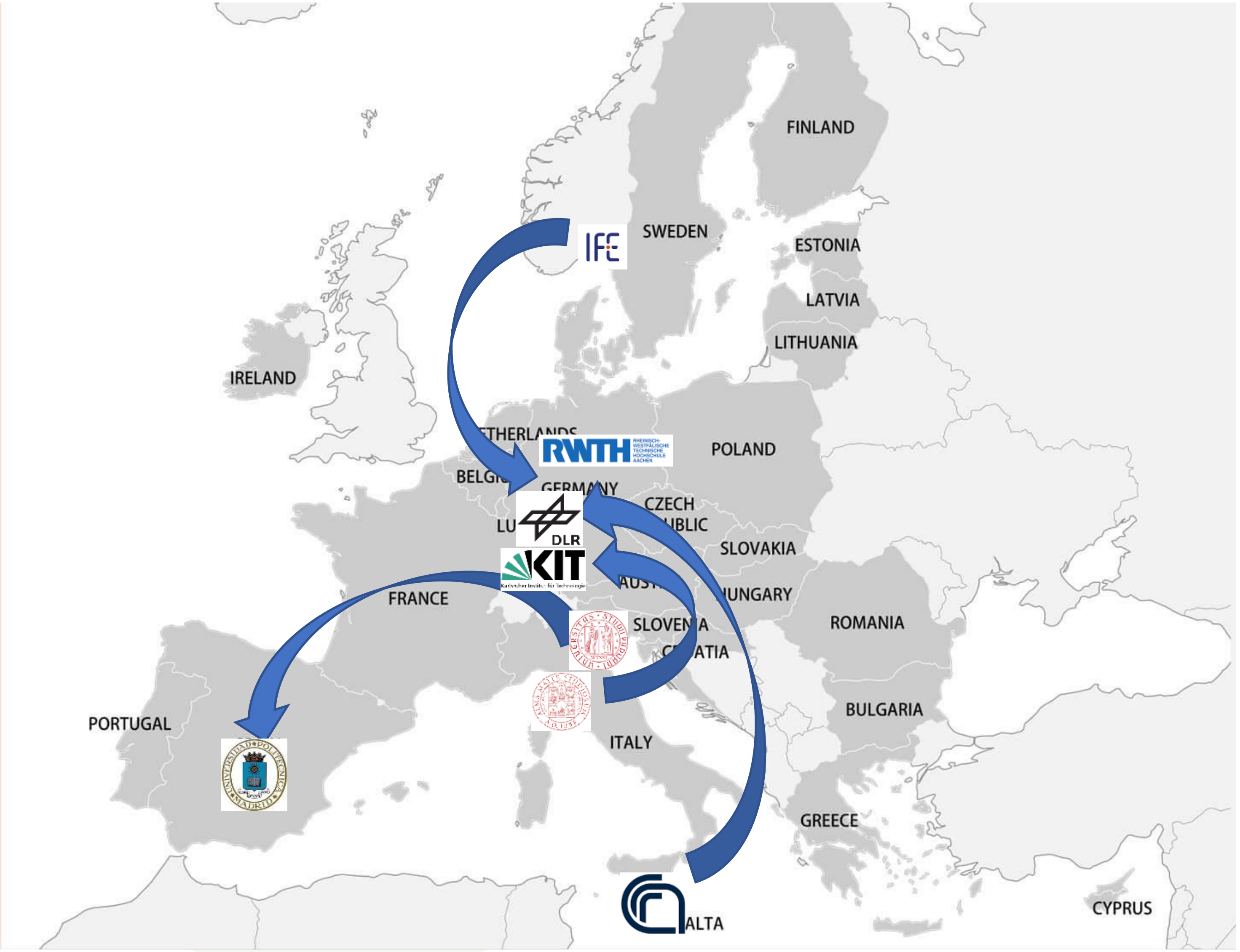
Energy Storage

Mobility Scheme 2021-2022



2021

1- UNIBO (IT) → KIT (DE)

2- IFE (NO) → RTW Aachen (DE)

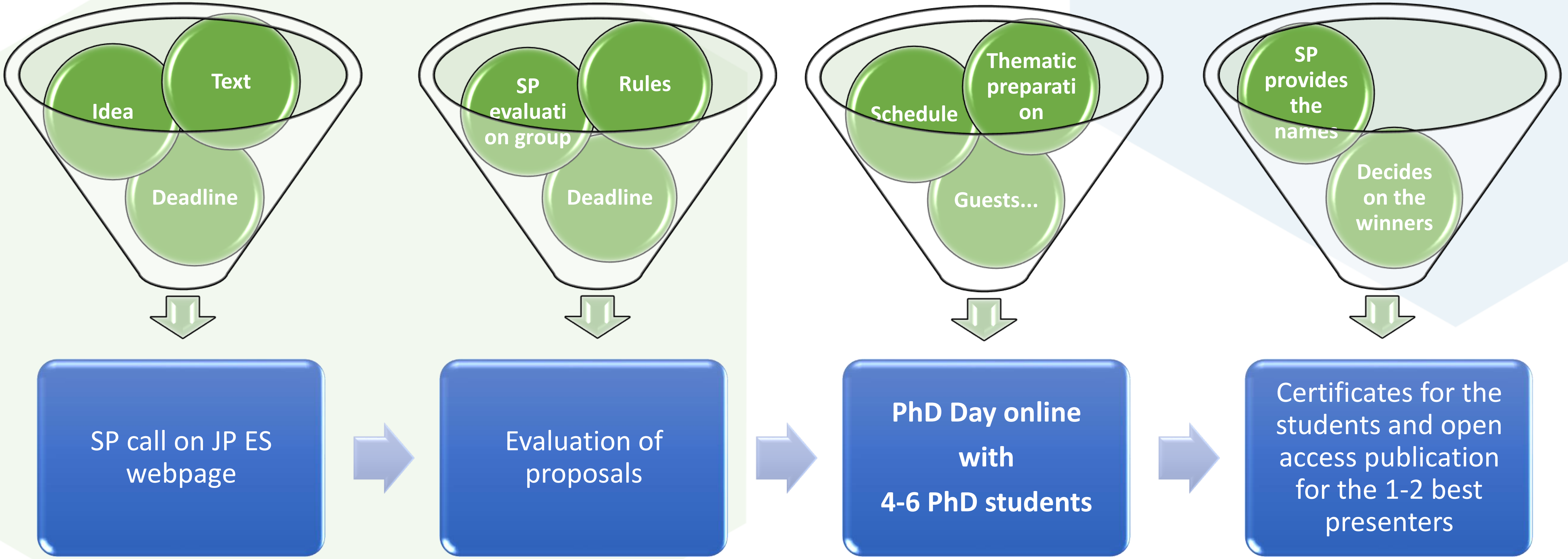
3- UNIPD (IT) → UPM (ES)

2022

4- CNR (IT) → DLR (DE)

EERA European Energy Research Alliance Energy Storage

PhD Days



Support of JP ES management (online publication of the call text, promotion, logistic, preparation of templates, certificates etc.)

EERA European Energy Research Alliance Energy Storage

PhD Days 2021-2022

Best oral presentaiton: €300
+ Open Access publication

Best poster presentation: €200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Energy Storage

EERA JP Energy Storage Award

The young scientist Best Oral Presentation Award
at the 15th International Virtual Conference on Energy Storage (ENERSTOCK 2021)
June 9 – 11, 2021, Ljubljana, Slovenia
has been attributed to

Kai Knobloch

for the presentation entitled
„Vertical rock bed for high temperature energy storage: pilot plant findings"
from the Technical University of Denmark, Lyngby, Denmark

www.eera-energystorage.eu

Prof. Stefano Passerini
EERA JP ES Coordinator

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European Energy Research Alliance
Energy Storage

Stakeholder Workshops 2021

Policy/industry oriented

Technology oriented

Recording and reports at www.eera-energystorage.eu

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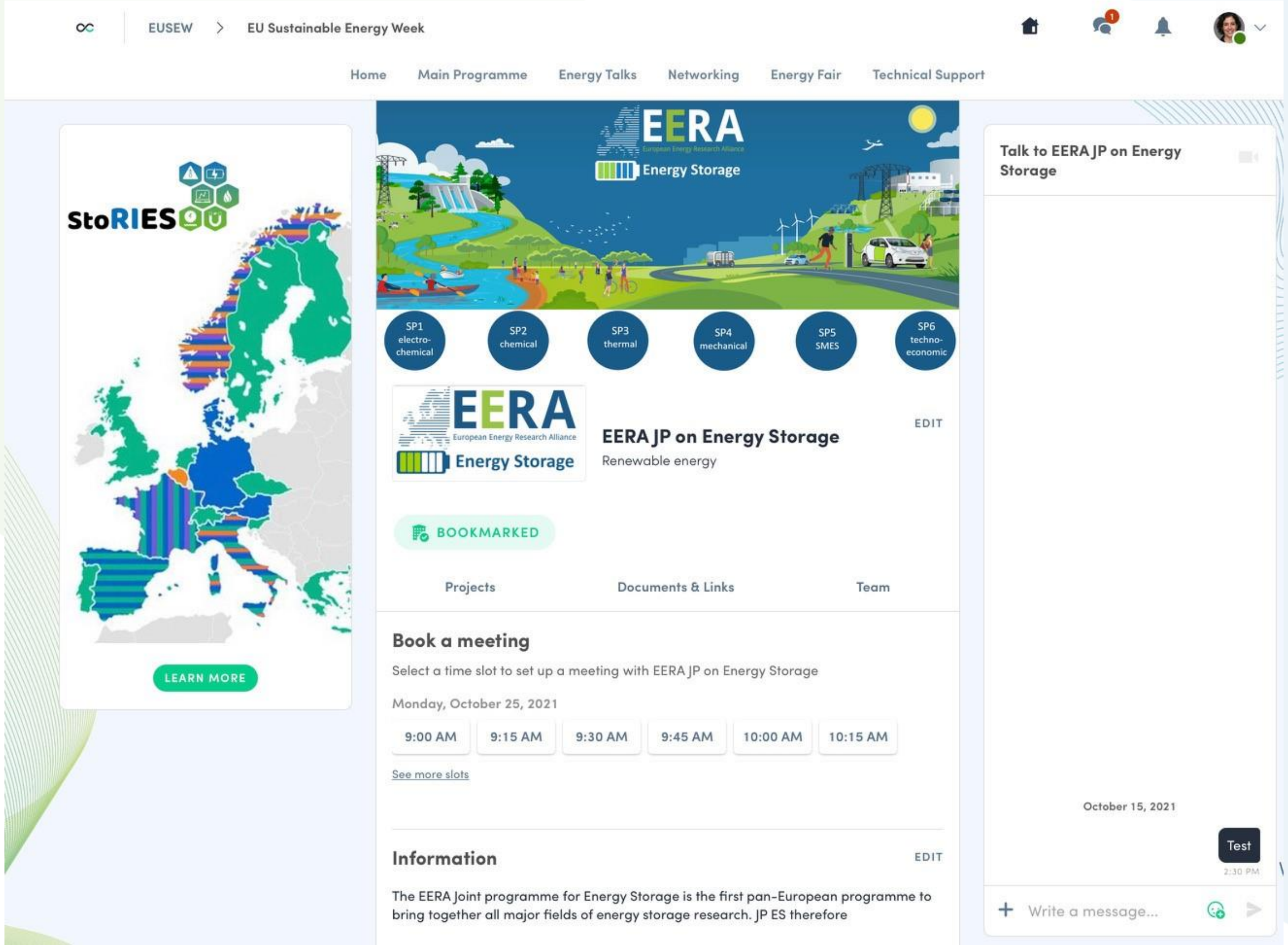
Energy Storage

JPES @EUSEW 2021



[EUSEW Energy Fair]()

SUSTAINABLE ENERGY WEEK
An initiative of the European Commission

StoRIES

THANK YOU

VERY MUCH FOR YOUR ATTENTION

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eera-energystorage.eu

The EERA Joint Programme Fuel Cells and Hydrogen

Stephen McPhail (ENEA)
JP FCH Coordinator

SUPEERA Workshop – 10 May 2022, Padova (ITA)

European Energy Research Alliance

JP FCH – in a nutshell

- 40 Members from 17 countries
- Universities and RTOs: profiles and competence sheets on line
- 7 Sub-Programmes:
  - SP1 Electrolytes
  - SP2 Electrodes & Catalysts
  - SP3 Stacks
  - SP4 Systems
  - SP5 Modelling & Validation
  - SP6 Alternative H2 production
  - SP7 H2 Handling & Storage

https://www.eera-fch.eu

European Energy Research Alliance

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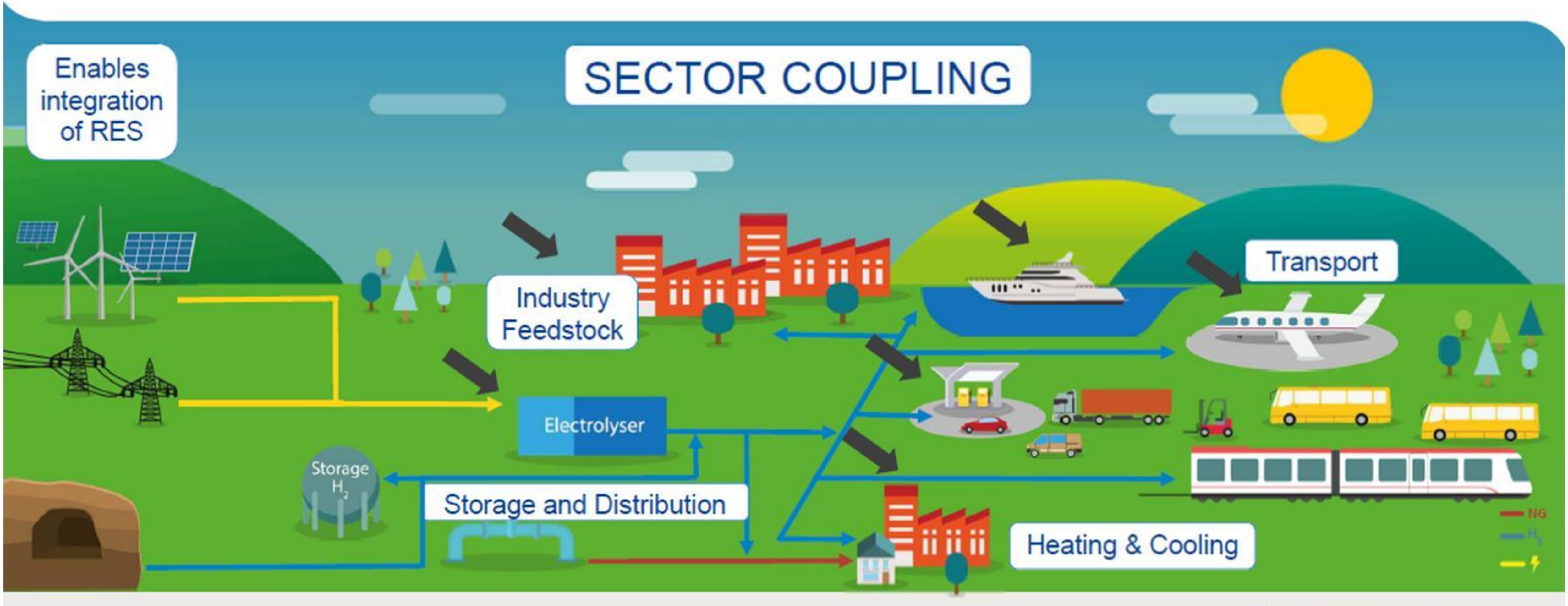
1	Electrolytes	HT Membranes, electrolytes, degradation mechanisms, accelerated testing methods
2	Catalysts & Electrodes	New cat/elect., deposition techniques, membrane assembling, low Pt load
3	Stack materials and Design	Interconnect, bipolar plates, contacting and gas diffusion layers, New sealing materials, novel design
4	Systems	New materials/coatings corrosion resistant, fuel processing and fuel upgrade/clean up, heat management, power conditioning
5	Modelling, Validation and Diagnosis	Cell, stack, system levels:. Models on: kinetic, thermal and water management, non isothermal operations, degradation mechanisms, simulation tools, predictive models for performance and life time, dynamic, control strategies
6	Alternative Hydrogen Production	Thermo chemical; Biochemical; Algae; Photo catalysis; Thermolysis, C&S gap analysis and pre normative research concerning H2 safety
7	Hydrogen Handling & Storage	Compressed and Liquid Hydrogen Storage, Hydrogen carriers, Hydrogen Storage Systems

What it's about: a hydrogen-based economy



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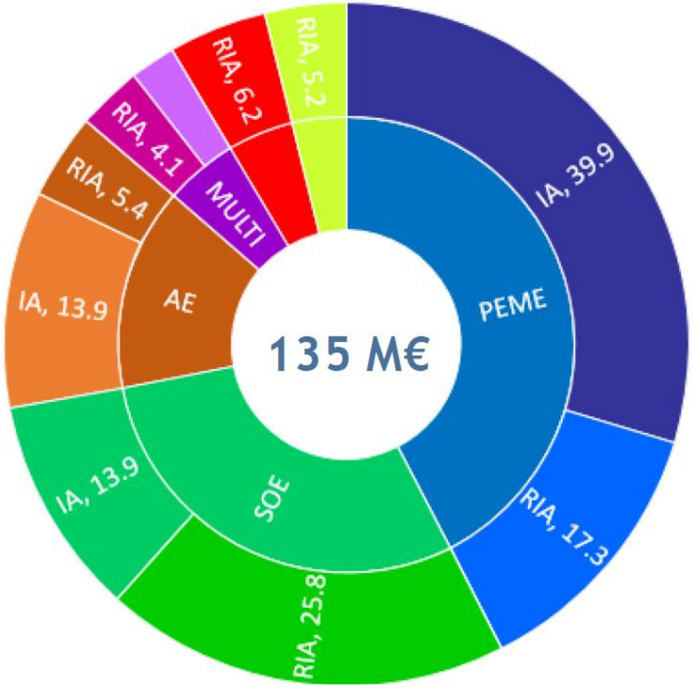
How Research and Innovation drive FCH development

A stable, visionary framework

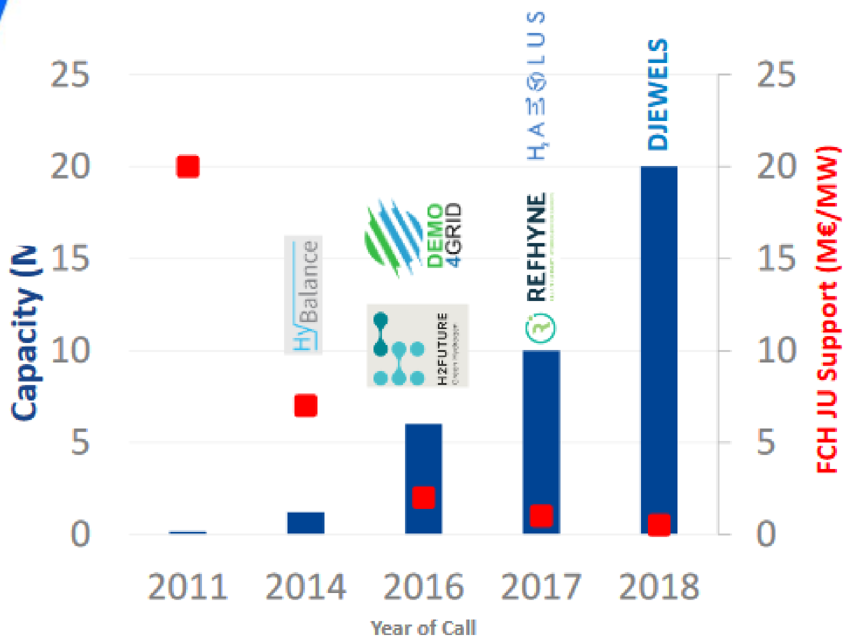
A strong backbone

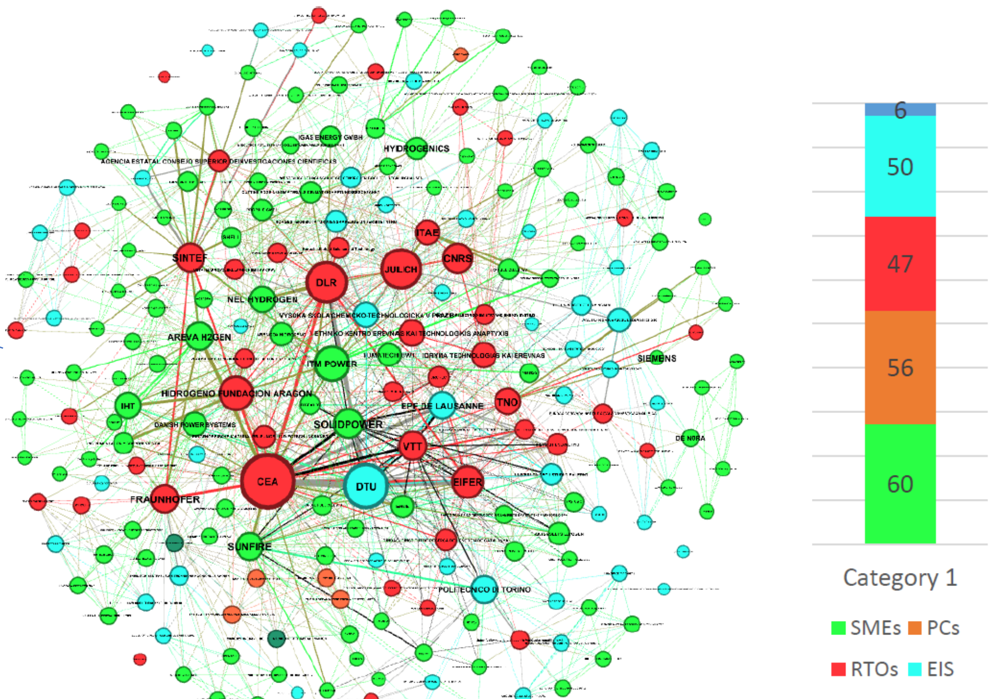
= Investment returns

Electrolysers, M€ FCH JU support



Electrolyser Demo Projects





SOURCE: Safwan Shurieh, 2020
(TNO / TU Delft)

Clean Hydrogen Partnership

EERA European Energy Research Alliance

How Research and Technology Organizations drive FCH development

Clean Hydrogen Partnership

Hydrogen Europe Research

EERA European Energy Research Alliance

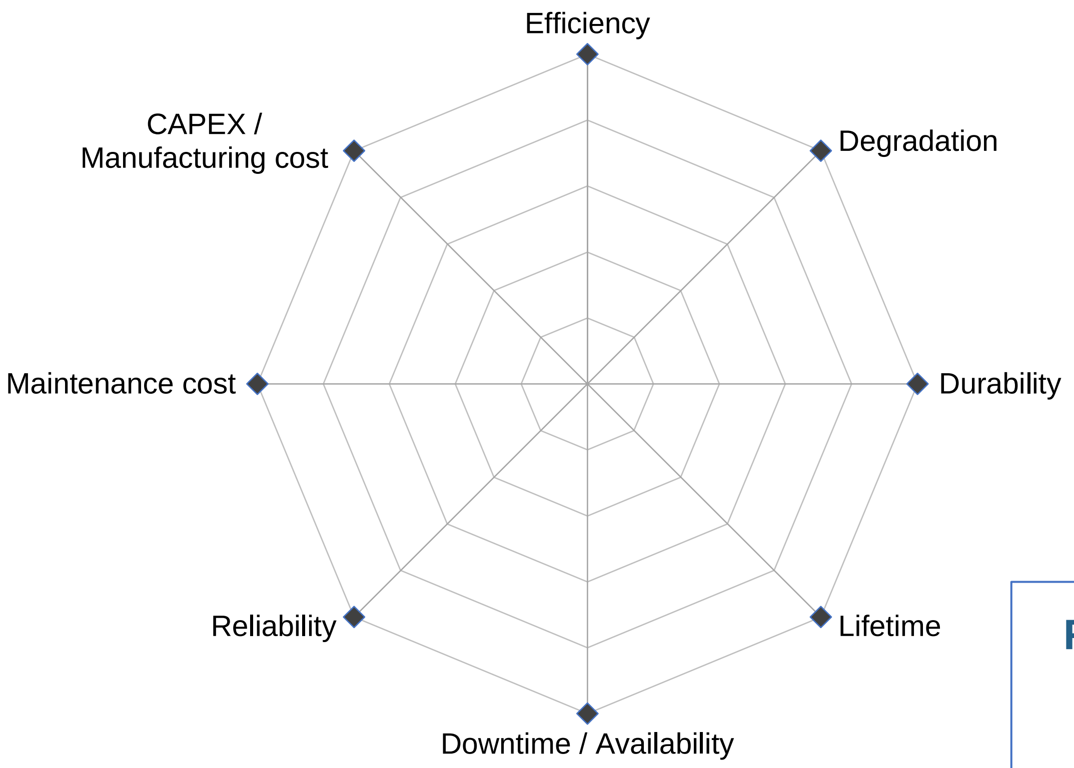
- **CHE** is the funding framework for Europe
  - Projects, studies, strategies, outreach
  - From Research to Demo to Deployment
  - Institutionalised PPP: independent operations with EC monitoring
  - Focused and effective

- **EERA JP FCH** is about talking about research
  - Think tank for the European Commission and DGs
  - FCH within the holistic energy paradigm that is EERA
  - Fertile interactions/events with multiple JPs/disciplines
  - Foot in the door of many programmes rather than one
  - Unhindered by fees and obligations

- **HER** is the Association of all Research players
  - Represents Research and RTOs in FCH JU
  - Direct connection with industry (Hydrogen Europe)
  - Speaks up for low TRL funding
  - Provides topics and rationales for FCH JU annual Calls

EERA European Energy Research Alliance

How Research and Technology Organisations drive FCH development



- **EERA JP FCH** and **Hydrogen Europe Research** collaborate on
  - Setting targets for research
  - Defining Key performance indicators for research
  - Stimulating systematic progress in research

Reference document on KPIs for FCH research

2020-2030

Published 18 September 2020

https://www.eera-fch.eu

JP FCH – Key results

- New logo and own JP FCH web page on line – 17 September 2020
- **Joint publication JP FCH & Hydrogen Europe Research** of **Research KPIs in FCH**: 2020-2030 – 18 September 2020
- 2 editions of the "Scientific Roundtables":
  - **Hydrogen Handling in the Energy Transition** – 28 October 2020
  - **What's next: the Hydrogen Decade** – 10 May 2021

Clean Energy Transition Partnership:

- Contributed to SRIA
- Integrated in White Paper
- Participate in the EERA Hydrogen Expert Group

ERA (European Research Area) Agenda Process

- Initiated dialogue to interact with Member States

Collaborations

- Horizontal: Joint Workshops with:
  - JP Bioenergy
  - JP Energy Storage
  - JP CCS
  - JP Nuclear Materials
  - JP Wind
- Vertical: Interaction with Hydrogen Europe Research (Research Grouping of the *Clean Hydrogen for Europe* Partnership)

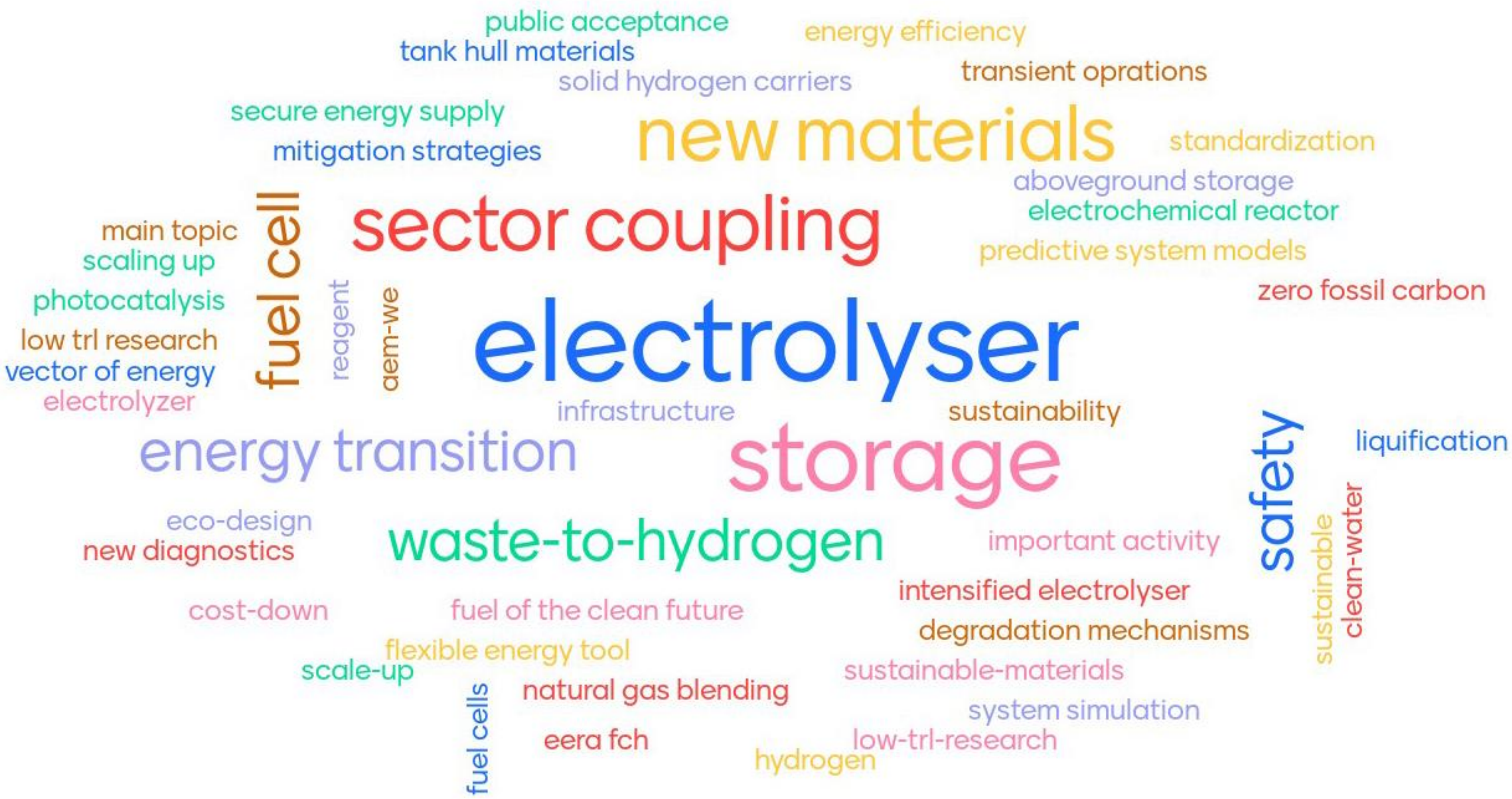
https://www.eera-fch.eu

EERA European Energy Research Alliance

JP FCH – in a nutshell

The Challenge:

To preserve research freedom while maintaining scientific acumen and upholding unbiased investigation into the role of hydrogen in our society



2022 and beyond

- **Ambition to continue as an independent group of scientists, fostering interaction with other JPs, providing ad-hoc contributions to research strategies and work programmes**

EERA European Energy Research Alliance

We love science,
we work solutions

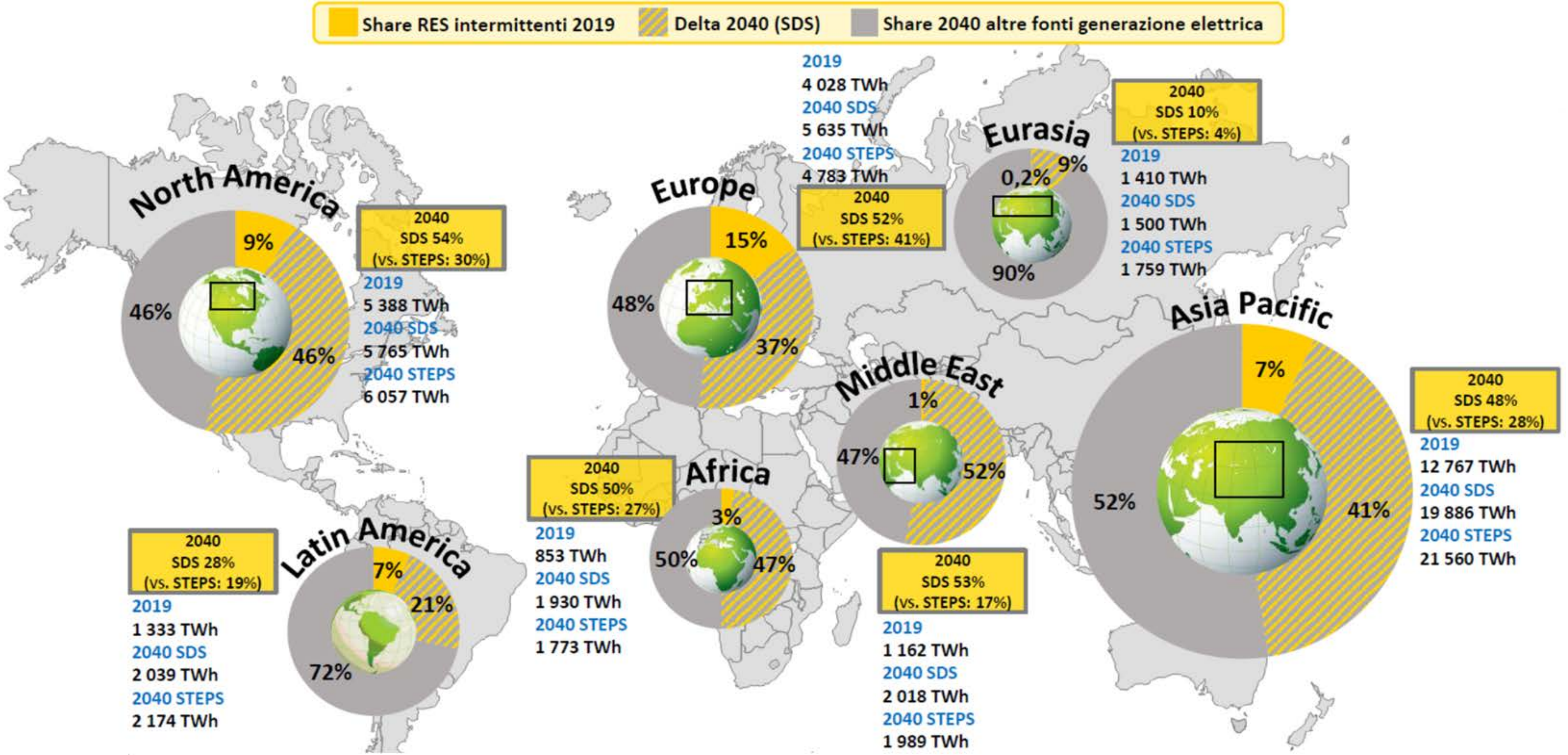
EERA
European Energy Research Alliance

R&I and Open Innovation: Eni's Vision and Approach to Energy Storage

Andrea Bernardi

10th May 2022

The World: outlook on green electrification



- INTERMITTENT SOURCES ON POWER WILL INCREASE FROM THE CURRENT 8% TO 28% BY 2040
- THESE SOURCES REQUIRE THE SUPPORT OF FLEXIBLE SYSTEMS TO ALLOW THEIR INTEGRATION
- THE COST OF THE ASSOCIATED FLEXIBILITY NEED INCREASES

ENI DISTINCTIVE APPROACH

Delivering value through the transition

PROPRIETARY AND BREAKTHROUGH TECHNOLOGIES

expanding a diversified portfolio of decarbonized products

LEADING EDGE
COMPETITIVE
BUILDING SCALE

BOOSTING ENI'S TRANSFORMATION LEADING ENERGY TRANSITION CARBON NEUTRAL BY 2050

Reduce, capture, transform or store CO2, increase energy efficiency, reduce emissions and promote decarbonised energy carriers

NEW BUSINESS MODELS

matching business growth with dedicated leadership team and capital structure

LEANER & FIT
GROWTH &
VALUE-ORIENTED

STAKEHOLDER ALLIANCES

partnering and jointly contributing to an inclusive transition

OUR PEOPLE
CUSTOMERS
INDUSTRIES
CITIZENS

PROPRIETARY AND BREAKTHROUGH TECHNOLOGIES

A portfolio of technologies to meet decarbonized energy needs

RENEWABLES & NEW ENERGIES

MAGNETIC FUSION
ENERGY STORAGE
WAVE ENERGY

on the path to clean and reliable energy

DECARBONIZED SOLUTIONS

CARBON CAPTURE UTILIZATION & STORAGE

deploying safe, easy to apply and cost-effective solutions for CO2 capture, utilization and storage

CIRCULAR & BIO PRODUCTS

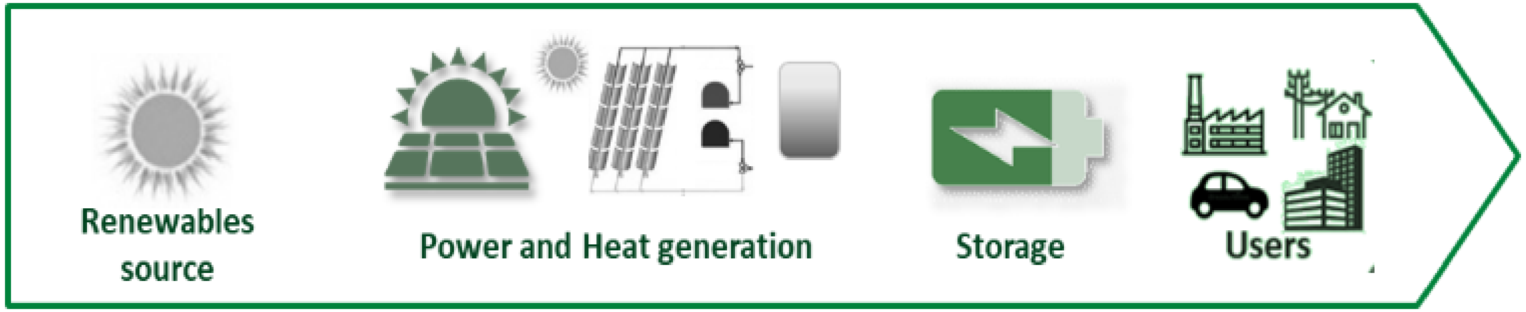
ADVANCED BIOFUELS
BIO-FEEDSTOCK
HYDROGEN
WASTE VALORIZATION

for a rapid transition to low-carbon mobility and circularity

- *Retail market;*
- *Increase REN Role in the energy portfolio;*
- *Smart Charging and e-mobility;*
- *Decabonization of industrial processes;*
- *Decoupling power and thermal generation in CCGT*

plenitude
bepower
eni
eni power

Electrification: an R&I integrated approach to renewables



An integrated approach to encourage the development of renewable energy, supported by energy storage to provide sustainable and reliable energy to retail customers and the grid

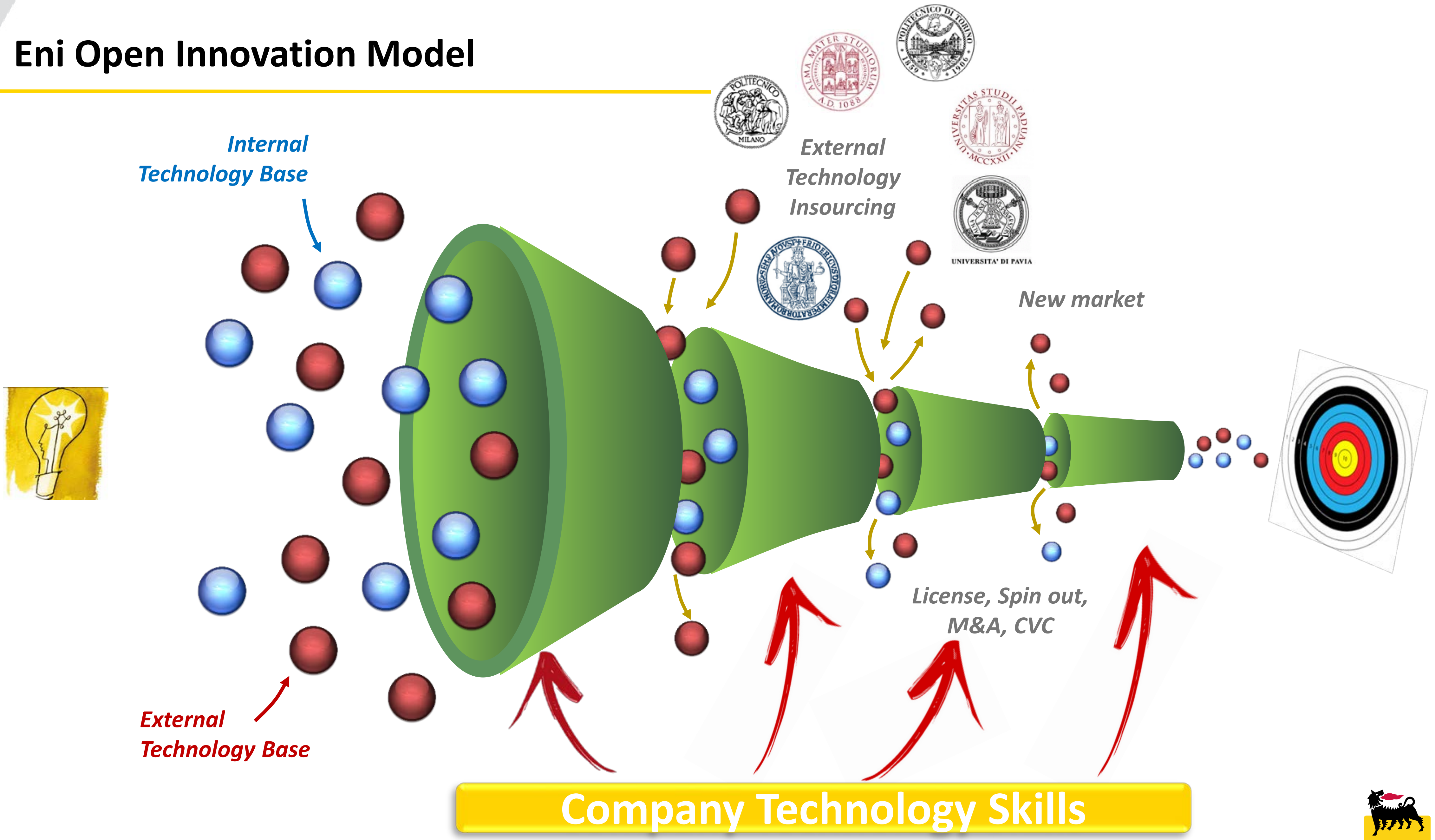
Wave Energy

Concentrating Solar Power

Energy Storage

Asset management

Eni Open Innovation Model



Eni's Industrial Research

R&D CENTERS

7

NETWORK OF COLLABORATIONS

70

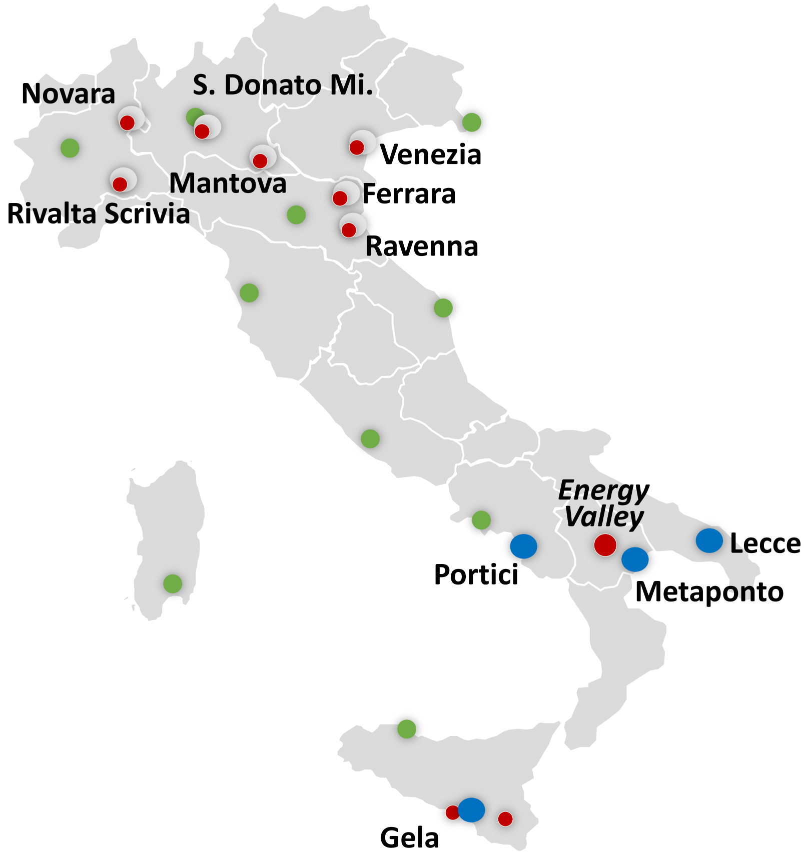
UNIVERSITIES AND RESEARCH CENTRES

COMPUTATIONAL CAPACITY

70

Petaflops/s

FOCUS ON ITALY



- Eni's R&D Centers
- Eni-CNR R&D Centers
- Main universities and research centres*
  - Politecnico di Milano
  - Politecnico di Torino
  - Università di Bologna Alma Mater Studiorum
  - Università degli Studi di Napoli Federico II
  - Università degli Studi di Palermo
  - ENEA
  - INGV
  - CNR
- Application of technologies

*with which Framework Agreements / strategic agreements are in place

Eni’s Renewable Energy Business Need and related R&I Activity

Business Topic	Main business target
Engineering *(new plants)* ***Emerging Technologies*** *(new plants)*	*Improve LCOE* *Longer-life plants*
Procurement & Construction *(new plants)*	*De-risking procurement/FAT* *De-risking Construction/SAT*
Operation & Maintenance *(existing plants)*	*Improve production* *Asset Integrity/Digitalization* *Automation/Unmanned Plants*
Market *(existing plants)*	*Increase revenues*
E.O.L. *(decommissioning/repowering)*	*Sustainability/competitiveness in tenders*

R&I Activity Lines
Adv. Design/Modeling Tools/Practices
Scouting, Tech validation, Eni developments
Quality Infrastructure (tests, scoring methods)
Operational Eccellence & Asset integrity (inspections, analytics)
Dispatch Multiservice Optimization
Recycle/2nd life

Technology development – Redox Flow Batteries

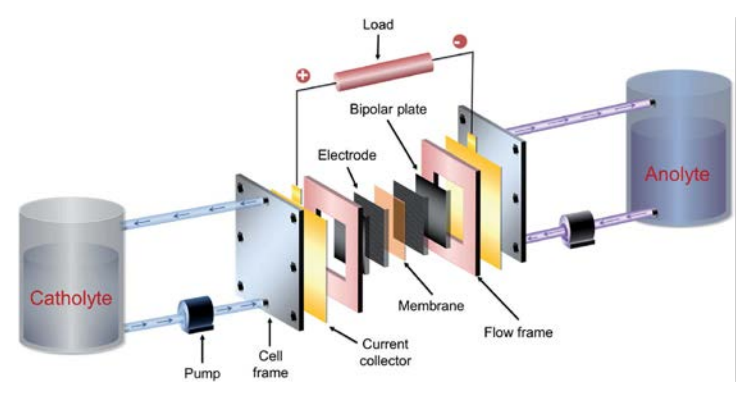
Redox Flow Batteries *use redox reactions for electrical storage. Charged species are stored in separate tanks.*

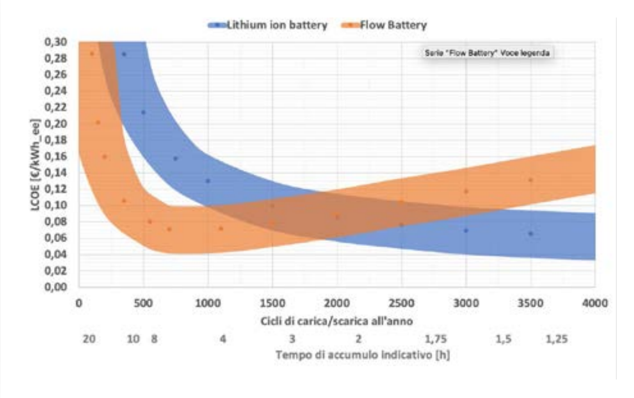
Advantages of the technology

- *Power and energy decoupling;*
- *High safety (negligible self-discharge, no fire safety issues);*
- *Long duration storage (>4h) or high cycling with low loss of performance compared to Li-Ion;*
- *LCOE lower than Li-Ion batteries for Energy intensive applications*
- *High recyclability*

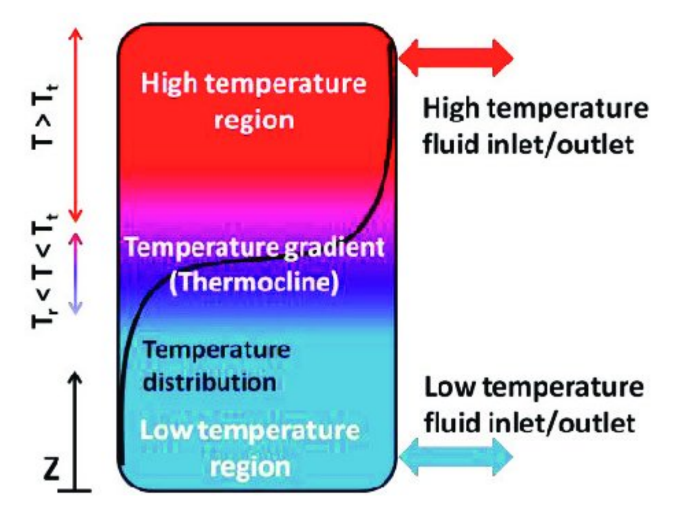
Eni's R&I activity on Redox Flow Batteries

- *Increase of performance by the development of new membranes, electrolytes and electrodes;*
- *Development of new generation of RFB (based on organic materials);*
- *Network with different universities and technological partnership with external companies.*





Technology development – Concrete based Thermal Energy Storage



Thermal storage system for medium/high temperatures (250° - 550°C) using ***concrete*** *for energy storage* ***in direct contact with the heat transfer fluid****.*

The system is based on a ***thermocline*** *that allows to overcome the use of two tanks ad different temperature to store heat.*

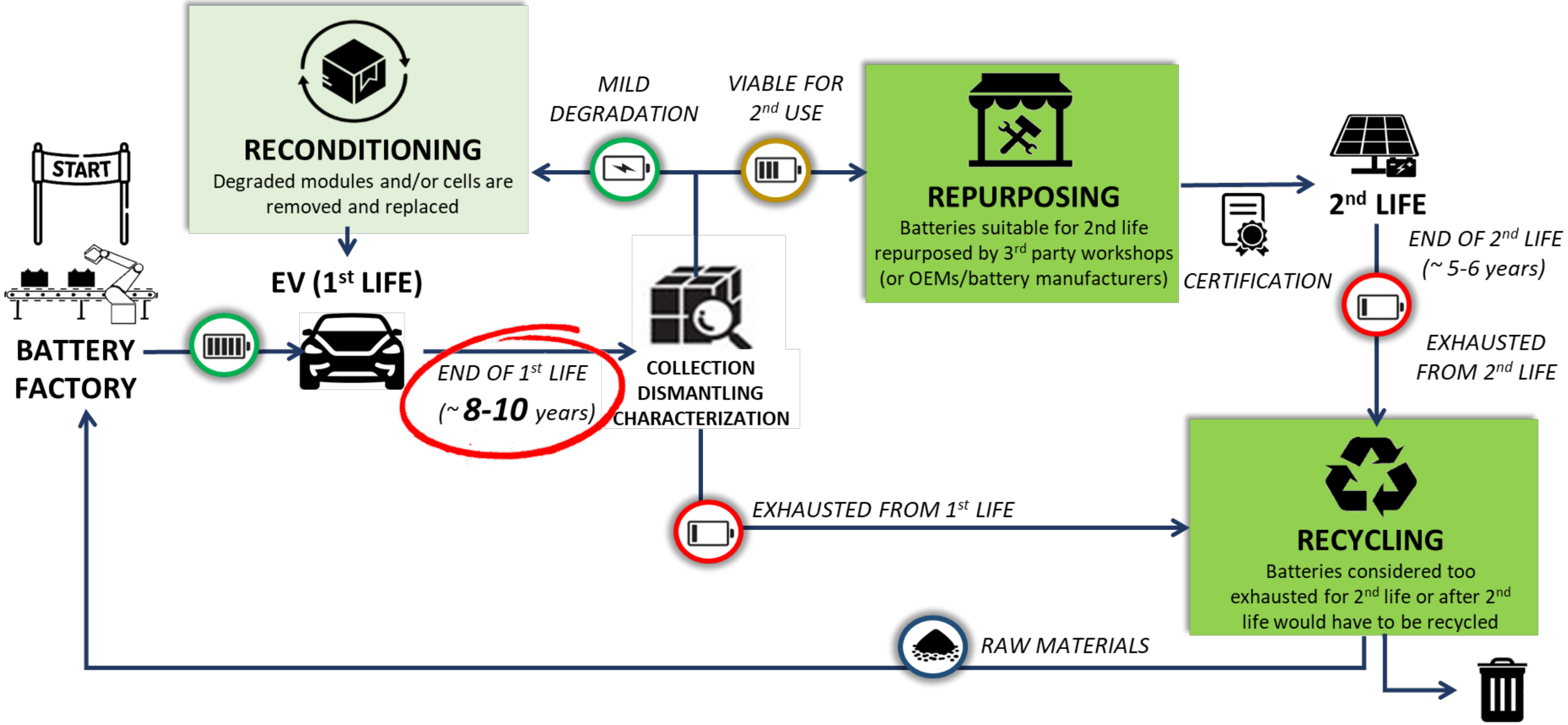
Advantages of the technology

- *Simplification of the plant design;*
- *Abundant, low-cost and non-toxic materials;*
- *Modular system, also suitable for small/medium sizes;*

Eni's R&I activity on Redox Flow Batteries

- *40 kWth prototype tested at lab scale in Eni's laboratories;*
- *A new design has been proposed based on experimental results;*
- *Experimental validation of manufacturing process for the new concept is ongoing;*
- *A technological partner from the cement industry has been involved in prototyping the new system.*

Technology development – Li-Ion batteries repurposing/recycling

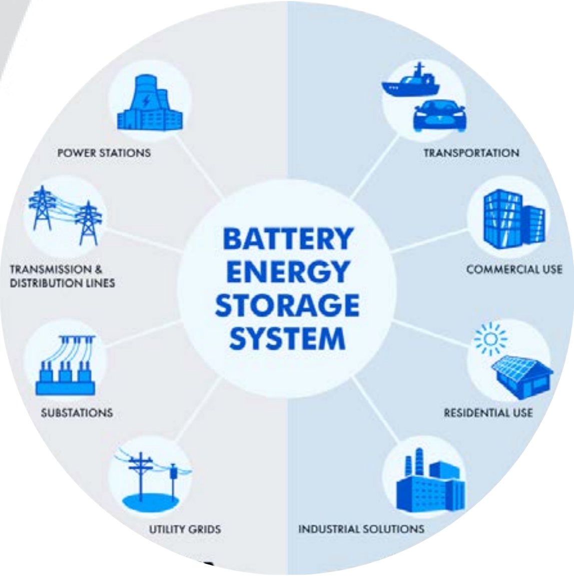


***Li-Ion batteries from EV** sector have up to 80% residual capacity and can be **reused** in different sectors, or can be **recycled** to recover high value materials contained inside (Li, Co, Al, Cu, ecc.).*

Eni's R&I activity on Recycling/Repurposing of Li-Ion Batteries

- *Support the process of repurposing for second life batteries;*
- *Develop new and more sustainable recycling processes able to separate high value materials from black mass;*
- *A variety of competences is needed: Strong partnership with achademia and technology providers is necessary to reduce the time to market.*

Eni R&D activities: Battery Energy Storage System Modeling & Monitoring



*A **technical and economical modeling** system to support Eni's Business in designing and monitoring Battery energy Storage Systems. The system integrate a priori data and data coming from operation to generate a digital twin of BESS.*

Technical Need

- *Define optimal BESS layout for grid services and/or support renewable generation.*
- *Get reliable data (performances and degradation) on operative battery technology.*

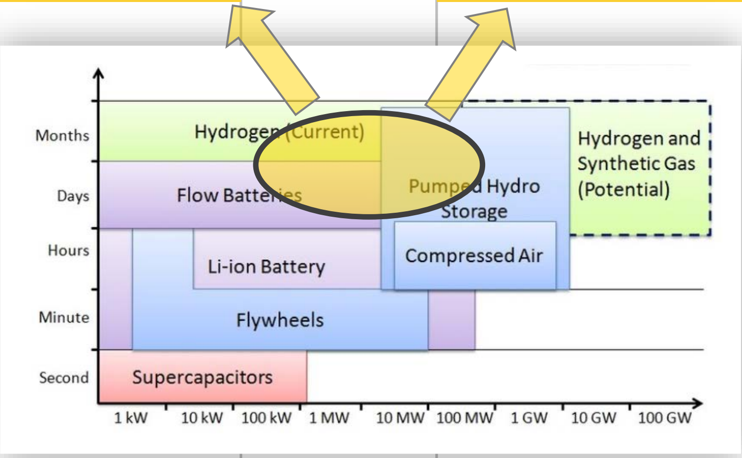
Output

- *Develop BESS numerical models*
- *Develop a test protocol for BESS.*

R&D Project born and run within Eni-Politechnic of Milan Joint Research Center.

Eni's CVC investments in Energy Storage

FORM ENERGY



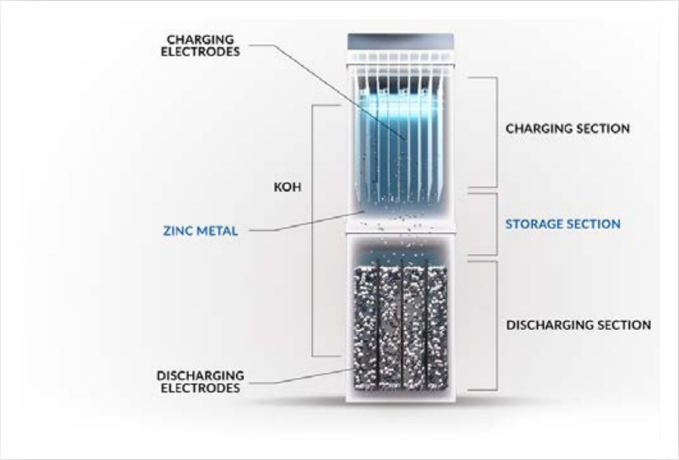
*Founded in **2017: Boston** (USA) MIT spin-out.*

Iron-air battery suitable for multi-day energy storage that will enable the grid to run on low-cost renewables year-round.

- *Suitable for **multi day Energy storage**;*
- *Low cost;*
- *Abundant materials;*
- *High modularity, suitable to ba scaled to GW scale.*

*Form Energy closed a **$40 million Series B** financing round led by Eni Next LLC (2019).*

E-ZINC



*Founded in **2012**: **Toronto** (Canada).*

Energy stored within zinc metal, the system can store hundreds of hours of energy capacity. Significantly cheaper than Li-Ion batteries.

- *Suitable for **long duration** Stotrage;*
- *Power and Energy decoupling;*
- *Low cost;*
- *Low self discharge;*
- *Modularity*

*Eni participated to a **25M$ Round A** investment (2022).*

Conclusions

Eni is committed to become **fully carbon neutral by 2050**

Energy storage will be one of the **pillar** of the decarbonization strategy

Electrochemical storage will give its contribution

Lithium is the **leading technology** and, nowadays, **the most cost effective** for a very wide range of applications

Eni has a **'technology neutral'** approach which make not always easy to bring to market innovative technologies

R&D activities in Eni leverage internal **know-how** and a **network** of Italian and international universities and Research Centers to support strategic targests in an open innovation model.

Funding and **financing** are financial tools to bridge the cost gap supporting the adoption of new technologies.

Eni pursues business goals also trough its Corporate Venture Capital vehicle (**Eninext**)

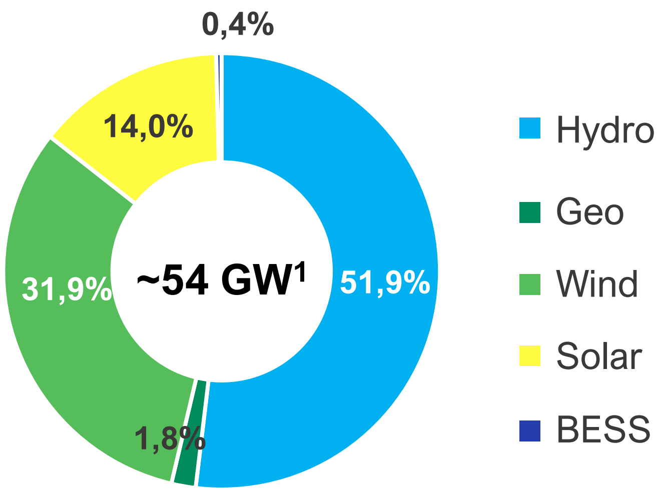
How to foster green hydrogen competitiveness with an Open Innovation Approach: the NextHy Initiative

10h May 2022

enel Green Power

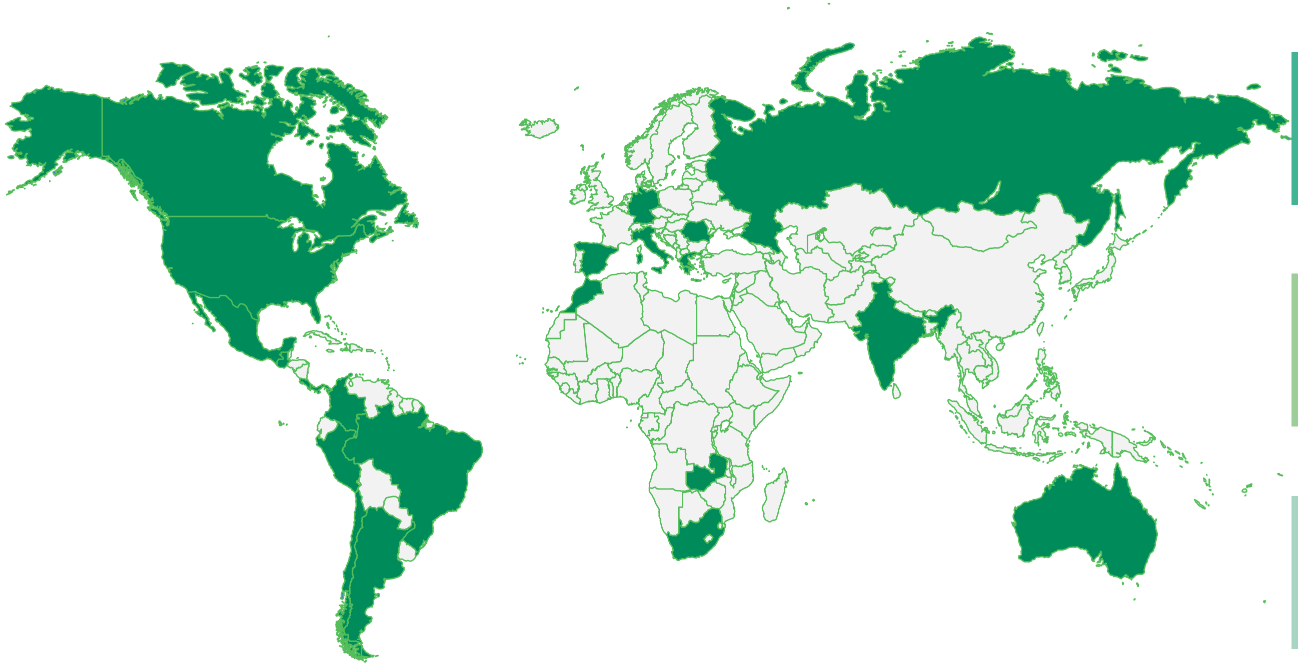
Green Power

Enel Green Power to foster renewable penetration …



2021 Installed RES Capacity[1] (GW)

of which 220MW BESS



~1.2k plants

22 Countries[2]

~15k employees

A global presence and a differentiated portfolio

1. Including managed capacity by 3.3 GW
2. Countries with assets in operation or under construction

Enel vision on Hydrogen

enel Green Power

Electrification is the most efficient tool to decarbonize large portions of final energy uses

Hydrogen is best used as a complement to electrification

Hydrogen needs to be renewable, fed by 100% renewable power

Sharp decrease in costs will make green hydrogen competitive

Green Hydrogen as a complement to electrification

Purpose

Accelerate green hydrogen entry and massive adoption in the market to foster decarbonization of our society, creating a bridge from labs to field operation

Barriers to adoption

Technology

- Efficiency and sustainability improvement
- CAPEX and OPEX reduction
- Enlargement of viable technologies
- Quick scale-up of the best solutions

Integration

- Optimal integration schemes with renewable plants to improve efficiency and effective enable grid-support services

Policy/Regulation

- Clear and well-designed **market** and **technical rules** to enable fast authorization process while guaranteeing high safety standards

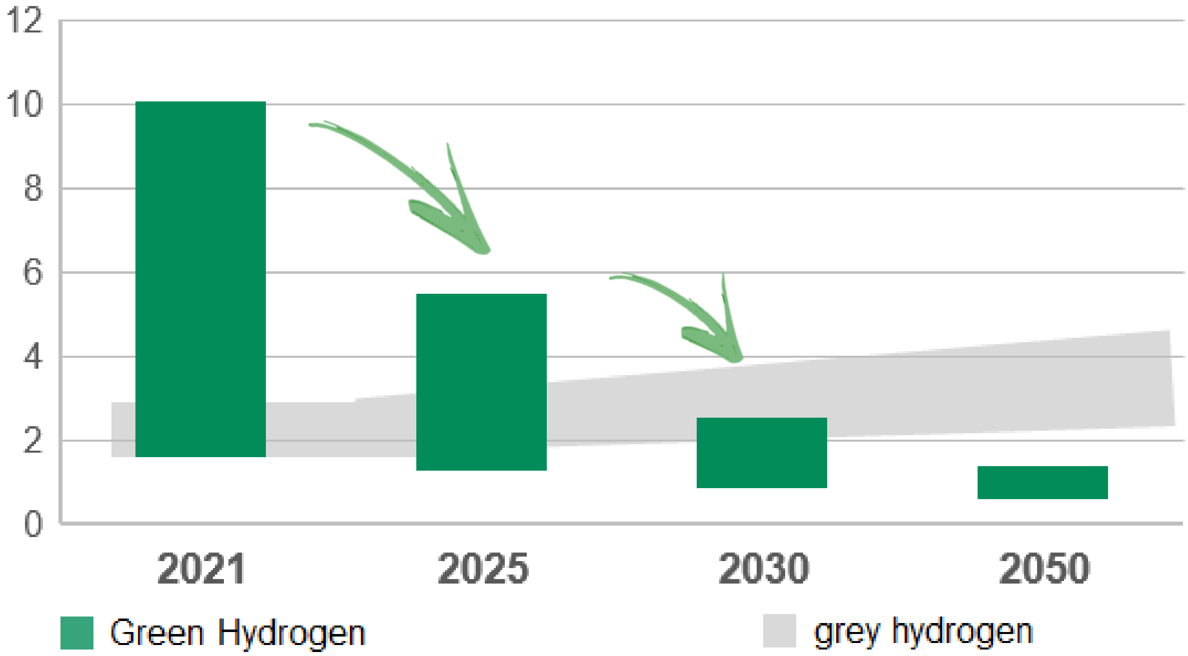
Awareness

- Promote awareness of how H2 may support industry decarbonization
- Foster public support for green hydrogen
- Prevent NIMBY effects

Green H_2 has the potential to become the cheapest option by 2030 …

Green Power

Production Costs of Hydrogen (LCOH, $/kg)[1]



Sources: 1.BNEF

To allow competitiveness of green hydrogen, the **cost and the efficiency of electrolysers will need to improve consistently:**

PV and batteries success story (2010-2020)[2]

	Cost Reduction	Efficiency Increase
PV	9X	**+31%** capacity factor[1]
Batteries	9X	**+49%** energy density[2] Wh/Kg

… but together with module size and manufacturing scale increase, a strong effort in technology innovation is required

We are launching NextHy, an Industrial Platform to bridge Innovation Ecosystem and Industry

Green Power

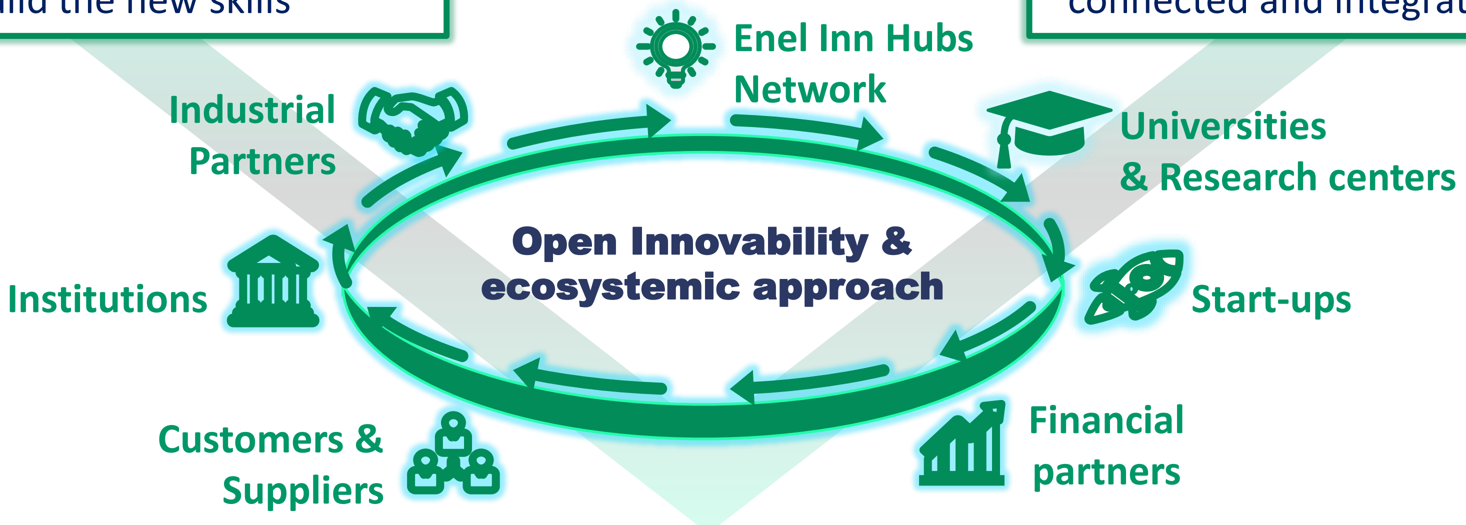
Catania Innovation Hub

- **2000** sqm offices
- **30.000+** sqm labs

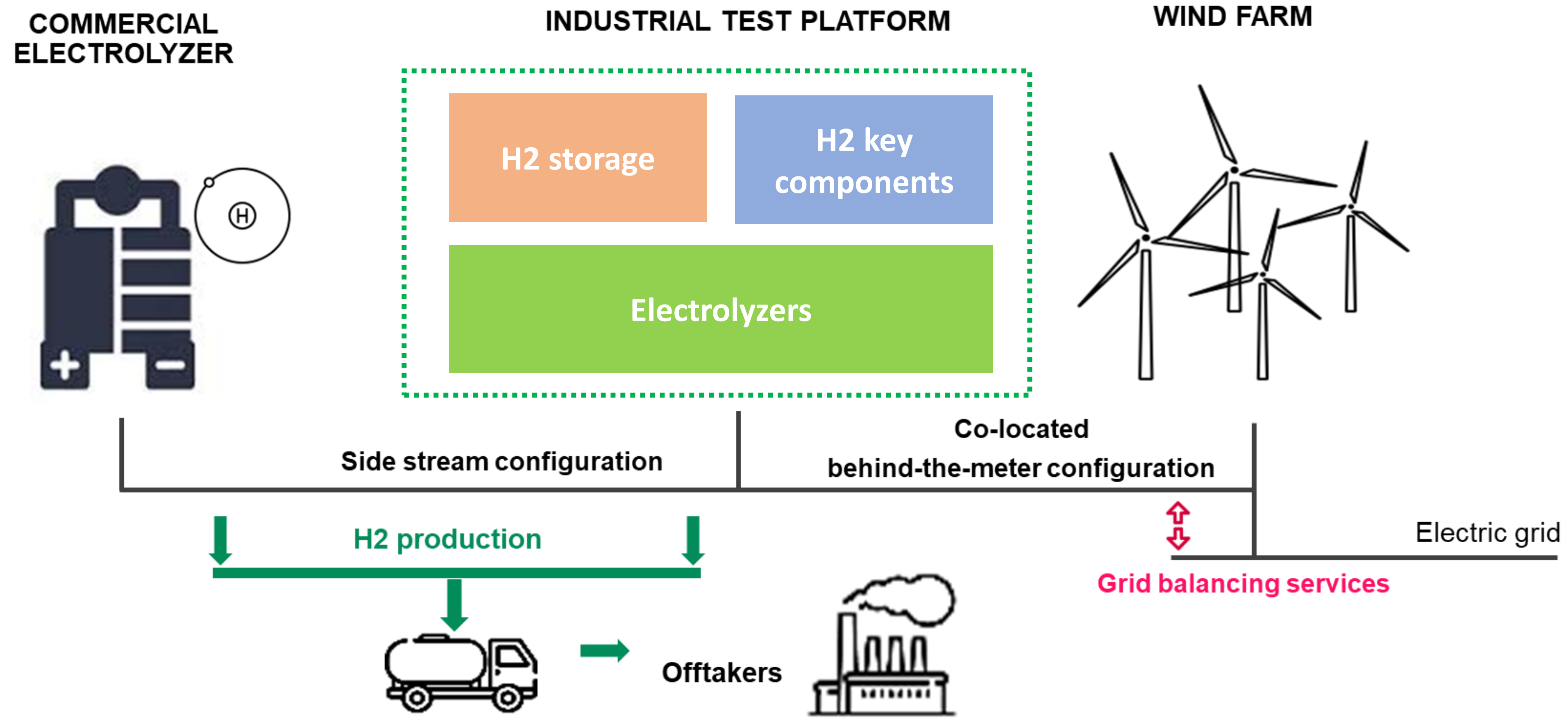
- **Scouting** and host-site for **start-ups**
- **Ecosystem** engagement and **development**
- **Webinars & events** w. experts & stakeholders
- **Training courses** to build the new skills

Hydrogen Industrial Lab

A **unique infrastructure** enabling the test of multiple emerging technologies in a **fully industrially representative configuration**, grid connected and integrated with a wind farm



We are launching NextHy, a bridge between Innovators and Industry



Pre-selected for IPCEI
Construction completion and operation start within 2023

Why Hydrogen Lab in Sicily

- Proximity to **industrial clusters** (off-takers)
- Presence of **scientific excellence on hydrogen research**
- **Sicily Region** has **ambitious plan** on **green hydrogen**

Platform Innovation focuses

Green hydrogen generation, storage, delivery and BOP components

Real Industrial environment

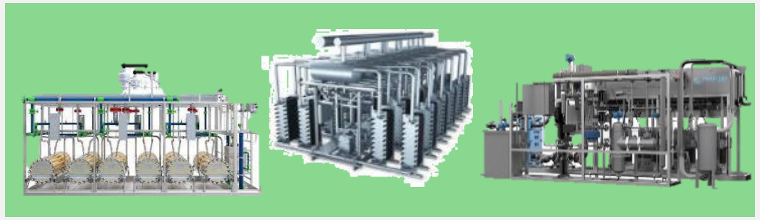
RES directly fed

Grid integrated (balancing)

H_2 to end users

Industrial Electrolyzers

TRL 7÷9 - Up to 3MW
3 systems up to **1MW each** for full scale electrolysis systems



Pre-Industrial Electrolyzers

TRL 5÷7 - Up to 300kW
4 stacks up to **100 kW each** for small scale innovative electrolyzers

BESS

1MW/1MWh
to test hybrid configuration also for **grid services**

H2

H2

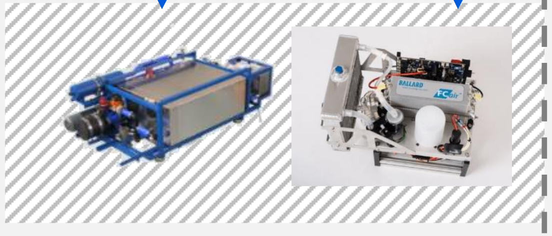
only infrastructure set-up in first phase

H_2 Storages Lab

Capacity up to 500kg H2

H_2 Components Lab

Valves, Instruments, Compressors,



Fuel cells only for industries

we continue to strive to build a more

sustainable

world through

innovation

Thank you

enel

Systemic and cross-sectorial issues pertaining to the Clean Energy Transition

Spyridon Pantelis, EERA,
Project Manager

Background

- → A template for **identification** and **categorisation** of cross-cutting issues in energy
- → Coordinated input to **decision-makers** for addressing systemic and cross sectorial solutions in the energy sector to support the **Clean Energy Transition**
- → Initial mapping of **existing cross-cutting** and interdisciplinary **topics** – both technological and non-technological - and related activities in the SET Plan Implementation Plans

Goal

- → Help to improve a conceptual framework for planning technological solutions for the Clean Energy Transition

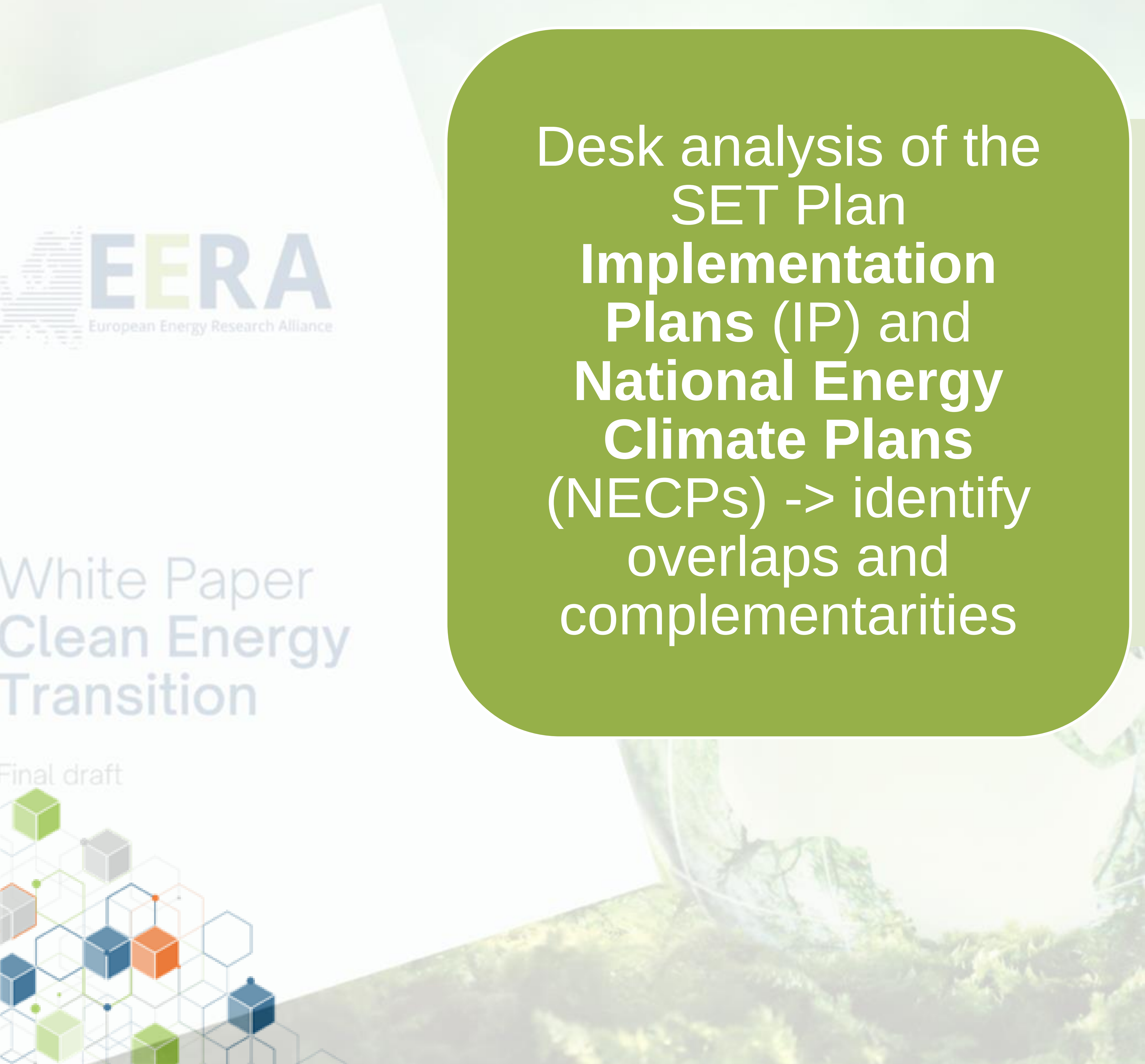
Why it is needed?

Provide a context for the Clean Energy Transition planning beyond specific technologies

Ensure that the clean energy transitions are designed with the **systems-thinking approach** (key element for socio-technical transformations)

In line with the current **European and global agendas** (e.g. European Green Deal, SDGs) - Impossible to achieve with a purely techno-centric mindset and without taking into consideration the cross-cutting aspects

Methodology



Desk analysis of the SET Plan **Implementation Plans** (IP) and **National Energy Climate Plans** (NECPs) -> identify overlaps and complementarities

List of categories and sub-categories for classifying in a more specific way the cross-cutting issues (other sources: CETP SRIA & EERA White Paper on the Clean Energy Transition)

Feedback from the EERA Joint Programme Coordinators

Technological cross-cutting topics

Technological cross-cutting topics

- Energy efficiency
- Energy System Integration
- High temperature & advanced materials
- Energy storage
- Digitization

Non-technological cross-cutting topics

Non-technological cross-cutting topics

- Education & training
- Policy & regulation
- R&I funding programmes & measures
- Social awareness, acceptance, engagement
- Standardization
- International cooperation

How it can be used?

- The template does **not** aim to serve as **an exhaustive list** of the technological and nontechnological cross-cutting topics
- **Preliminary exercise** that can be elaborated further to eventually provide a universal framework
- Be used for developing **energy** and **climate transition plans**

Energy sector asks for more cross-sectorial cooperation!

For more information, click here to download the report

Thanks
Spyridon Pantelis
EERA
Email: s.pantelis@eera-set.eu

energy to inspire the world

Snam's strategy for Hydrogen

The infrastructure role as enabler of hydrogen value chain

SUPEERA Padua 10th May 2022

Dina Lanzi, Head of Technical Hydrogen Unit, **SNAM**

snam

energy to inspire the world

Agenda

Snam as a player in the energy sector

Hydrogen Strategy

Snam as a player in the energy sector

energy to inspire the world

Snam is one of the main global energy infrastructure company

Key figures

€ 22.6 bn RAB + affiliates ('19)	**€ 28 bn** Enterprise Value	**1.1%** Debt cost
€ 1.093 m Net Profit Adj ('19)	**~ € 15 bn** Market Cap	**BBB+** Rating

snam

cdp CDP Reti

69.7%

Free float
~80K investors

International associates

Trans Austria Gasleitung
TERĒGA
Trans Adriatic Pipeline
GAS CONNECT AUSTRIA
Interconnector
DESFA
albgaz
Snam Beijing Gas & Energy Services
ADNOC

Natural gas[1]

Transport	Storage	Regasification
~41,700 km	~20 bcm capacity	~20 bcm/y capacity

BU Hydrogen

Snam4 Mobility

Snam4 Environment

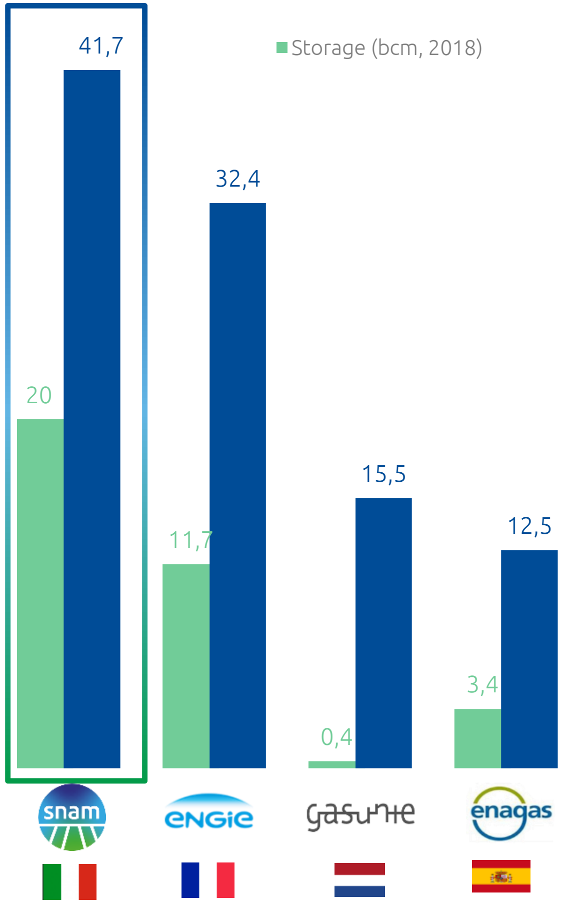
Snam4 Efficiency

ARBOLIA

snam **energy** to inspire the world

[1]Italy and international associates

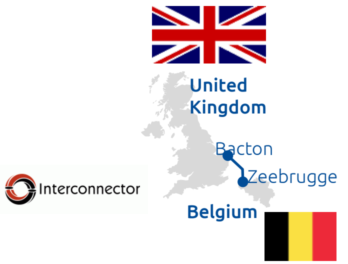
Undisputed leader in the natural gas infrastructure



3/3 Our regasification terminals in Italy

NOTE: Data referred to Snam and its subsidiaries (Teréga, TAP, IUK, TAG, Desfa). Countries are France, Austria, Belgium, UK, Greece, Italy. (Source: Snam)

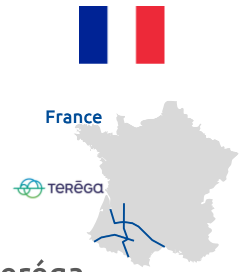
2012



Interconnector

Bidirectional underwater gas pipeline of 235 km linking United Kingdom and Belgium

2013



Teréga

Trasmission (~5.000 km of network) and storage (2,8 BCM) in south west of Francia

2014

TAG

Gas pipeline (~1.140 km) transporting Russian gas to Italy through Austria

2015

TAP

Mediterranean corridor last section transporting azeri gas to European pipeline (878 km) connecting Greece to Italy

2016

GCA

Transport and distribution network (564 + 322 km) in Austria connecting Germany, Hungary, Slovenia e Slovakia

2018

DESFA

Snam, Enagas, Fluxys acquisition of Desfa 66% share, Greek gas infrastructure operator

2020

ADNOC

Only industrial industrial within 49% share of ADNOC Gas Pipelines, controlled by ADNOC

snam **energy** to inspire the world

Snam owns 100% of Panigaglia LNG terminal and 7.3% of Adriatic LNG

*On 26th Feb 2020, Snam completed the acquisition from Iren Group of a 49,07% stake in the share capital of OLT Offshore regasification terminal

Hydrogen strategy

energy to inspire the world

The role of hydrogen in the decarbonization

HYDROGEN

The «colours» of hydrogen

«Grey» Hydrogen	«Blue» Hydrogen	«Green» Hydrogen
Natural gas is separated into hydrogen and carbon dioxide (CO2)	Natural gas is separated into hydrogen and carbon dioxide (CO2). The carbon dioxide is stored and reused	Water is separated into hydrogen and oxygen molecules thanks to the use of electricity from renewable sources
CO_2 emitted into the atmosphere	**CO_2 captured and reused**	**No CO_2 emitted**

Why hydrogen?

- It can be produced **carbon-neutrally** through RES and can **support the development of a decarbonised economy**
- It can be used **to transport and store energy**, but also in **end uses**. Will enable **sector coupling**
- Can be used in **existing infrastructure**

BU Hydrogen

Created in 2019, Snam BUH2 is focused on different kind of activities: **scouting of hydrogen-related technologies, designing of innovative business models** and **definition of business cases** for the utilization of hydrogen in different sectors: mobility, industry, energy, services

H2 for Sector coupling and RES integration

Solutions for innovative utilities and sector coupling

H2 for Industry

Supply for green industrial processes

H2 for Transportation

Solutions for sustainable mobility systems

H2 for Commercial Use

Supply for green industrial processes

energy to inspire the world

snam

Snam's pillar for hydrogen development

HYDROGEN

1. Asset Readiness

- **Pipelines:** network is largely hydrogen ready, key reason to underpin replacement
- **Components:** gas chromatographs and other minor instruments would need replacing (<1% RAB)
- **Gas compressor units:** testing the impact of a 5-10% blend
- **Geological storage sites:** ongoing analysis and research
- Ongoing assessment of use of **membranes to separate NG and H2** out of NGH2 blend

Negligible investment to reach
5-10% NGH2 readiness
Ongoing investment in the grid «Hy-ready»

2. System design

- **Long-term scenarios:** Expected key role of hydrogen in the energy mix
- **Grid evolution:** Development of pathway analyses with increasing share of green gasses
- **Technical standards:** involvement in focus groups to develop common rules on H2 in Italy and Europe

Ongoing work to support
long-term grid planning

3. Value chain development

- Evaluating potential opportunities/pilot projects to scale up clean H2 production and use
- **Partnership** with other operators of the value chain
- Scouting for promising **technologies**

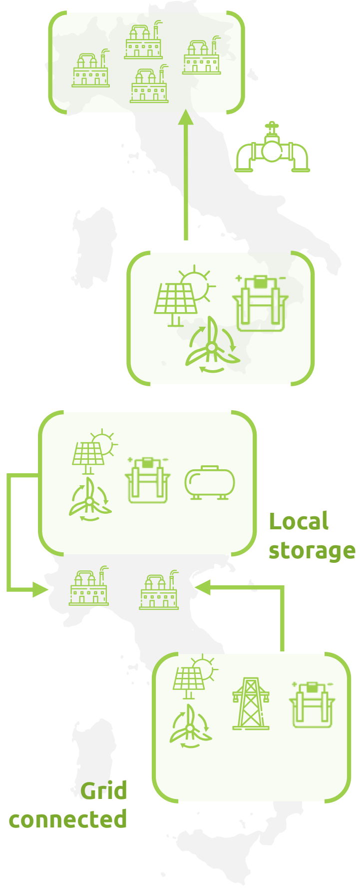
Scouting the market for investment
opportunities and partnership

Snam as an Enabler

energy to inspire the world

snam

Pipelines will be required to carry hydrogen to create an efficient system



Delivered cost in 2030, €/kg: Production; Storage and transport

Archetype	Delivered cost in 2030, €/kg	Production	Transport & Storage	Security of supply
Centralized H2 pipeline	2 - 4	Low-cost RES Economies of scale for H2 production	Existing natural gas pipelines can be repurposed Optimized storage requirements	Large scale production and storage sites spread over large areas Enables import from different routes
Decentralized Local storage	4 - 10[1]	High cost RES: small, low productivity RES No economies of scale for H2 production	High cost of decentralized storage to balance seasonality	Requires local and non-optimal backup solutions
Decentralized Grid connected	6 - 9[2]	Grid power needs 100% green resources No economies of scale for H2 production	High transport cost due to electricity grid fees	Depends only on electricity network

1. Lower bound considering daily storage to manage intermittency – Upper bound considering monthly storage.
2. Lower bound considering 60% power from grid and 40% from RES – Upper bound considering 100% power from grid.

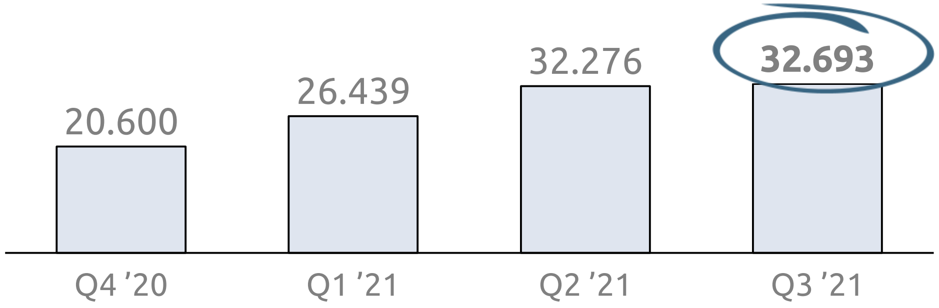
Source: Snam team analysis.

Energy networks

Snam pipelines are verified for H2 transport

100% of Snam network verified for H2 transport

(km, cumulated)



Snam network verified according to ASME regulation

≈ 99% of the network

is ready[1] to transport 100% H2

70% with no or limited reductions on max operating pressure.

Future revisions of the technical standards are expected to overcome limitations

Setting standards for H2 transport

RINA

First example in EU of network H2 readiness certification

H2GAR

H2 Gas Assets Readiness

Co-operation with other European TSOs to share test results, analysis, studies

enagas GRTgaz OGE

Collaborations with universities and institutions

Collaboration with fire department and universities to develop technical standards for H2 transport

energy to inspire the world

snam

1. Based on Option A of ASME B31.12.

10Y view: deliver first section of H2 backbone

Energy networks

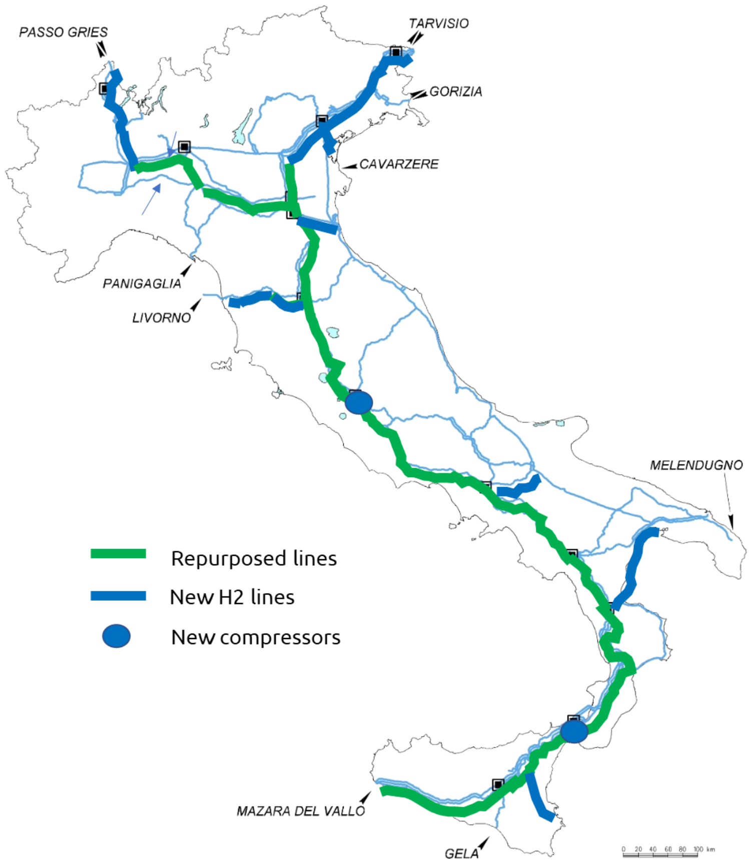
H2 backbone

Ca 2,700km of H2 network to bring production from north Africa and Southern Italy to consumption areas

- **75%** of km from repurposing
- **50MW** for compression stations to ensure suitable pressures on the network

Key figures

- Cost of repurposing **ca €0.6m** per km
- Cost of new build **ca €2m** per km



Ca €3bn

Cumulated capex 2021-2030

Premium regulated

Return expected

Our project for an Italian H2 backbone

The European Hydrogen Backbone: a vision for a truly interconnected H_2 market for Europe

- The European Hydrogen Backbone (EHB) is **a pan-European dedicated hydrogen pipeline transport network**, connecting hydrogen supply and demand at an international level and create a EU market
- **23 gas infrastructure companies** from **21 countries**
- Total network length of ca. **40.000 km**
- Estimated total **investment cost of € 43-81 billion by 2040**, optimized by asset repurposing:
    - **69% of repurposed natural gas pipelines**
    - 31% new pipeline stretches
- **First local networks announced in Germany, Netherlands, UK** enabling also low-carbon gas production projects
- A connected network enables market **liquidity**, **flexibility** and **security** of supply, low cost **import**, access to **storage** sites

Technology and R&D: key pillars to create sustainable competitive advantage

1 – **Technology development** to support industrial & mobility commercial projects

2 – **Technology leadership** to identify "game changer" technologies in key H2 segments

3 – **Technology Scouting** to bring disruptive technology to the market

Technology Development Program

- Identification **of target technologies**
- Mapping of **production processes, technologies and suppliers**
- Identification and strategic partnerships with **technology providers**

R&D with Top Academic Institutions

- **Network** of R&D Centers and Universities
- Promote funded **R&D Activities**
- Reference **test & certification labs**

Proactively scout for start-ups

- **Start-up Acceleration Programs** Hyaccelerator powered by snam
- **Scout** the most promising and strategic **start-ups** in the H2 space
- **Stimulate** corporate and external **innovation**

Projects: some on-going initiatives

End user enablers

On may 2021, within the Forgiatura A. Vienna plant, the **first global NG-H_2 blend test composed by 30% of H2 has been performed in forging processes employed in industrial scale steel manufacturing.** The experimentation on plant furnaces has been performed with success on site, after a series of studied and laboratory tests lasted almost a year

Focus next slides

The **'Divina' project** (Decarbonisation of the Glass Industry: H_2 and New Equipment), **co-ordinated by Snam, RINA and Bormioli**, aims to **reduce emissions in the glass melting stage**. In the working group also STARA GLASS, Università degli Studi di Genova, Stazione Sperimentale del Vetro, IFRF Italia, SGRPRO and RJC SOFT collaborate.

Industrial & Services

On 9th December 2020 FNM, a2a and Snam signed an MOU for the **conversion from Diesel to Hydrogen of the railway service on the section Brescia - Iseo – Edolo.** The project foresees the commissioning of **14 Ilint-coradia hydrogen trains** from Alstom **by 2024**

Focus next slides

Tenaris, Edison and Snam will collaborate to identify and implement the most suitable solutions for the **production, distribution and use of green hydrogen at the Tenaris mill**, contributing their skills to invest in the best available technologies.

Snam is currently involved in different projects in the airport sector aimed at **decarbonising the production of electricity and heat consumed at the airport** and supplying **green H2 for the refuelling of vehicles** used for airport internal and external transport

Snam and **Iris Ceramica Group** have signed a MoU in order to develop a **new green H2 and gas fueled ceramic factory**. The company is responsible for 90% of the national ceramic production and the new factory will be 100% hydrogen ready.

Focus next slides

Scout for disruptive technologies: HyAccelerator approach & results achieved so far

Vision:

HyAccelerator is the first corporate accelerator in the world 100% focused on deep technology for H2, internally developed and managed by Snam

Strategic mission:

HyAccelerator is meant to reinforce Snam's presence in the innovation ecosystem in order to **discover, accelerate and eventually incorporate breakthrough hydrogen technologies**, leading the path to the energy transition

Acceleration model:

Snam will support startups and talents by **offering an initial grant plus services** (e.g., access to our Hydrogen Innovation Center network), with the aim to develop a First Industrial Deployment design (FID-d) to scale up the technology

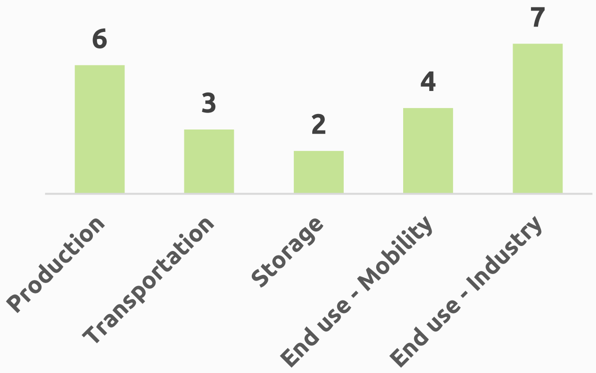
2021 Call4Startup:

The"**HyAccelerator Challenge"** has been launched in October **to scout and select the participants that will access the first edition of the HyAccelerator program.** The current call covers the entire H2 value chain.

2021 Call4Startup: The HyAccelerator Challenge

Overall, **45 startups have applied** to the challenge:

Finalised applications per focus area:*



Finalised applications per geography of origin:

(*) Startup's proposed solution might cover multiple focus areas

energy to inspire the world
Snam as a player in the energy sector
Hydrogen Strategy

StoRIES: Creating an Eco-System for Innovation

Stefano Passerini (KIT)
StoRIES Coordinator
EERA JP Energy Storage Coordinator

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No 101036910

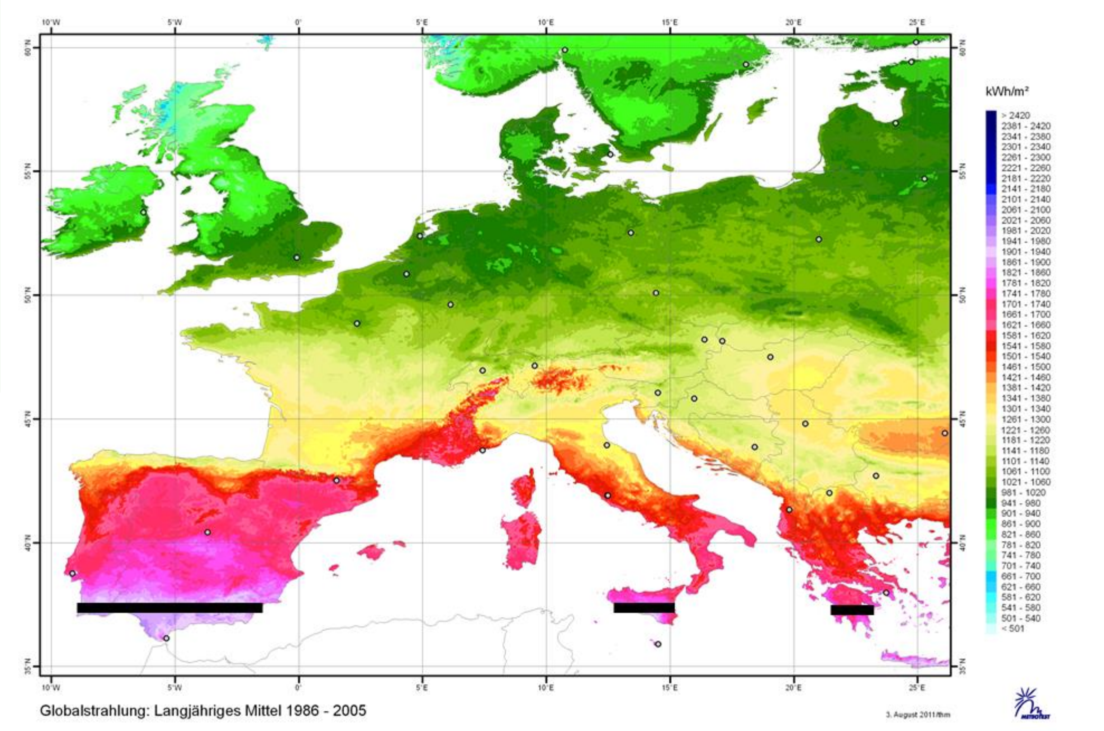
CONTENT

- Why energy storage?
- StoRIES overview
- Main Objectives
- Main Outcomes
- Storage Eco-System
- Work Packages
- Working Groups
- First TNA call

Why Energy storage?

Renewable Energy for Energy Transition

EUROPEAN ENERGY DEMAND: 21400 TWh (2018)



Assumptions

- Energy through renewable energy from PV only (20% collection efficiency)
- Solar radiation˜1500 kWh/m^2 (Perugia)

Area of photovoltaic systems to meet energy needs

Europe:

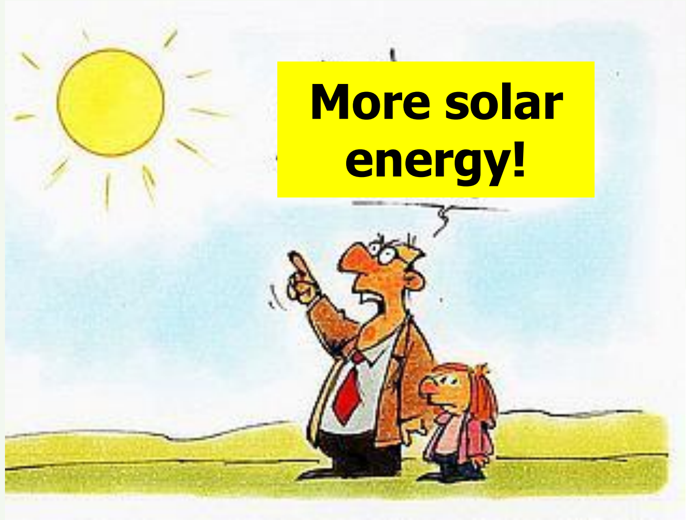
62.600 km^2 (Sicily + Sardinia + ½ Apulia)

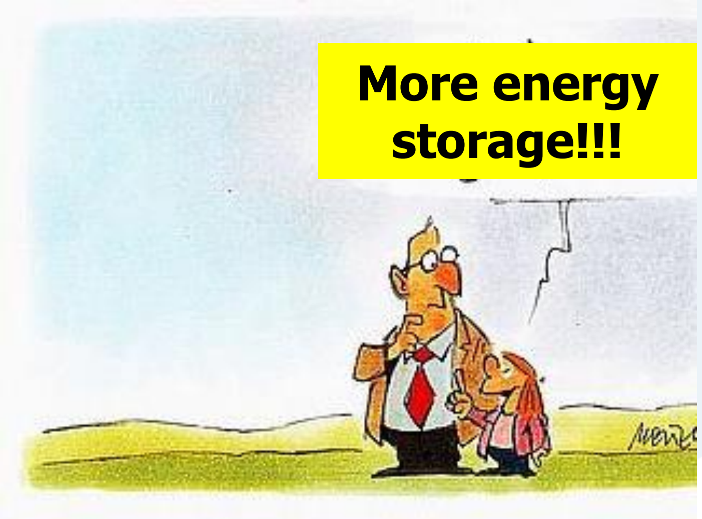
Italy:

20.000 km^2 of urbanised territory
(Buildings, Railways, Roads and Motorways)

https://mapsontheweb.zoom-maps.com/post/83907154436/solar-irradiation-map-of-europe
https://yearbook.enerdata.net/total-energy/world-consumption-statistics.html

Renewable Energy for Energy Transition





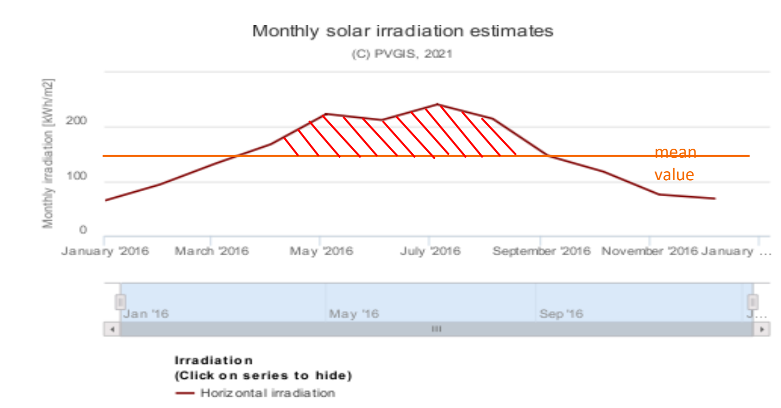
Seasonal/annual energy storage – The KEY to renewable energy, energy independence and decarbonisation.

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No 101036910

StoRIES

RENEWABLE ENERGY: INTERMITTENCY OF SOURCES

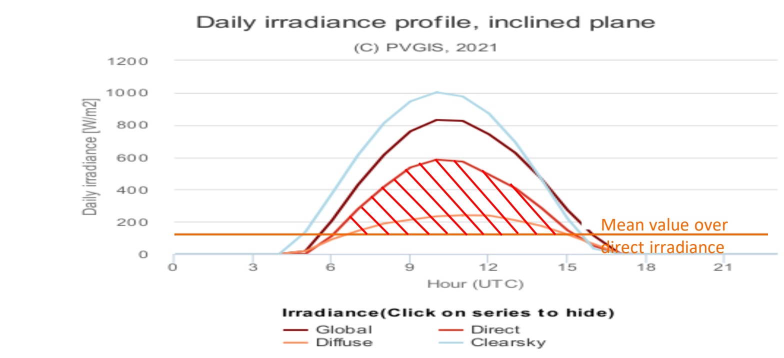
ENERGY STORAGE NECESSARY FOR ENERGY INDEPENDENCE



Seasonal Accumulation

European needs: 4059 TWh

Italian needs: 399 TWh



Daily Accumulation

European needs: 29 TWh

Italian needs: 3 TWh

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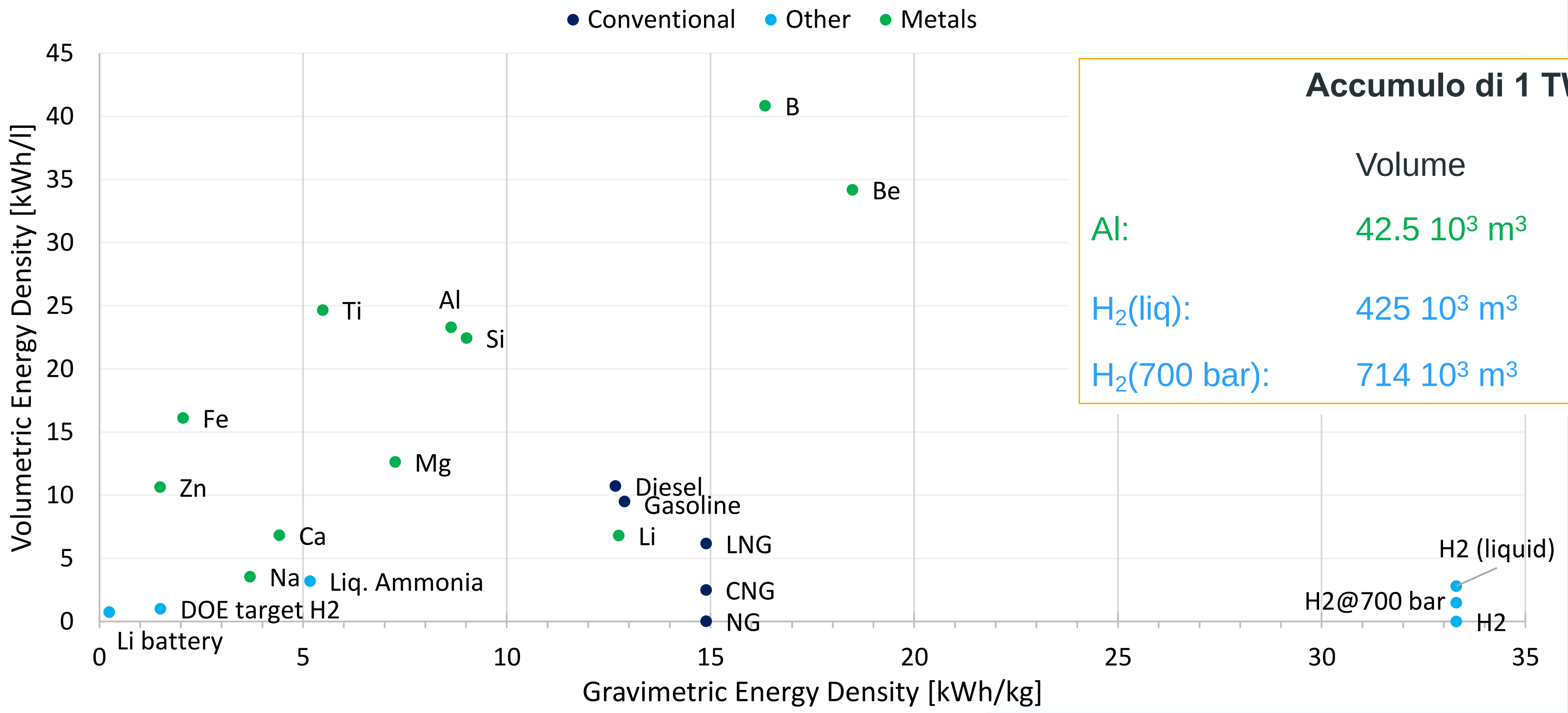
Research and Innovation Programme under Grant Agreement No 101036910

Energy Storage - Substitution of Oil and Natural Gas



Accumulo di 1 TWh

	Volume	Peso
Al:	42.5 10^3 m^3	116 10^3 Tons
H_2(liq):	425 10^3 m^3	30 10^3 Tons
H_2(700 bar):	714 10^3 m^3	30 10^3 Tons

- Reactive metals (e.g. aluminium) allow simple, cheap and permanent energy storage.
- A football field covered with 7 metres of aluminium corresponds to 1 TWh (1800 football fields for the annual needs of Italy).
- One cubic metre of aluminium provides 25 MWh in excess of the annual needs of a household.

StoRIES

Storage Research Infrastructure Eco-System

Numbers and Figures

BENEFICIARIES

Partners and RI providers:

KIT (DE), AIT (AT), CIEMAT (ES), CNR (IT), CSIC (ES), DTU (DK), EDF (FR), ENEA (IT), ENI (IT), FZJ (DE), SINTEF AS (NO), SINTEF EN (NO)

Partners:

EASE (BE), CLERENS (BE), ECCSEL ERIC (NO), EERA AISBL (BE), UNIPG (IT)

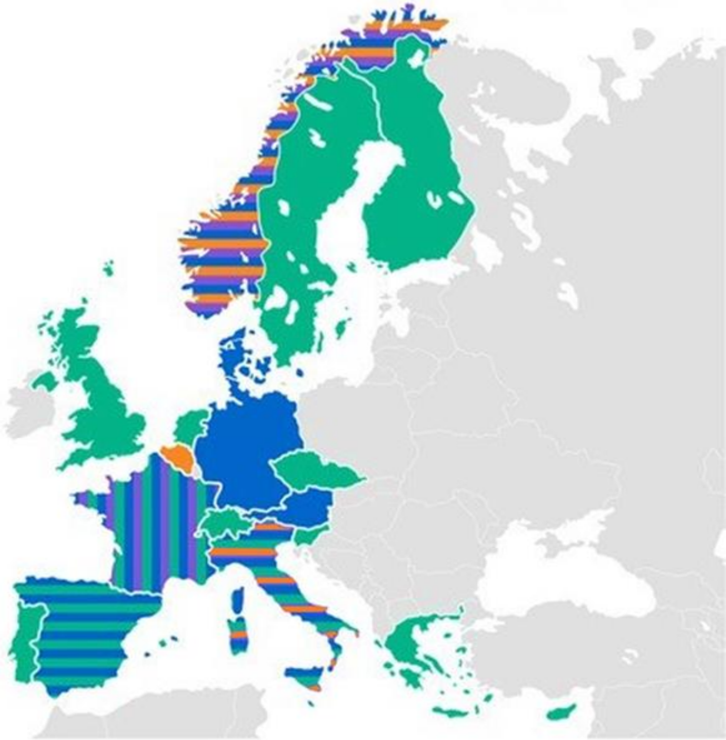
RI providers:

CENER (ES), TBU (CZ), TNO (NL), BGS (UK), BRGM (FR), ISTO (FR), SOTACARBO (IT), EMPA (CH), LUT (FI), RSE (IT), UNIBO (IT), UNIPA (IT), UNIPD (IT), VTT (FI), CERTH (GR), CICe (ES), CyI (CY), FHa (ES), HSLU (CH), HMU (GR), IREC (ES), KTH (SE), LNEG (PT), NIC (SI), UDL (ES), UoB (UK), RINA (IT)

Linked Third parties:

IFE (NO), HVL (NO), RTE (FR)

StoRIES



- Start: 1st November 2021
- Duration: 4 years (2021-2025)
- Budget: 7 Mio €
- Beneficiaries: 47
- Research Infrastructures: 64
- Countries involved: 17
- Coordinator: KIT (DE)

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No 101036910

StoRIES

MAIN OBJECTIVES

- Foster a European ecosystem of industry and research organisations on hybrid ES technologies
- Provide access to world-class materials and ES related research infrastructures
- Enlarge and advance the integration of the European ES community
- Enhance innovation by involving industry experts in the setting up and implementing of a pro-active innovation support scheme
- Ensure the long-term sustainability of ES research:

  - by defining scenarios and strategic roadmaps
  - by setting up a framework for the scientific and technical training of young researchers

- Promote and coordinate the international cooperation in ES research from and to Europe

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No 101036910

MAIN OUTCOMES

- Six Transnational Access calls (TNA)
- Materials Acceleration Platform for ES (MAPs)
- Roadmap for hybridisation of Energy Storage
- Strategic Research and Innovation Agenda (SRIA)
- White Paper on ‘Open Data in the ES community’
- Sustainable ES Workshop Series
- White paper on ‘Sustainable hybrid ES for the European CET’
- International Mobility Scheme
- University Master Programme on hybridisation of ES
- 3 Summer Schools

This project has received funding from the European Union’s Horizon 2020 Research and Innovation Programme under Grant Agreement No 101036910

Energy Storage Eco-System

PROJECT CORE

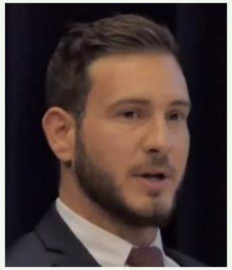
- 17 Full Participants (P)
- 18 Linked Third Parties (LTP)
  - 10 to EERA AISBL from academia and ressearch
  - 4 to EASE from industry
  - 4 to ECCSEL ERIC From large research infrastructure
- 12 Sub- Contractors (SubC) to KIT

EXTERNAL LAYER

Selection Panel (SP)
Advisory Board (AB)
Extended Network (EN)

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No 101036910

Work Packages



WP1 - EERA
Spyridon Pantelis

WP2 – KIT
Olga Suminska-Ebersoldt

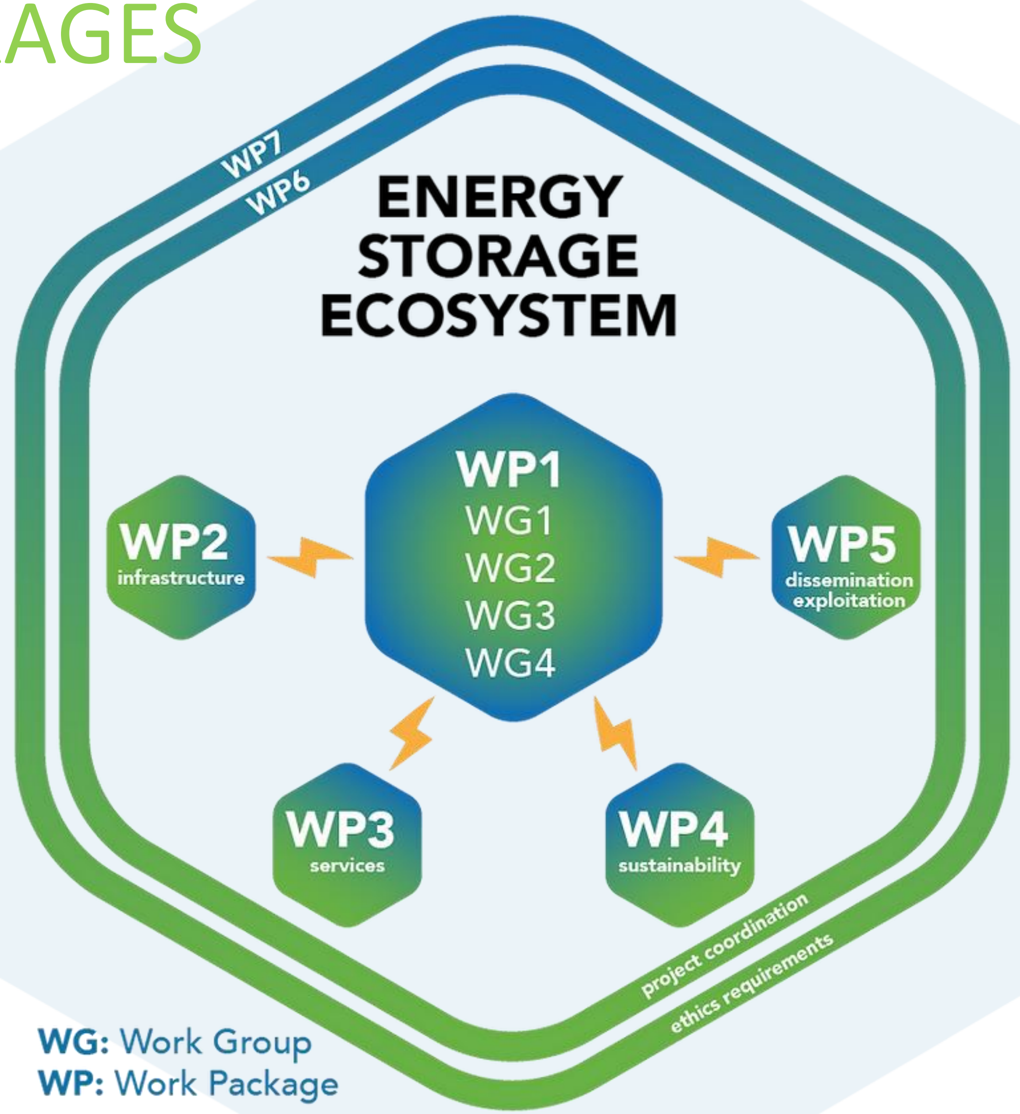
WP3 – SINTEF EN
Ellen Krohn Aasgår

WP4 – CNR
Marco Ferraro

WP5 – CLERENS
Emin Aliyev

WP6 – KIT
Myriam Gil Bardají

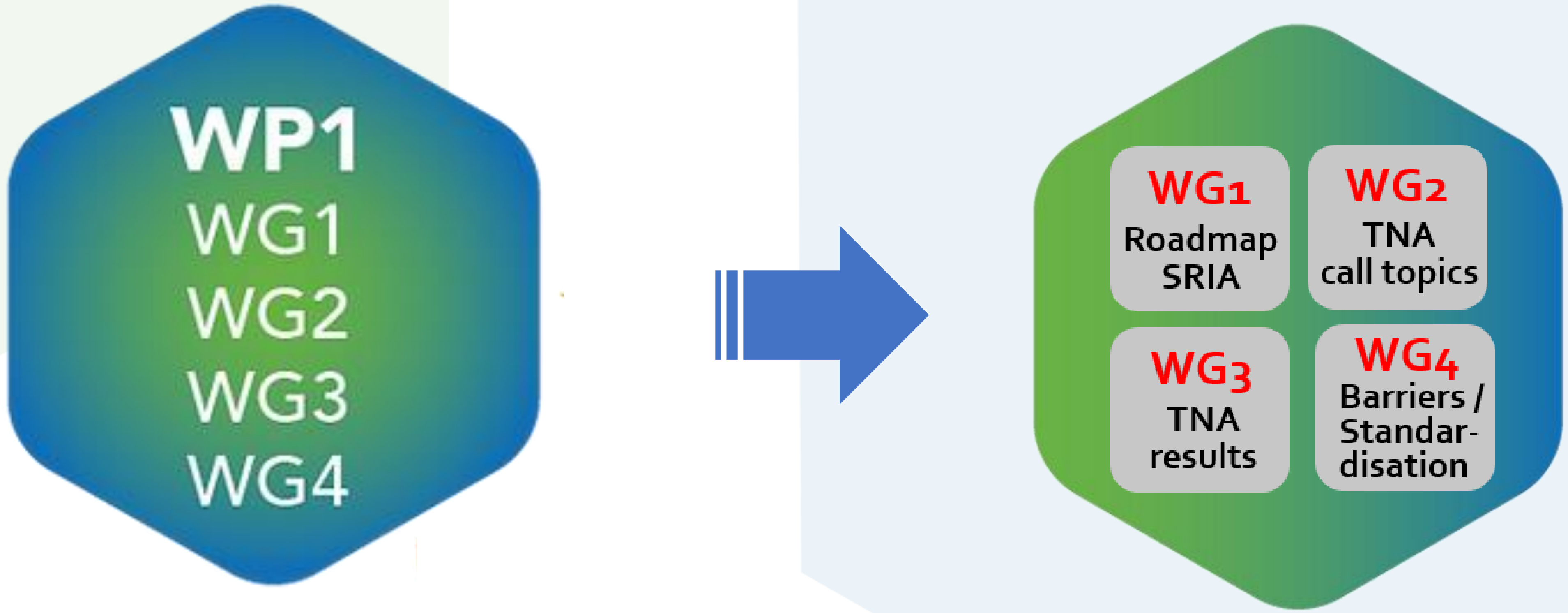
WP7 – KIT
Alexandra Lex-Balducci



This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No 101036910

StoRIES

WORKING GROUPS



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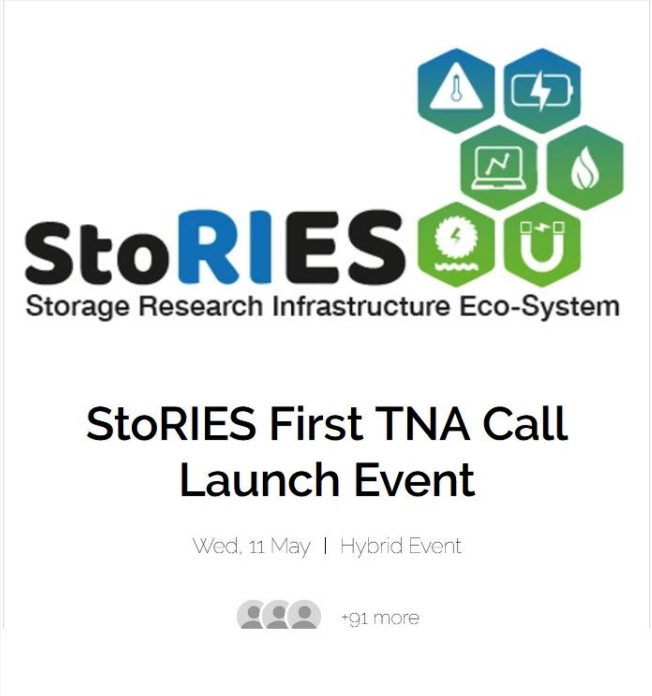
First Transnational Access Call

‘Application oriented hybrid and sustainable energy storage solutions’

Time & Location

11 May, 14:00 – 15:30 CEST
Hybrid Event



This project has received funding from the European Union’s Horizon 2020 Research and Innovation Programme under Grant Agreement No 101036910

How to Join StoRIES Eco-System

External Layer

9 advisory board members

32 energy experts in the selection panel

48 external stakeholder organisations

17 countries

eera-jpes@b3.kit.edu

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No 101036910

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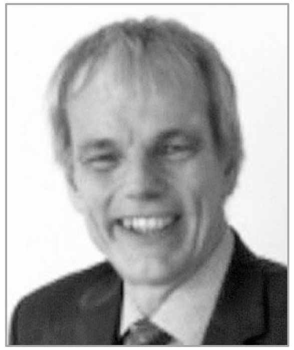
StoRIES Project H2020
StoRIES Project
@StoRIES_H2020
storiesproject.eu

THANK YOU VERY MUCH

StoRIES

www.storiesproject.eu

KIT coordination team



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BATTERIES
EUROPE
EUROPEAN TECHNOLOGY
AND INNOVATION PLATFORM

European Commission

BATTERIES EUROPE
EUROPEAN **TECHNOLOGY**
AND **INNOVATION** PLATFORM

BATTERIES EUROPE

EUROPEAN **TECHNOLOGY** AND **INNOVATION** PLATFORM

Batteries Europe – Shaping the EU battery ecosystem to effectively support the Industrial uptake

10.05.22

Batteries Europe in its essence

BATTERIES EUROPE
EUROPEAN TECHNOLOGY AND INNOVATION PLATFORM

Batteries Europe is the Think Tank of the EU Battery Community.

It has the scope of:

- tracking the progress of battery technology
- collecting knowledge about the entire value chain and monitoring how different part of the value chain impacts on each other

It is an inclusive platform to share ideas and inputs. Participation is on a voluntary basis and free of charge.

The knowledge produced by Batteries Europe - picture of technologies gaps - is at disposal of the entire Batteries community and publicly accessible.

European Commission

Why do we participate in Batteries Europe ?

BATTERIES EUROPE

EUROPEAN **TECHNOLOGY** AND **INNOVATION** PLATFORM

01 NETWORK BUILDING

02 STRENGTHEN EUROPEAN BATTERY INDUSTRY

03 TECHNICAL KNOWLEDGE SHARING

04 CONTRIBUTE TO EUROPEAN BATTERY R&I STRATEGY

05 TO SUPPORT JOB CREATION FOR THE FUTURE

06 TO PLAY OUR PART IN THE GREEN ENERGY TRANSITION

BONUS POINTS:
FRIENDSHIPS
MOTIVATION
FUN

Batteries Ecosystem in few words

BATTERIES EUROPE
EUROPEAN TECHNOLOGY AND INNOVATION PLATFORM

Think tank on European Battery Research

Prioritizing R&I activities and defining HEU Call topics (together with EC)

Inventing the Sustainable battery of the Future

Supporting the creation of a European battery industry

R&I and first commercial deployment projects

Questions that we want answer today

How can the European Batteries Ecosystem facilitate the acceleration of innovation?

Which role is playing Academia in such scenario?

How is such Ecosystem evolving based on previous lesson learnt?

Which other actions Batteries Europe will carry out to support the industry?

How can the European Batteries Ecosystem facilitate the acceleration of innovation?

BATTERIES EUROPE
EUROPEAN TECHNOLOGY AND INNOVATION PLATFORM

ACTION	IMPACT
Interaction with Initiatives representing other Sectors (ETIPs)	To enable end segments to anticipate the batteries to come in their own technical roadmaps, business models and cost estimation. i.e. Non-road transport; construction; logistic
Monitoring of global battery development	Ensure Europe is at the forefront of battery technology, sustainability and competitiveness and to identify cooperation opportunities.
Technological Road Maps and SRIA	To identify the key R&I challenges which must be addressed in Europe to give a leading edge in battery technology development and implementation
Benchmarking for KPIs assessment	Identification of KPIs per application will be submitted to the EC to provide fact-based data for political decision making

Which role is playing Academia in such scenario?

BATTERIES EUROPE
EUROPEAN TECHNOLOGY AND INNOVATION PLATFORM

Industry (and notably automotive industry) is about to be exposed to a significant need for skilling and re-skilling due to the electrification shift.

Academia is at the core of such transition and will support the Industry in the establishment of due skilling and re-skilling programmes.

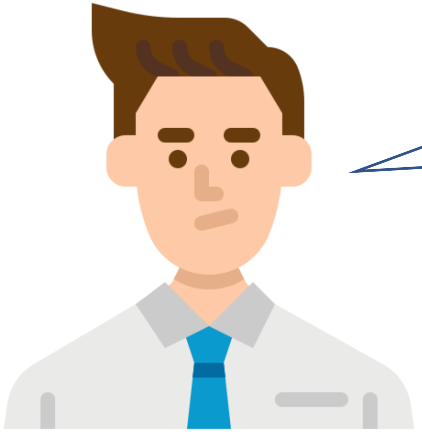
Batteries Europe *effort*

- Identification of needs and provide recommendations (next 5-10yrs)
- Support MS to recognize the urgency of identify skill gaps and mapping national needs
- Specify the attractiveness of talents fitting the battery sectors

EBA Academy *initiative*

Building a pan-European education ecosystem that will reduce the cost to up-and reskill workers while increasing the efficiency and quality of programmes.
EBA Academy will reduce the lead time to start and test new courses and programmes.

How is such Ecosystem evolving based on lesson learnt?



We want the Batt Ecosystem to be easier to understand and more efficient

And therefore, attract more stakeholders

- ❖ Joint Strategic Research & Innovation Agenda BE/BEPA
- ❖ Creation of Integrated Working Groups BE/BEPA
- ❖ Simplification of Batteries Europe Governance

Which other actions Batteries Europe will carry out to support the industry?

BATTERIES EUROPE
EUROPEAN TECHNOLOGY AND INNOVATION PLATFORM

New tasks are introduced in the new contract of Batteries Europe which will be beneficial for the Industry

Integration of Social realities into technological system planning

Understand and communicate the social reality complexities associated with batteries with focus on the use phase

Support and coordinate Safety & Standards

- Definition of Safety KPIs
- Support JRC in contributing to developing test methodologies for battery technology for various applications

Hybridization of battery solution with other technologies

Focus on hybridization of storage technologies > interaction with StoRIEs Project.

European Commission

BATTERIES EUROPE
EUROPEAN **TECHNOLOGY** AND **INNOVATION** PLATFORM

Thank you for your Attention

Alessandro Romanello
Batteries Europe Coordinator
EIT InnoEnergy
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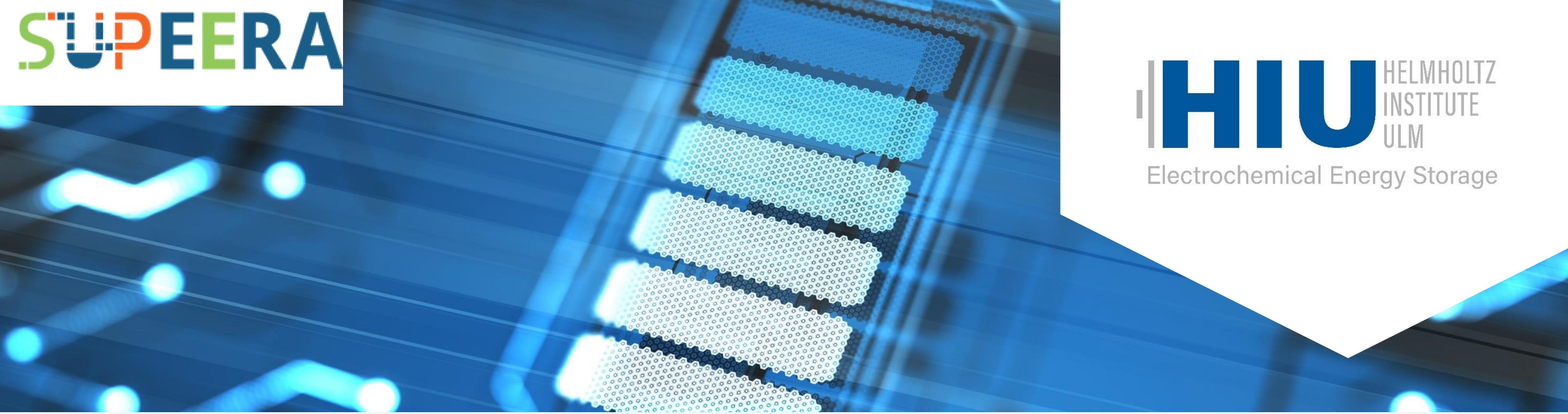


Maider Zarrabeitia

Good practice of R&I funding programmes: SIMBA project

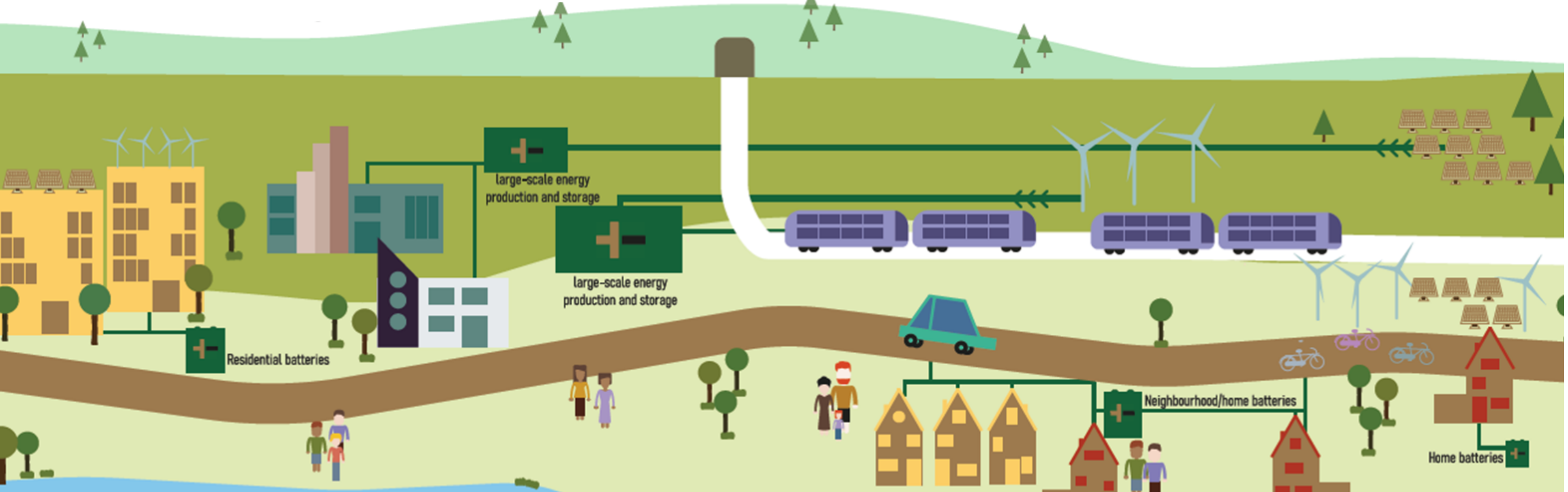
Helmholtz Institute Ulm, Helmholtzstr. 11, 89081 Ulm, Germany
Karlsruhe Institute of Technology, Karlsruhe, Germany

SIMBA project

- Funded by European Union's Horizon 2020 research and innovation programme (grant agreement No 963542)
  - Topic: Next-generation batteries for stationary energy storage
- Duration: 42 months (01.01.2021 – 30.06.2024)
- Budget: 7.91 M €
- Partners in project: 16 (5 different EU countries, 2 associated countries and 1 other country)
  - Universities, (private) research centres and energy sector companies

SIMBA
SODIUM-ION AND SODIUM METAL BATTERIES

- Main goal: **Development of a highly cost-effective, safe, all-solid-state battery with sodium as mobile ionic charge carrier for stationary storage applications**

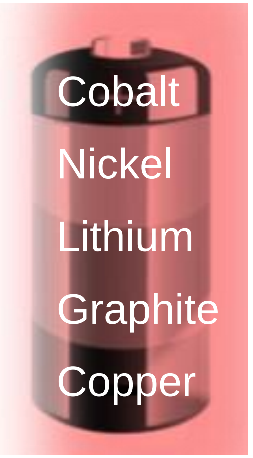


https://simba-h2020.eu/

Why sodium technology?

HIU HELMHOLTZ INSTITUTE ULM
Electrochemical Energy Storage

LIB: dependency on critical materials



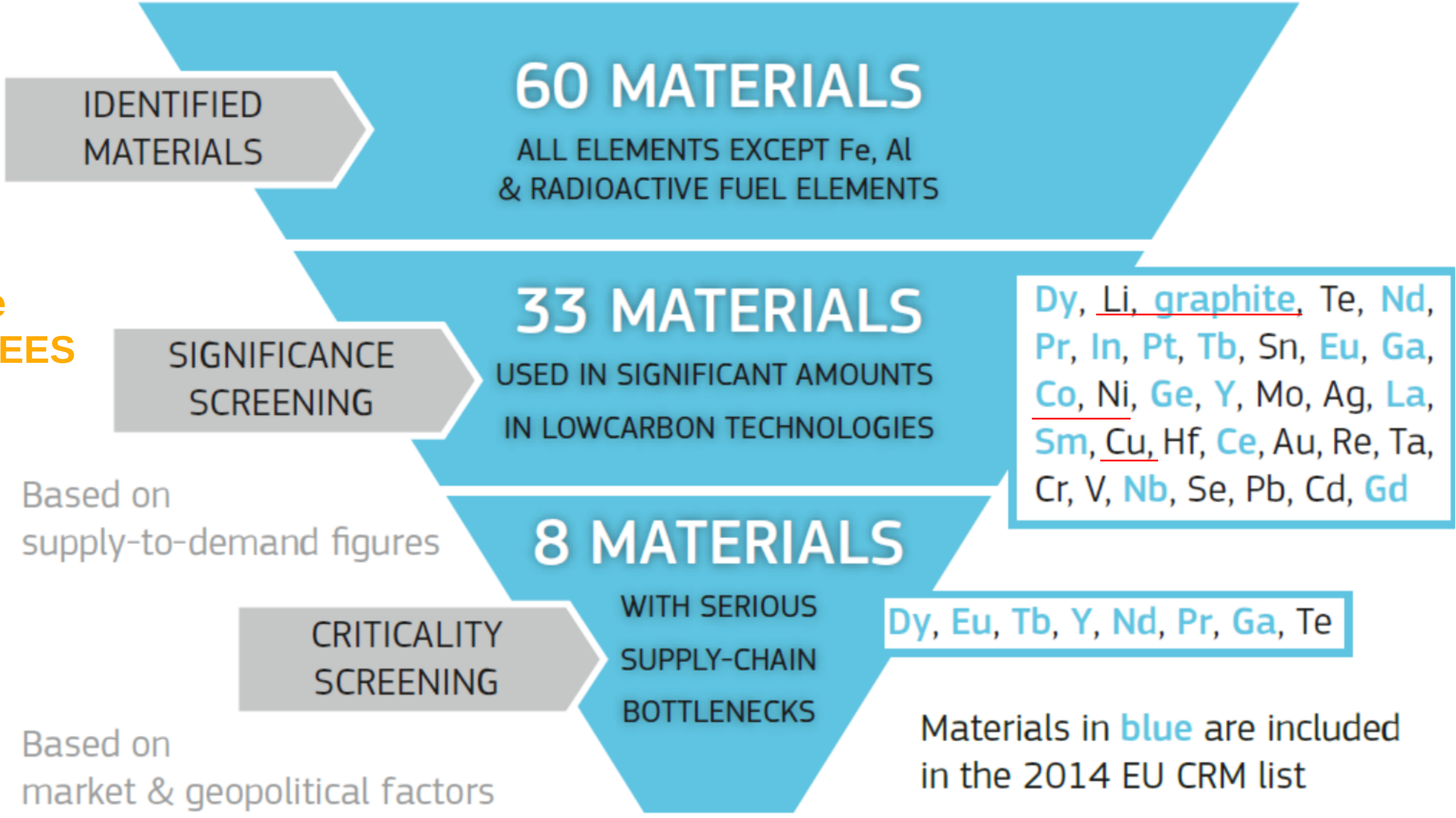
- ❑ Geopolitical supply risks
- ❑ Substitutability supply restrictions
- ❑ Environmental implications

Alternative low-cost, sustainable and more environmentally friendly EES

Sodium-ion batteries

Manganese
Iron
Hard Carbon
Sodium
Aluminum

Identification of critical materials for the EU



https://setis.ec.europa.eu/setis-reports/setis-magazine/materials-energy/critical-materials-energy-technologies-evangelos
I. Hasa et al. J. Power Sources (2021) 482, 228872

12 V, 1 Ah sodium module

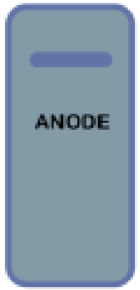
Option 1

Hard carbon (TRL5)
- Sustainable sources
- High capacity (280 mAh g^{-1})

Option 2

Porous ceramic structure
- Support for Na plating
- High specific capacity (> 500 mAh g^{-1})

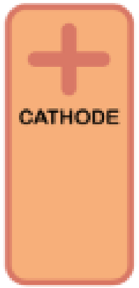
Aluminum substrate



Na+

Solid state electrolyte (SSE) (TRL3-5)
- Single-ion conductive polymers
- Optimised safe Na-ion transport
- Stability window up to 4.4 V
- Ionic conductivities of 10^{-3} S cm^{-1} at RT

Na+



Option 1

Iron-based Prussian White (TRL5)
- Ultra low-cost (< 4 € kg^{-1})
- Good capacity (165 mAh g^{-1})
- Acceptable working voltage (3 V)
- Scalable

Option 2

2^{nd} Gen: layered oxide (TRL5)
- High energy material (> 200 mAh g^{-1} and > 3 V)

Aluminum substrate

Two sustainable electrode production processes
- Water-based binder
- Extrusion solvent free

New modelling and characterization tools
- Deep understanding of interface kinetics and degradation mechanism
- Design optimal chemical interface

https://simba-h2020.eu/

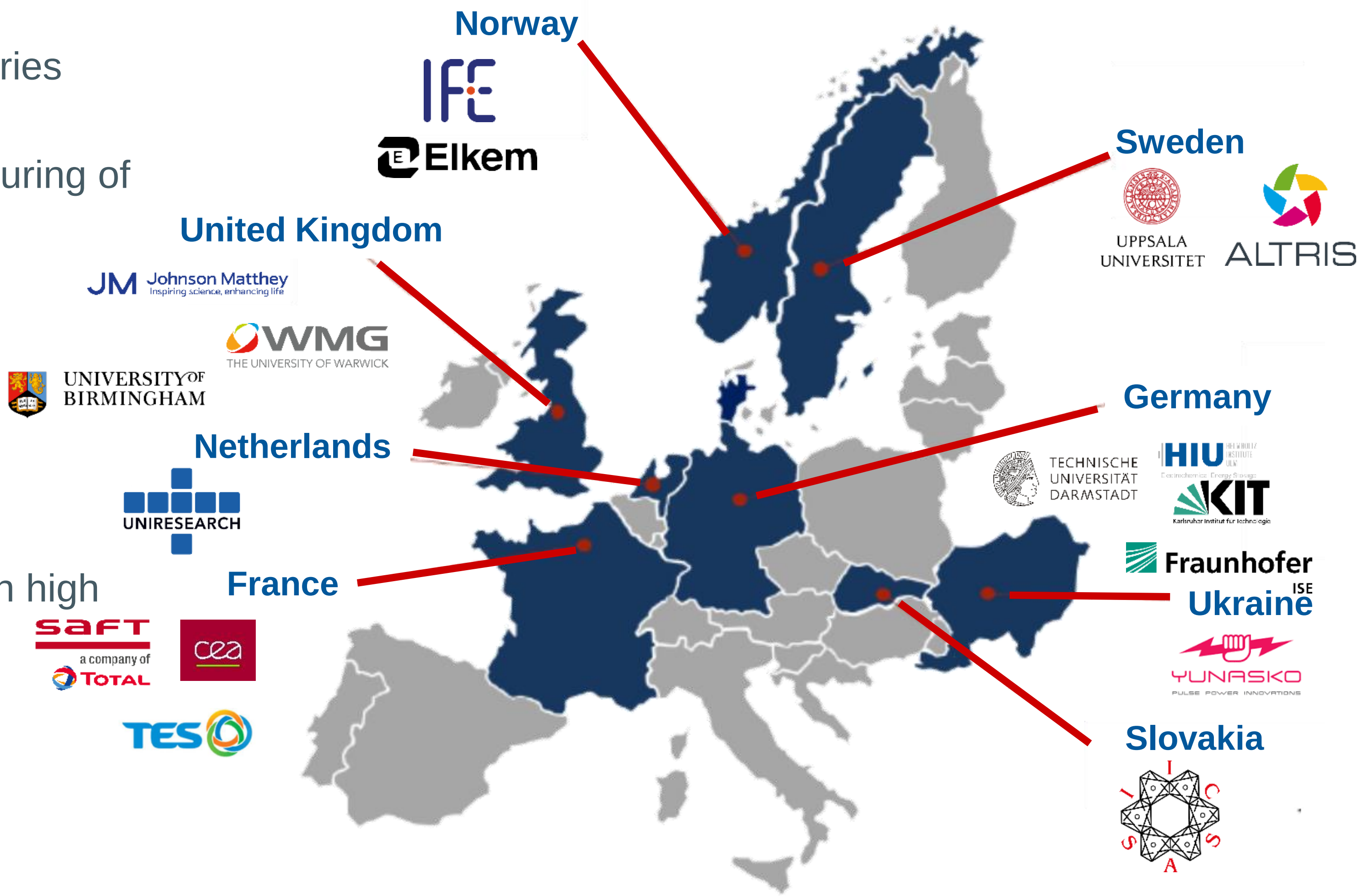
SIMBA project: Consortium - activities

Material development	Charac. and Modelling	Material production up-scaling	Electrode and cell production	Module and BMS development	Testing and validation	Recycling	End user
IFE	TUDa	**Elkem**	CEA	Yunasko	UU	Ubham	**SAFT**
Altris		**JM**	WMG	FHG	SAFT	SAFT	Yunasko
KIT-HIU		Altris	Ubham				
TUDa		KIT-HIU					
UU							

Reinforcing the competitiveness of participating companies and European battery industry

SIMBA project: Partners

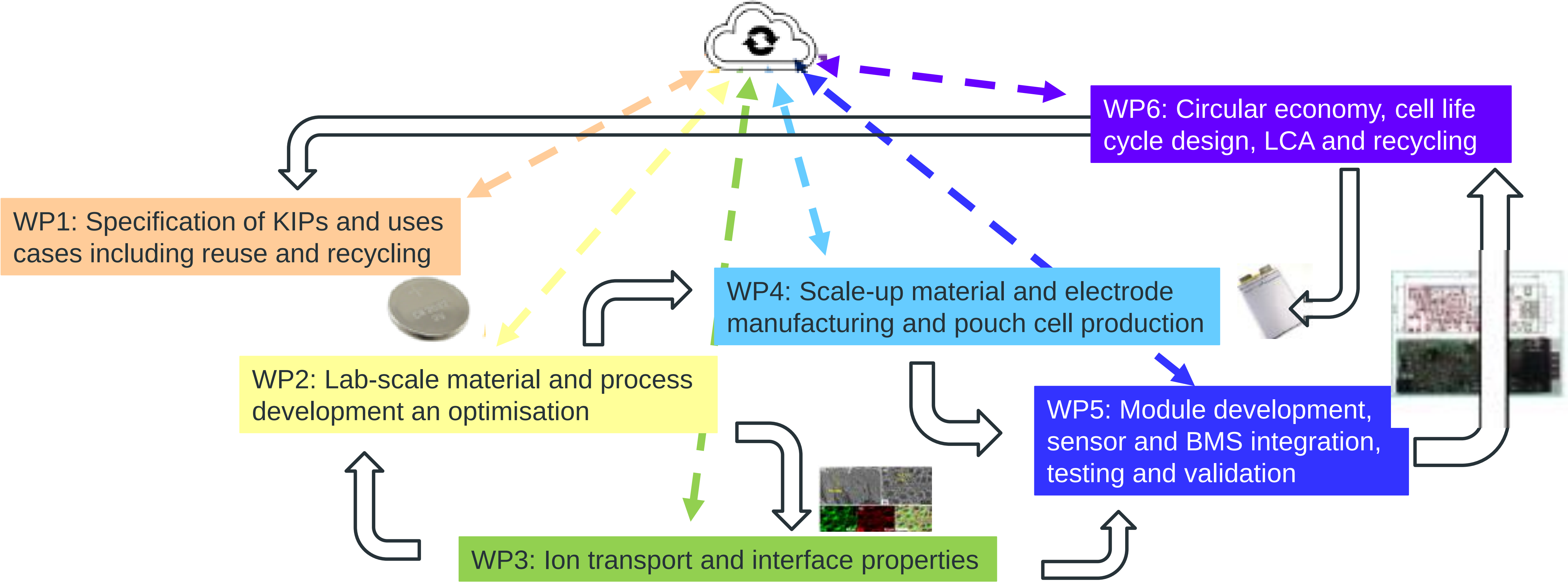
- Partners in project: 16
  - Material science and battery experts
    - make breakthrough in all-solid-state batteries
  - Competitive centres in materials and manufacturing of SIBs
  - Know-how in reuse and recycling technology
  - Material suppliers
    - creation of novel products
    - open new business lines and markets with high added value and end-users



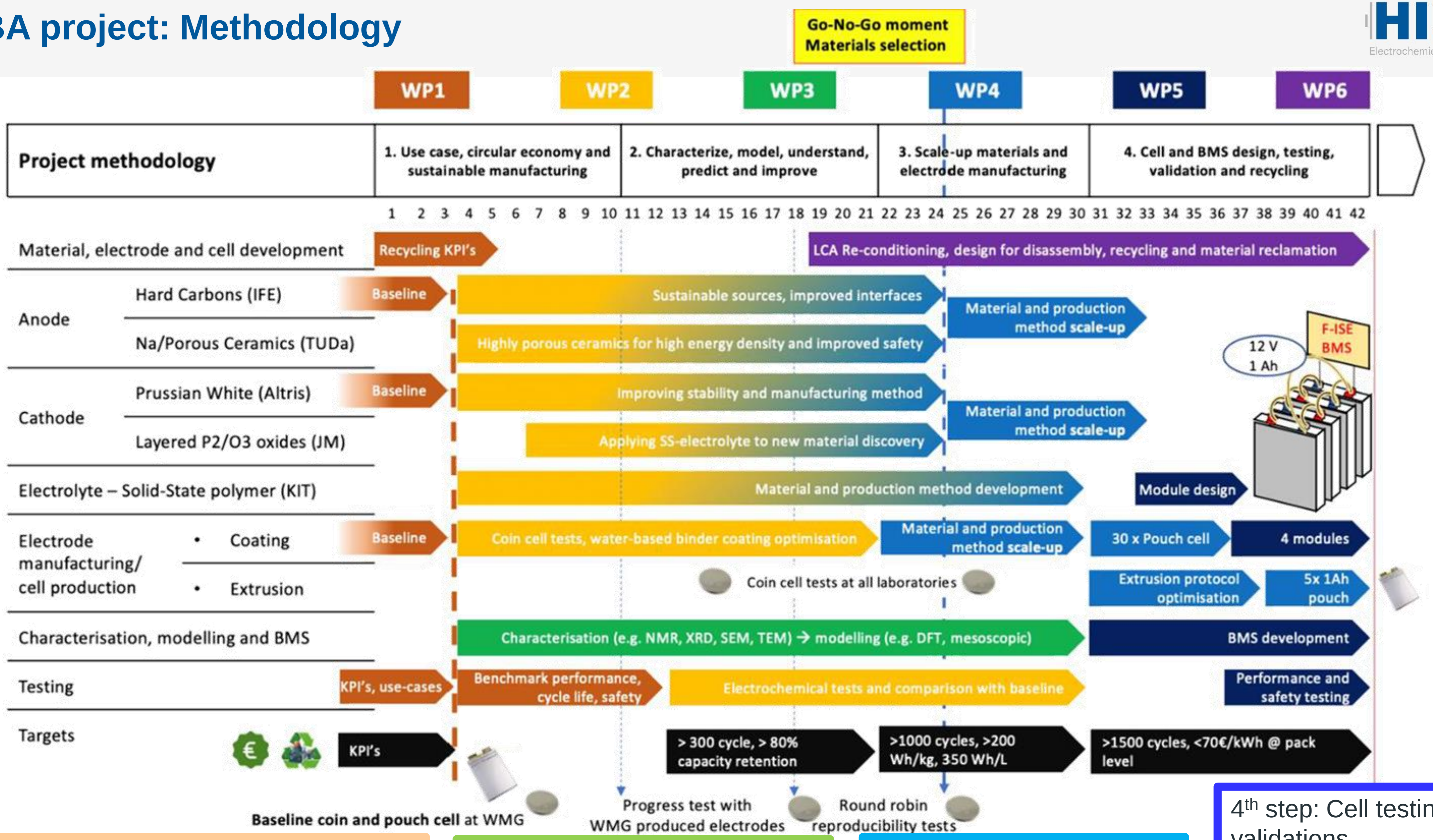
https://simba-h2020.eu/

SIMBA project: Work plan

- From materials development (WP2), characterization (WP3) to the scale-up (WP4) and module performance testing/validation (WP5)
- Identifying KPIs and use cases (WP1) and circular economy, cell life cycle design, LCA and recycling (WP6)



SIMBA project: Methodology



1st step: Circular economy and sustainability
Baseline cell

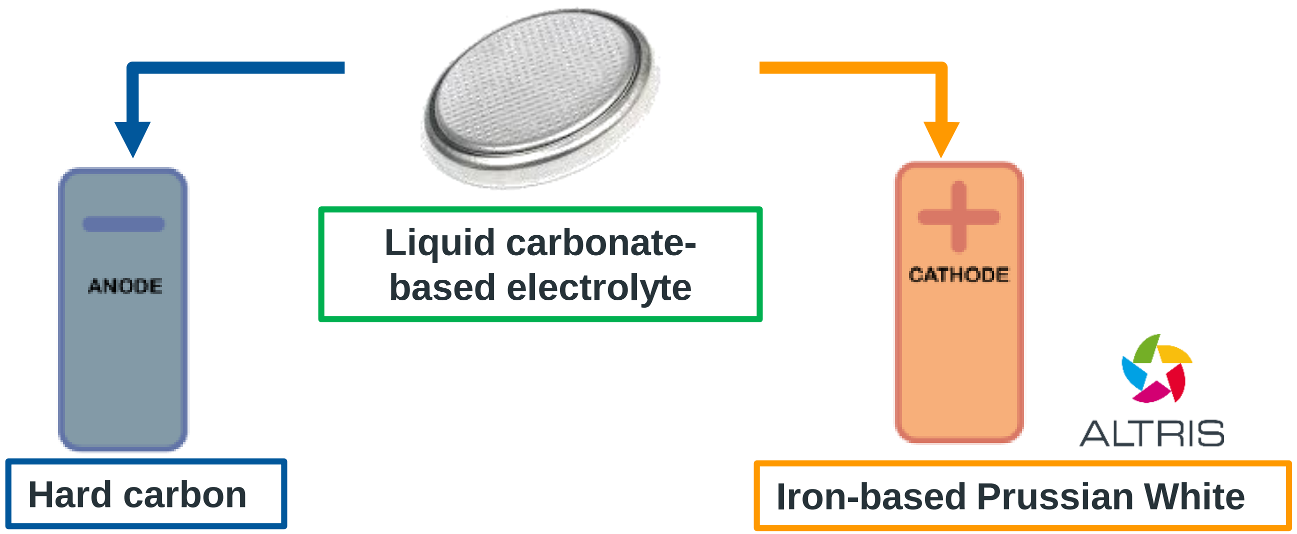
2nd step: Characterization, improve proposed materials

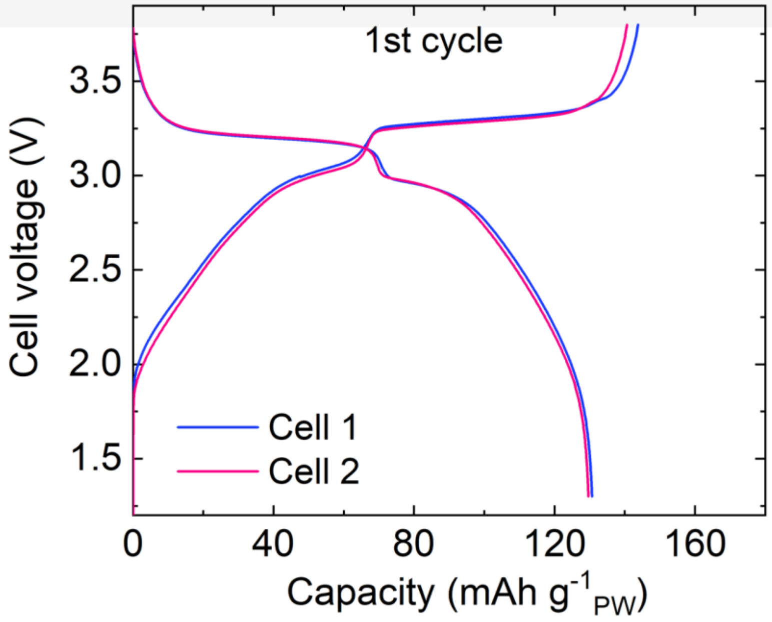
3nd step: Scale-up
Electrode manufacturing

4th step: Cell testing and validations

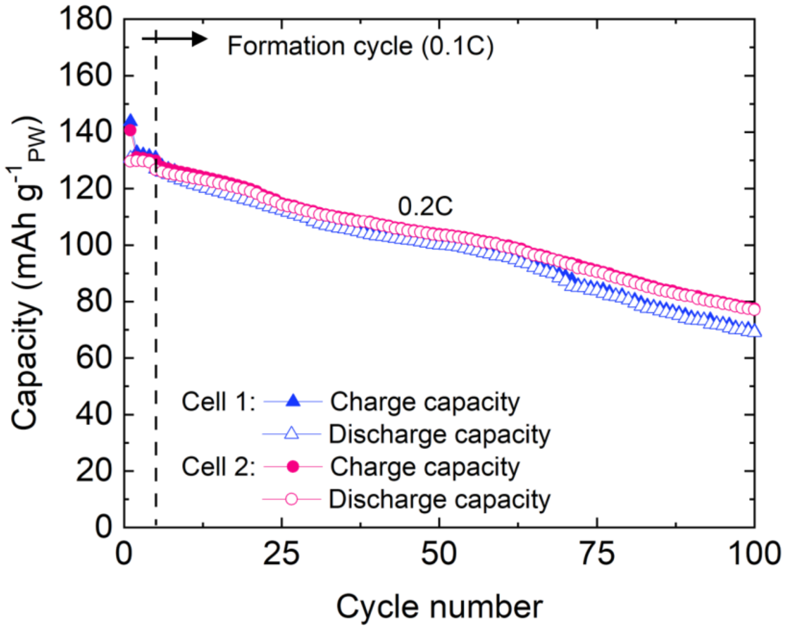
SIMBA project: Baseline cells

- Electrochemical testing of single side baseline electrodes in coin-cell configuration





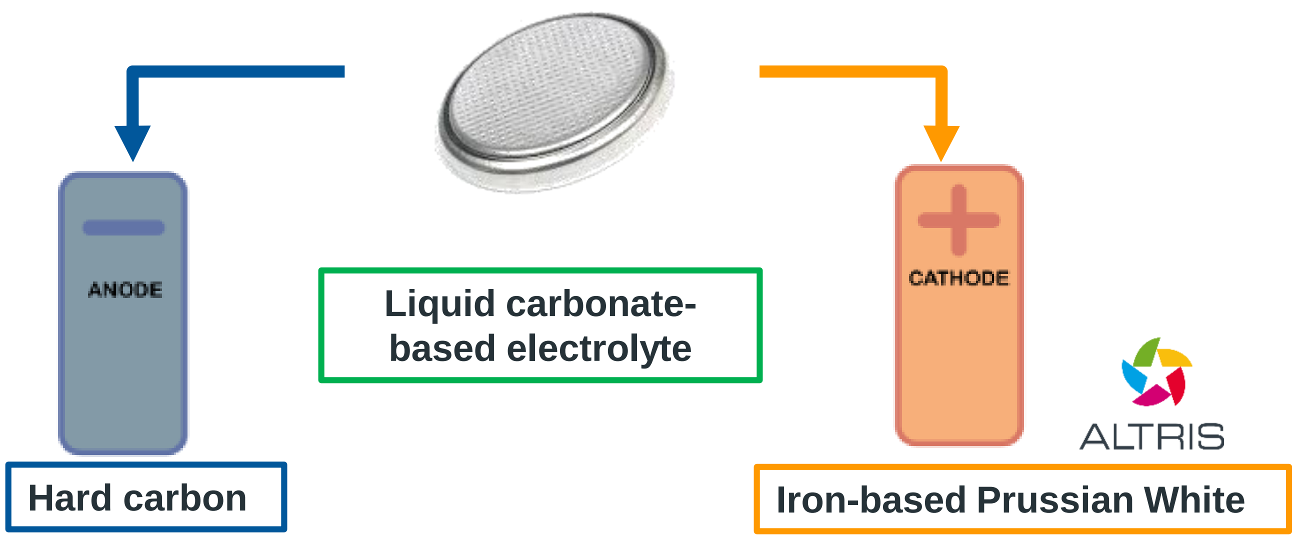
Cell	1st DQ (mAh g^{-1}_{PW})	Cap ret. (6th vs 50th)	CE (1st cycle)	CE (50th cycle)
1	130.68	82.5%	90.9%	99.5%
2	129.64	82.2%	92.2%	99.7%

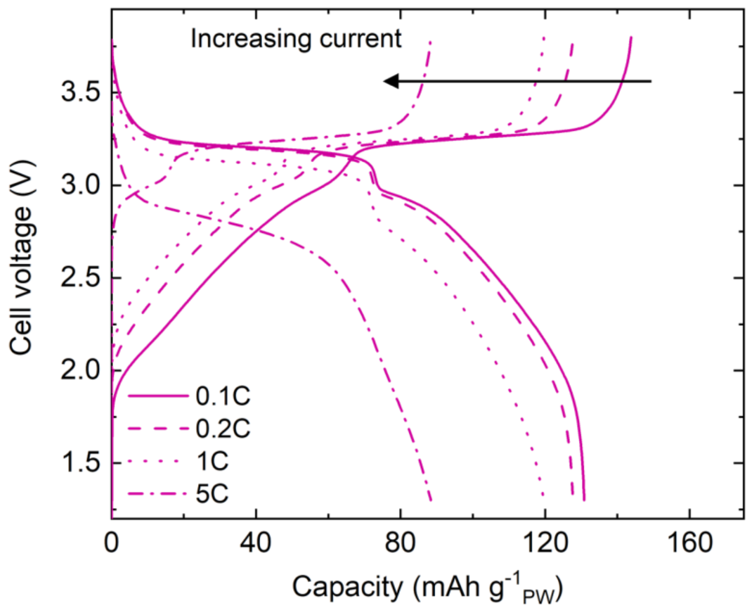


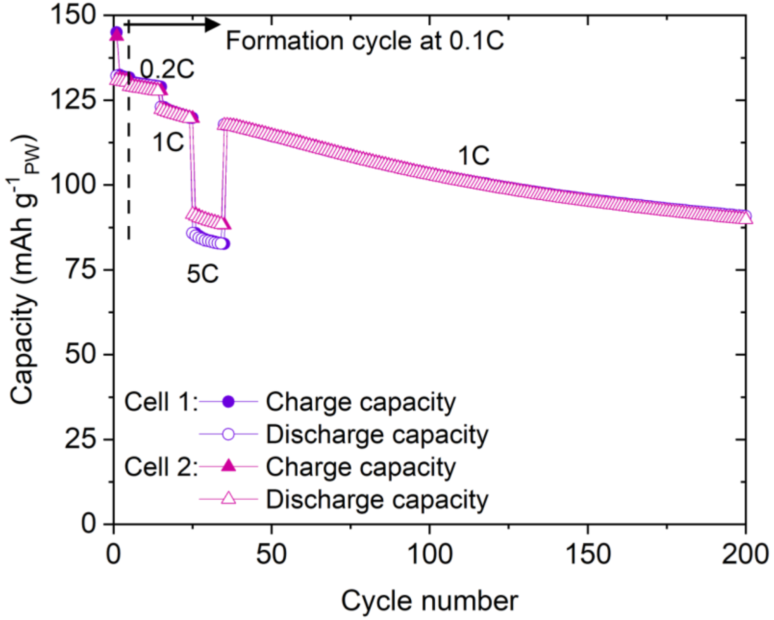
- Reproducible data
- Initial specific capacities of 130 mAh g^{-1} at 0.2C

SIMBA project: Baseline cells

- Electrochemical testing of single side baseline electrodes in coin-cell configuration: Rate capability



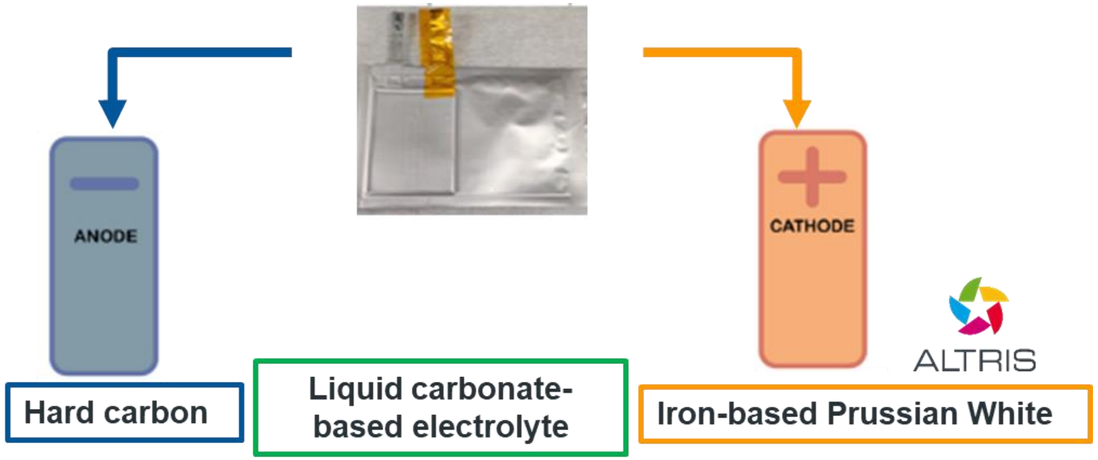




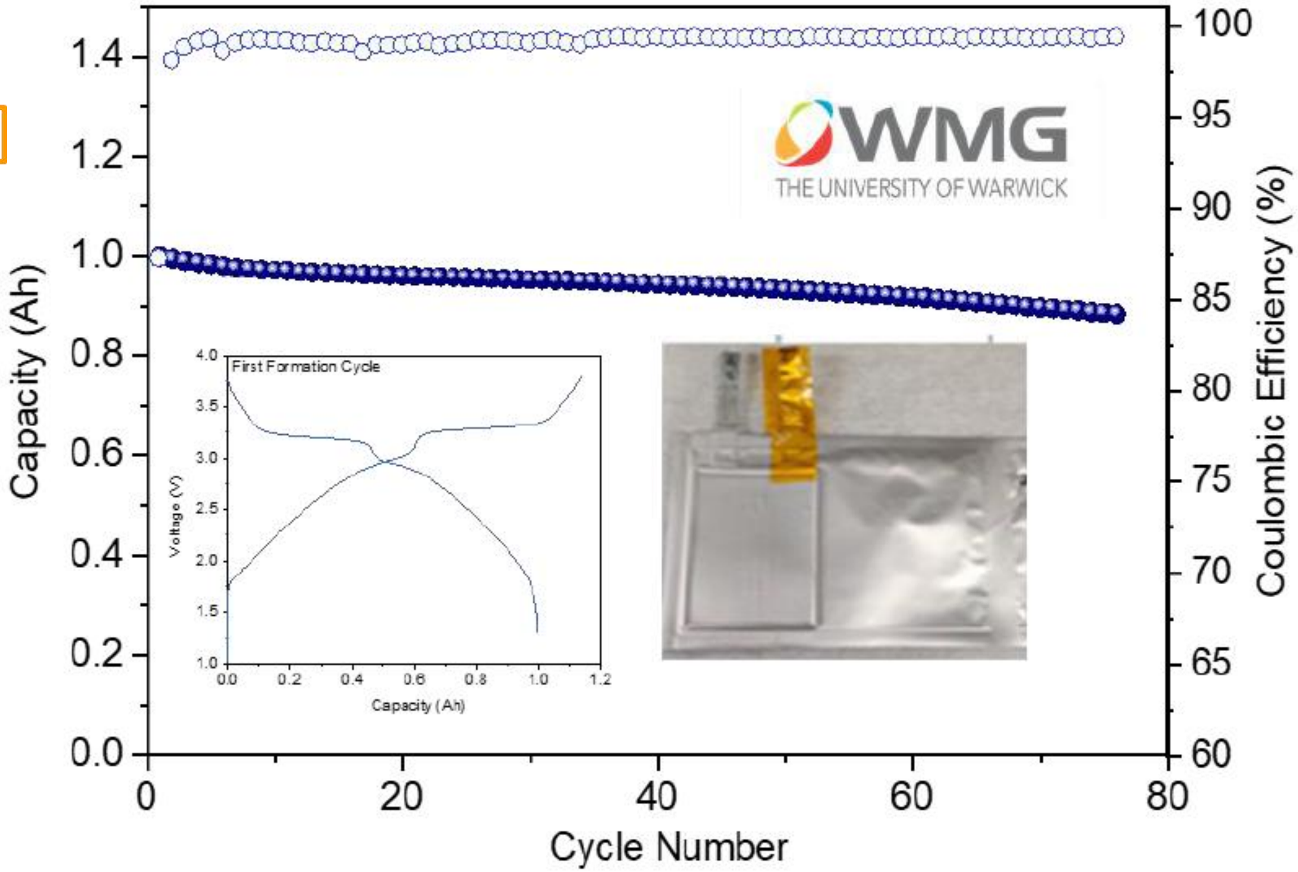
- Reproducible data
- Acceptable rate capability
  - 120 mAh g^{-1} at 1C
  - 90 mAh g^{-1} at 5C

SIMBA project: Baseline cells

- Electrochemical testing of double side baseline electrodes in A 7 pouch cell



WMG
THE UNIVERSITY OF WARWICK



- Baseline cell successfully achieved
  - Target: 1 Ah capacity
- 1st step of SIMBA project achieved

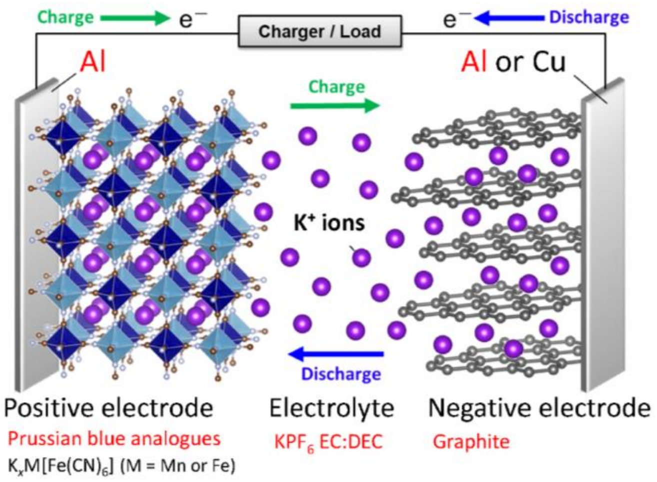
https://simba-h2020.eu/

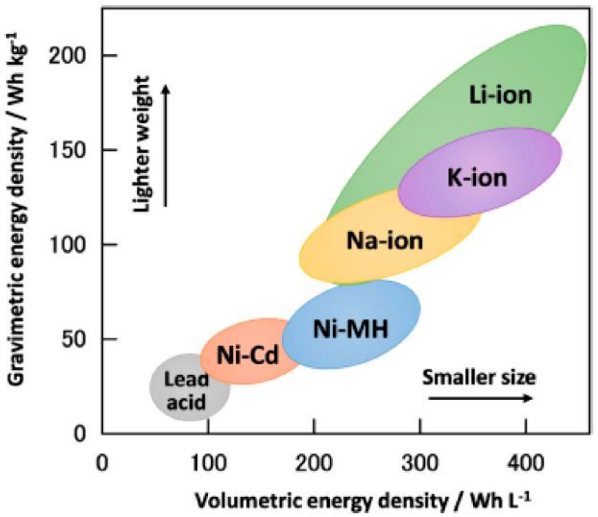
SPIRIT project

- Funded by National public agencies within M-ERA.Net 3 (Call 2021)
  - Agencia Estatal de Investigation (Spain)
  - Projektträger Jülich - BMBF (Germany)
  - Israel Ministry of Science and Technology (Israel)
  - Topic: Functional materials – Materials and battery technologies
- Duration: 36 months (01.10.2022 – 30.09.2025)
- Partners in project: 5 (2 different EU countries and 1 other country)
  - Universities, research centres and small- and medium-sized enterprise
- Main goal: **Develop a safe, sustainable and cost-competitive solid-state Potassium-ion battery for large-scale stationary applications**

SPIRIT project: Why Potassium batteries?

- Alternative chemistry
  - Low-cost and environmentally friendly batteries
    - Based on Mn, Fe, Al, Carbon
  - High power density
    - K^+ diffuse faster than Li^+/Na^+ (weaker interaction with solvent)
  - High energy density
    - Low standard electrode potential of K/K^+ (high operating voltage)
  - Safety
    - Lees chances of metal plating





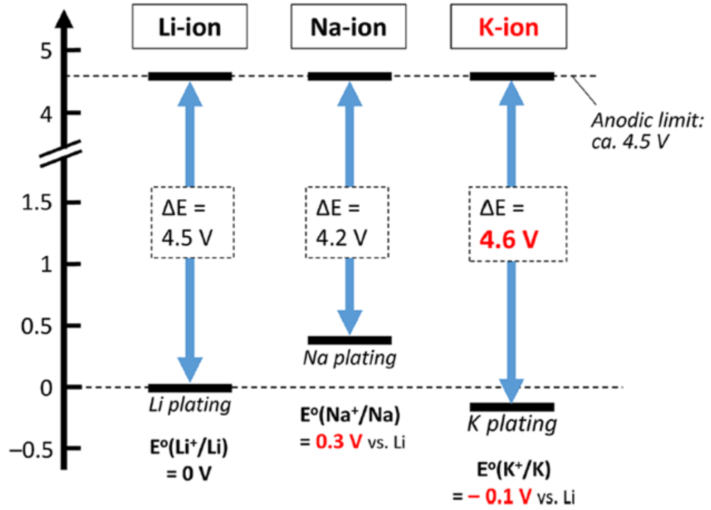
Potassium batteries

Manganese

Iron

Hard Carbon

Aluminum



i) T. Hosaka, et al. *Chem. Rev.* **2020**, *120*, 6358-6466 ii) V. Annopkumar et al. *ACS Appl. Energy Mater.* **2020**, *3*, 9478-9492

SPIRIT project: Concept

Iron-/ Manganese-based Prussian White (TRL4)
- Ultra low-cost
- Good capacity (142 mAh g^{-1})
- Good working voltage (4 V)
- Excellent life time

Solid polymer electrolyte (TRL3-4)

Option 1
- Dual-ion polymer (PEO:K-salt: IL)

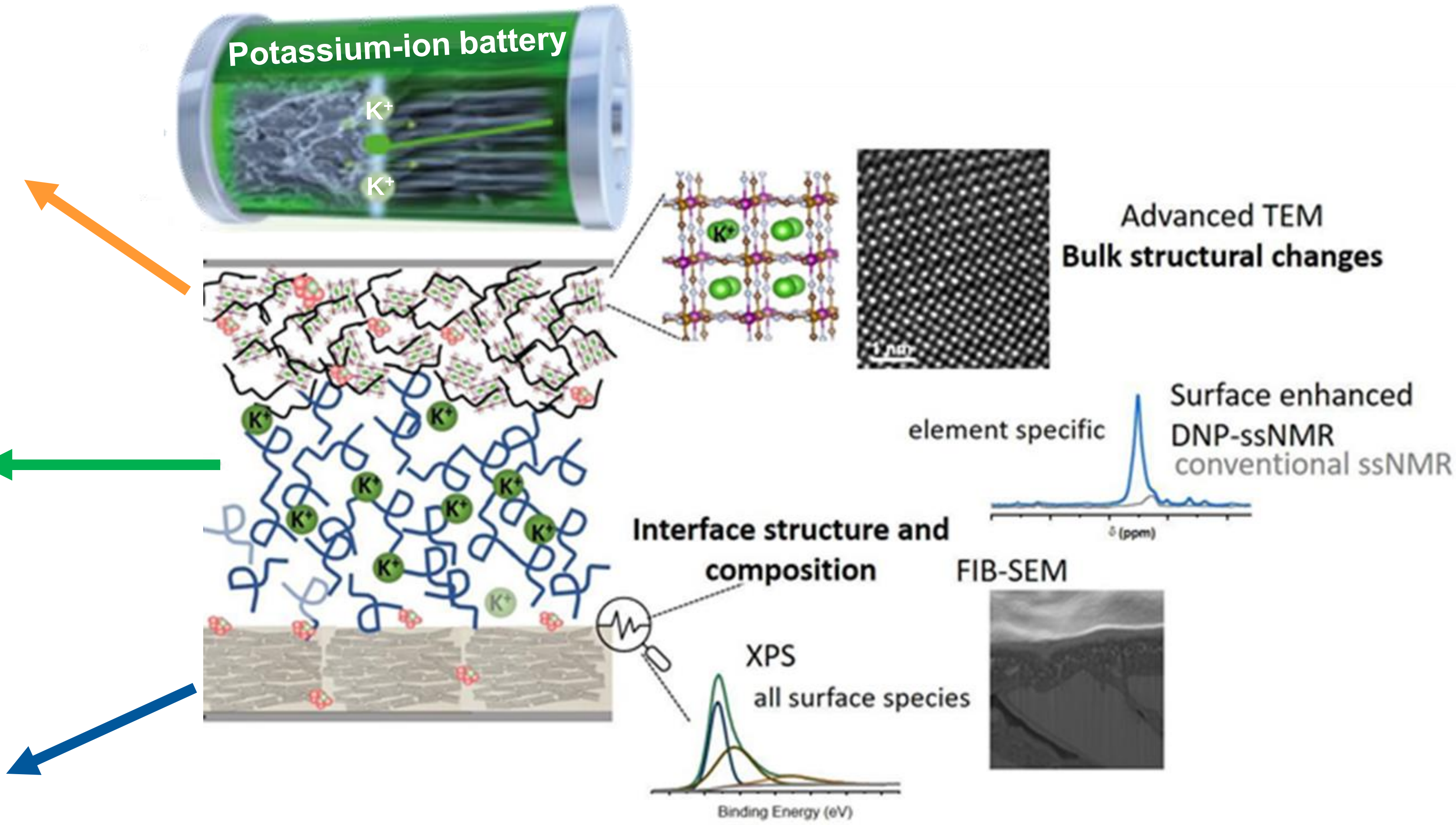
Option 2
- Recyclable single-ion conductive polymer

Option 1

Hard carbon (TRL4)
- Lower cost processing than Graphite
- Good capacity (200-250 mAh g^{-1})

Option 2

Ti-oxides
- Higher operating voltage (1-1.5 V)
- Good rate capability (75 mAh g^{-1} at 300 mA g^{-1})



- Funded by European Union's Horizon 2020 research and innovation programme (grant agreement No 963542)

SIMBA
SODIUM-ION AND SODIUM METAL BATTERIES

https://simba-h2020.eu/

- Funded by national public agencies within M-ERA.NET

SPIRIT

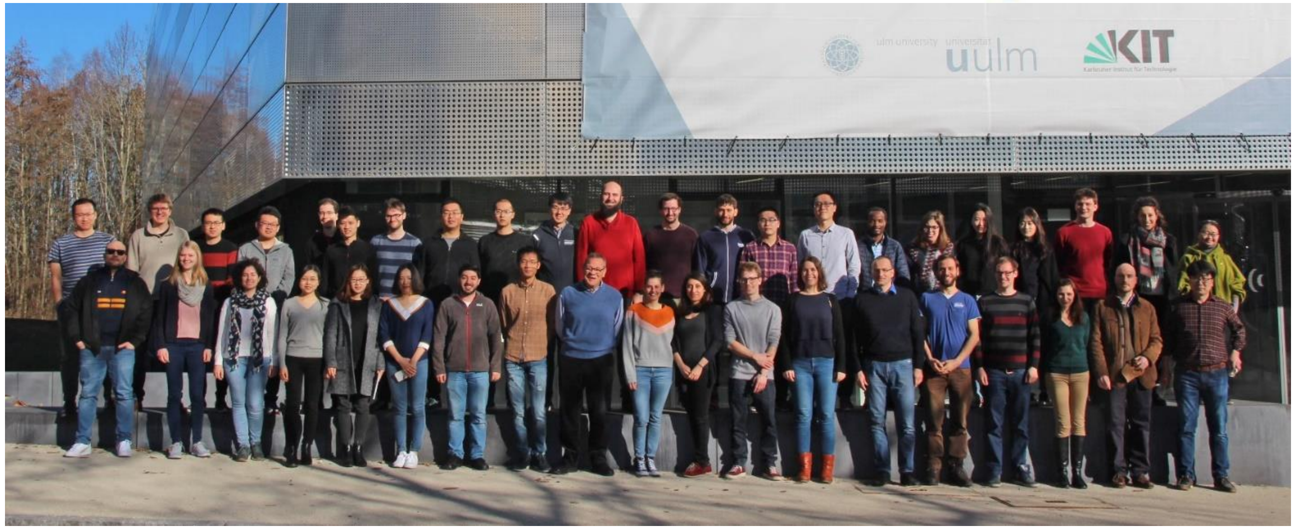
M-ERA.NET

AGENCIA ESTATAL DE INVESTIGACIÓN

ptj Projektträger Jülich Forschungszentrum Jülich

Bundesministerium für Bildung und Forschung

Israel Ministry of Science & Technology
משרד המדע והטכנולוגיה



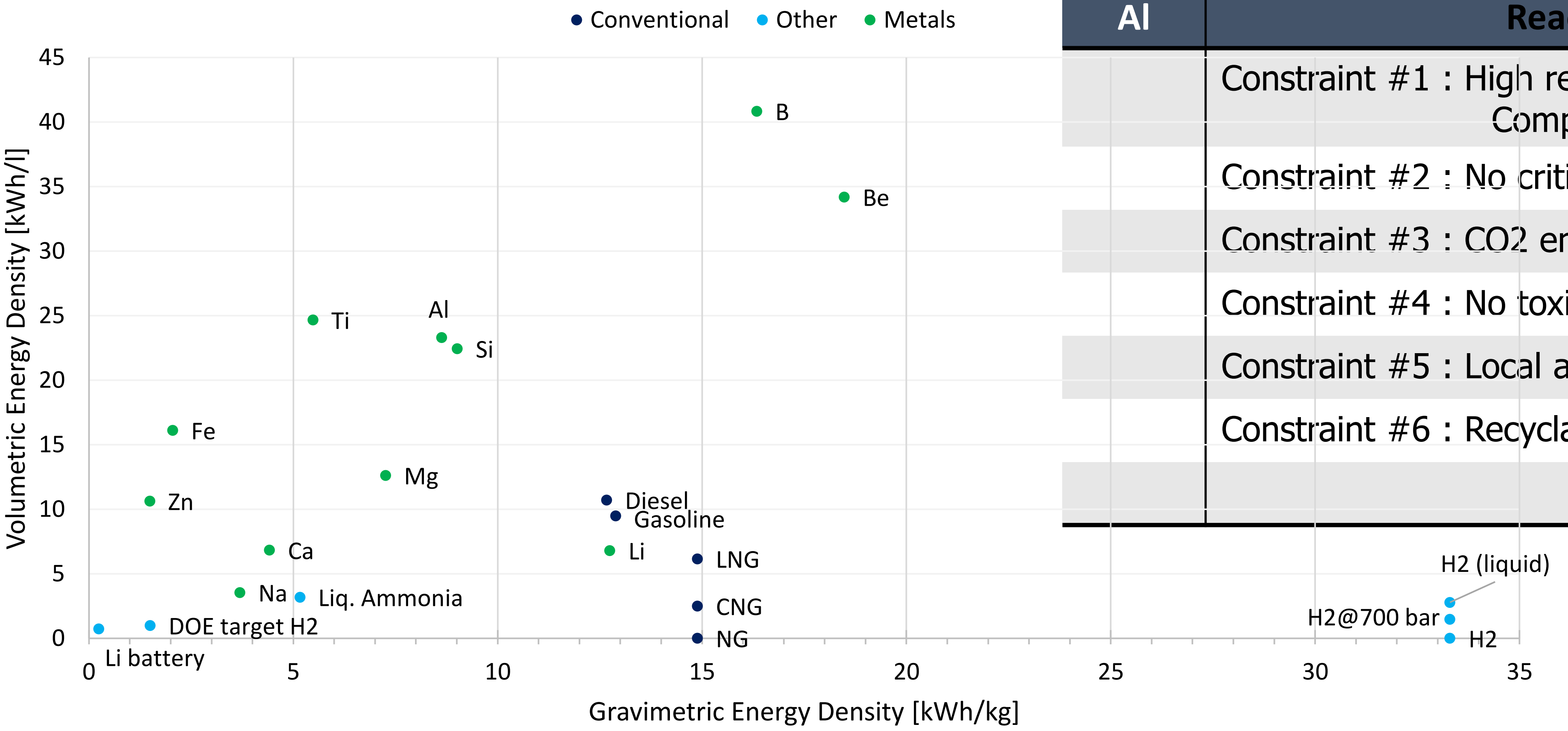
From the oil to the metal barrel

- Reative metals as the new energy vectors

Linda Barelli linda.barelli@unipg.it

Implementing Scenario: Decarbonisation @2050 - energy carriers features

Reactive metals (e.g., aluminium) enable easy, low cost, “perennial” storage

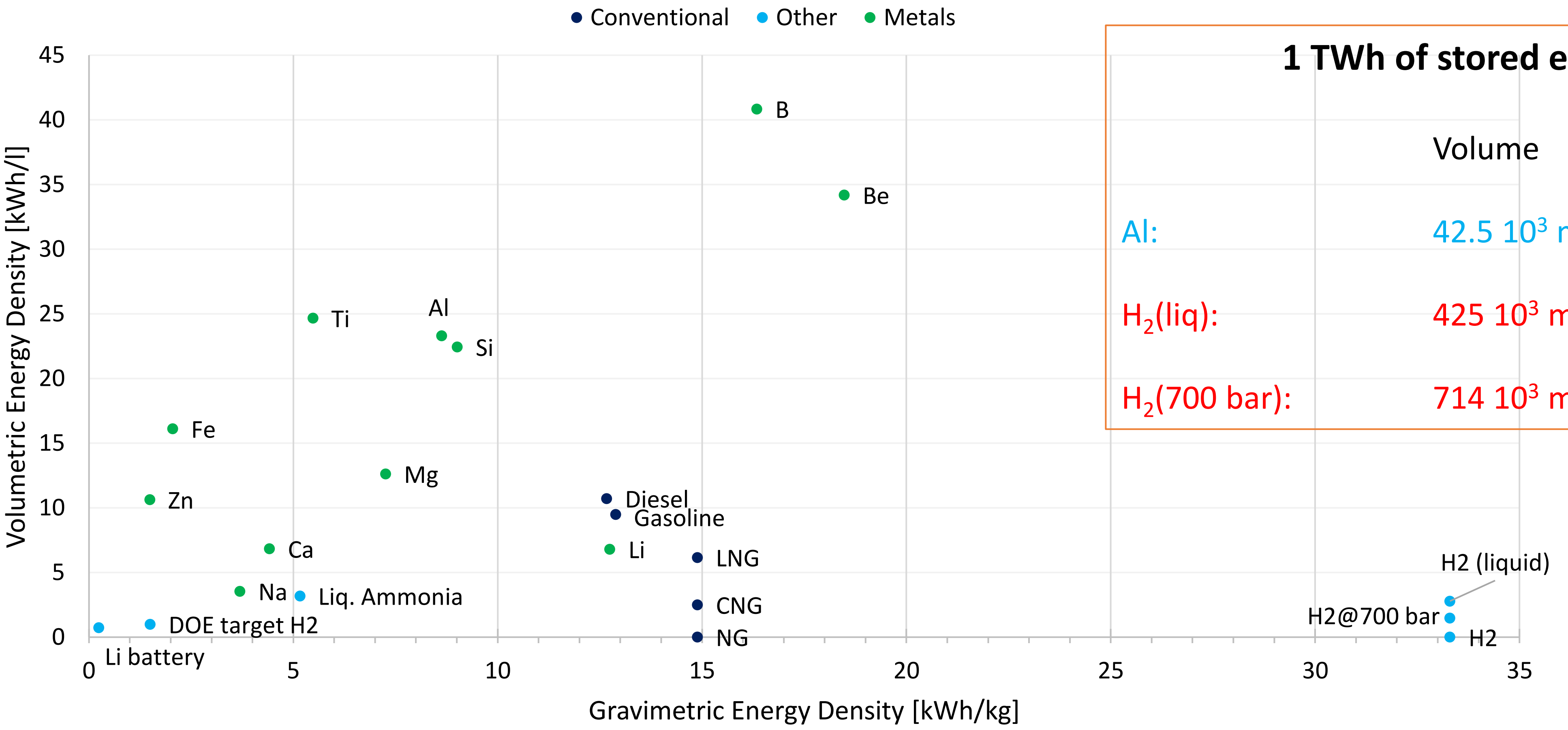


Al	Reactive metals
	Constraint #1 : High reactivity Competitive energy density
	Constraint #2 : No critical material
	Constraint #3 : CO2 emission free reduction
	Constraint #4 : No toxicity or hazard risk
	Constraint #5 : Local availability & Transportability
	Constraint #6 : Recyclability

P. Julien, J. M. Bergthorson, *Sustainable Energy Fuels* (2017) 1, 615.
D. J. Durbin and C. Malardier-Jugroot, *Int. J. Hydrogen Energy* (2013) 38, 14595–14617.

Implementing Scenario: Decarbonisation @2050 - energy carriers features

Reactive metals (e.g., aluminium) enable easy, low cost, “perennial” storage



1 TWh of stored energy equals to:

	Volume	Weight
Al:	42.5 10^3 m^3	116 10^3 Tons
H_2(liq):	425 10^3 m^3	30 10^3 Tons
H_2(700 bar):	714 10^3 m^3	30 10^3 Tons

A football field covered with 7 meters of Al corresponds to 1 TWh storage
1 cubic meter of Al yield 25 MWh – exceeding the consumption of a houshold for one year
Sodium (Na) – One of the most reactive metals, electrochemically active

Renewable production and storage demand for IT energy Independence

Assumptions

- **1807 TWh** TOTAL primary energy demand (2019)[1]
- TOTAL energy demand through RENEWABLE ELECTRICITY from PV (20% collection efficiency)
- **~1500 kWh/m² y** solar source (horizontal) weighted average value on Italian territory

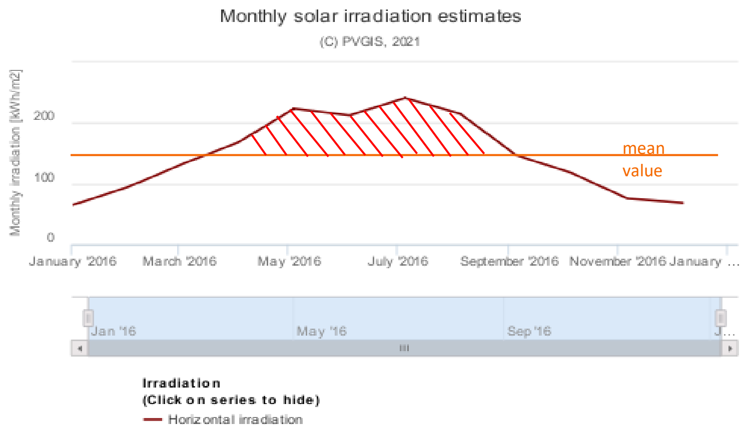
PV area to be covered in Italy

- **6024 km²** to satisfy IT primary energy annual demand

Urbanized territory

- **20000 km² (only partly exploitable)**

30% (6600 km2) → Civil & Industrial buildings
28% (6160 km2) → Roads & railways



Long-term (seasonal) energy storage

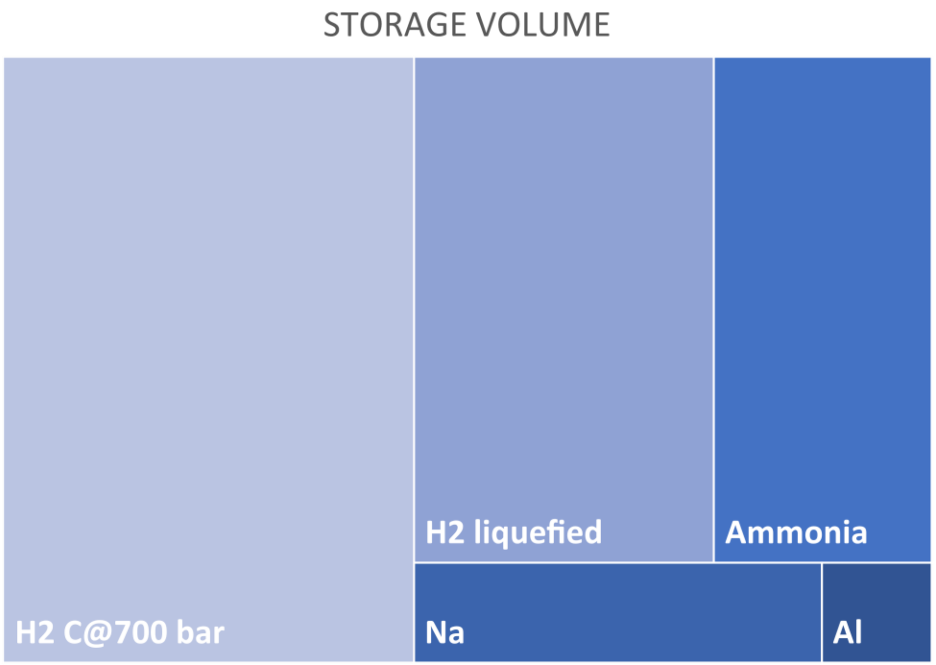
Italian demand: 399 TWh

Source: https://re.jrc.ec.europa.eu/pvg_download/map_pdfs/G_hor_IT.png

Source: https://re.jrc.ec.europa.eu/pvg_tools/en/#MR

[1]https://annuario.isprambiente.it/sys_ind/825

Implementing Scenario: IT Decarbonisation @2050 – Assessment of energy storage volume



Seasonal energy storage demand: 399 TWh (with reference to primary energy need)

Storage Media	Al	Na	Amm.	H_2 liq.	H_2 C (700 bar)
Vol. en.density (kWh/m^3)	23500	5400	3161	2300	1400
Al-to-power efficiency	0.81[2]	0.95	0.6	0.6	0.6
AVAILABLE Vol. En. Density (kWh/m^3)	19035	5130	1897	1380	840
STORAGE VOLUME (million m^3)	21	78	210	289	475
Million BARRELS (1 BARREL = 159 l)	132	489	1323	1818	2987

IT Territory occupation:

Al (10 m height): 210 km²

C H2@700 bar (10 m height): 4750 km²

+

PV area 6024 km²

vs

Urbanized territory: 22000 km²

[2] Barelli, L.; et al.. Reactive Metals as Energy Storage and Carrier Media: Use of Aluminum for Power Generation in Fuel Cell-Based Power Energy technology, 8 (9), Art. Nr.: 2000233. doi:10.1002/ente.202000233

Aluminium production & conversion

Storage phase

Al_2O_3 reduction to Al through Carbon-free (*inert non carbon anodes* [3]) Hall-Héroult process

Utilization phase

Al-to-power conversion through:

- The electrochemical path → **primary Al-batteries**
- The thermodynamic path → **water/steam oxidation**[4,5]

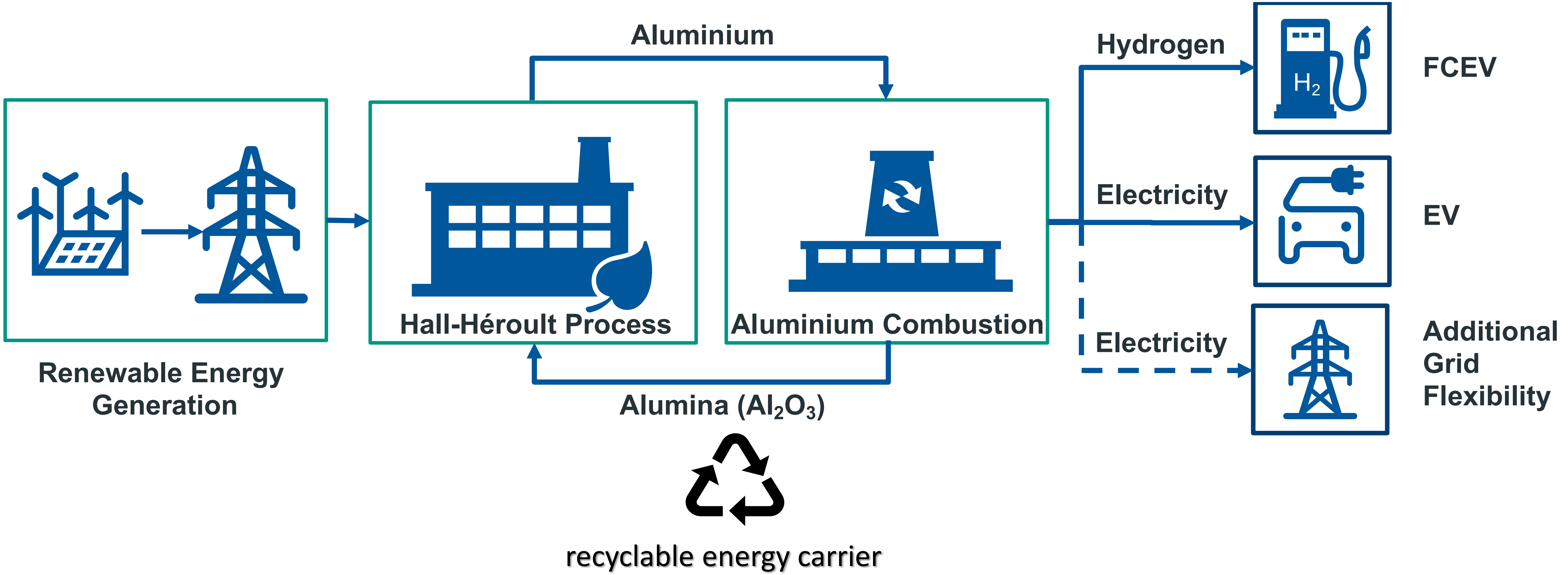
$$2Al(s)+3H_2O(g) \rightarrow Al_2O_3(s)+3H_2\,(g) \quad -815.4\ kJ/mol\ (298K,1atm)$$

1 kg of Al produces:
15.1 MJ heat
0.11 kg H_2
1.9 kg Al_2O_3 → to be recycled in the Al production

[3] Energy Efficiency and GHG Emissions: Prospective Scenarios for the Aluminium Industry, (n.d.). https://setis.ec.europa.eu/sites/default/files/reports/energy_efficiency_and_ghg_emissions.pdf

[4] E. I. Shkolnikov, A. Z. Zhuk, M. S. Vlaskin, Renewable Sustainable Energy Rev. 2011, 15, 4611.
[5] Y. Yavor, S. Goroshin, J. M. Bergthorson, D. L. Frost, R. Stowe, S. Ringuette, Int. J. Hydrogen Energy 2013, 38, 14992.

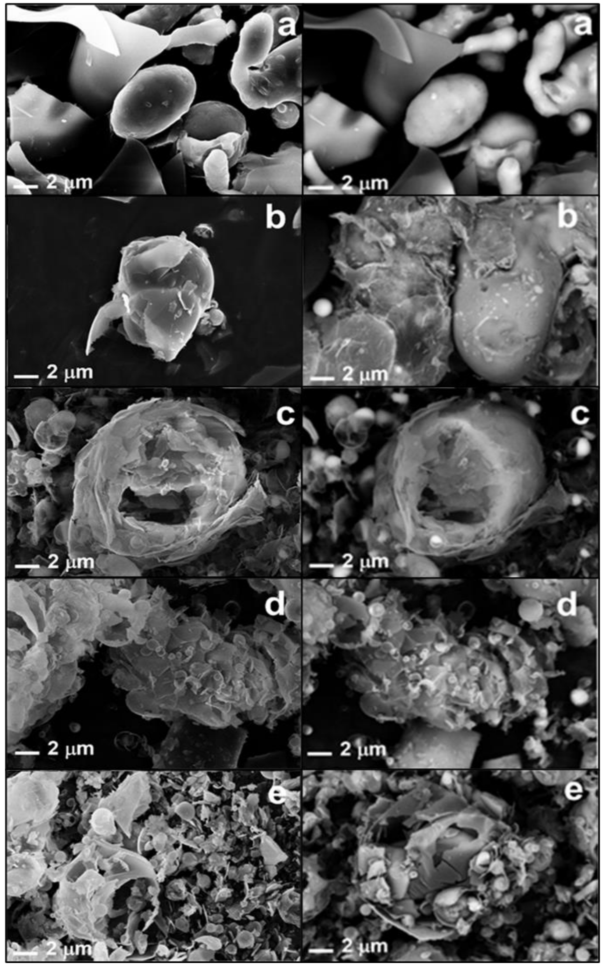
Al as energy carrier in Power-to-X applications: circular approach



H. Ersoy et al., "Hybrid Energy Storage and Hydrogen Supply Based on Aluminum—a Multiservice Case for Electric Mobility and Energy Storage Services"
Advanced Materials Technologies, Jan. 2022, doi: 10.1002/admt.202101400

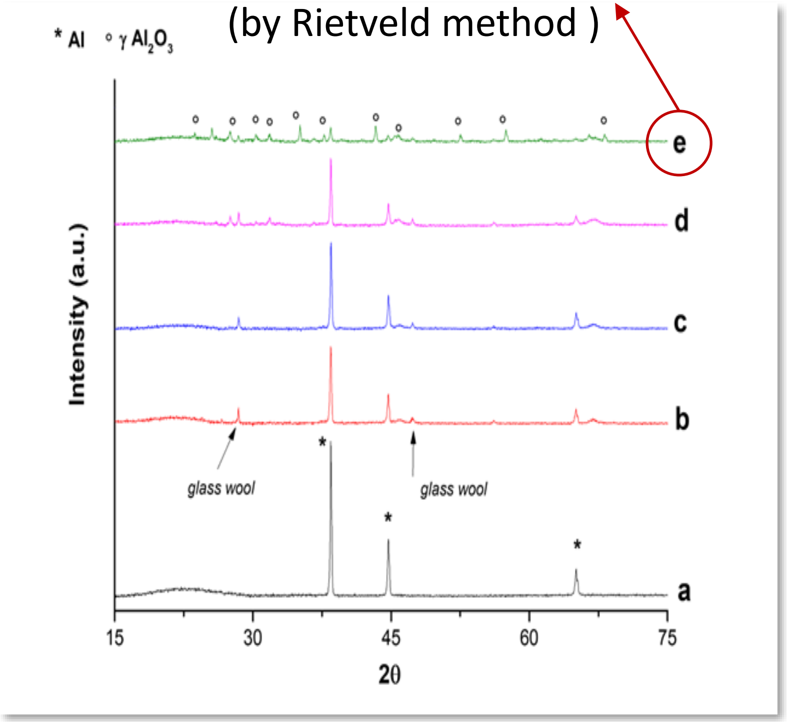
Implementing Scenario: Decarbonisation @2050 - Aluminium steam oxidation

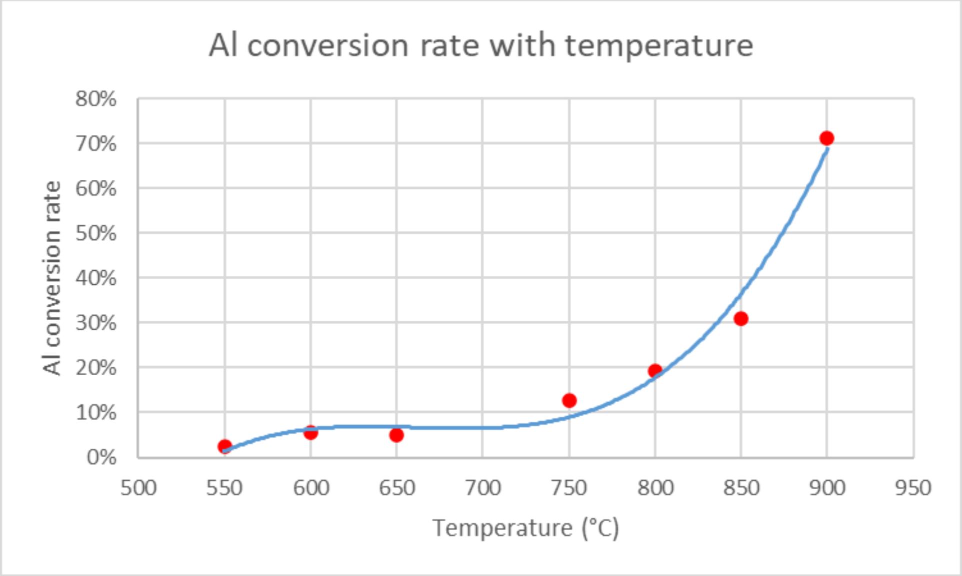
Solid product SEM images



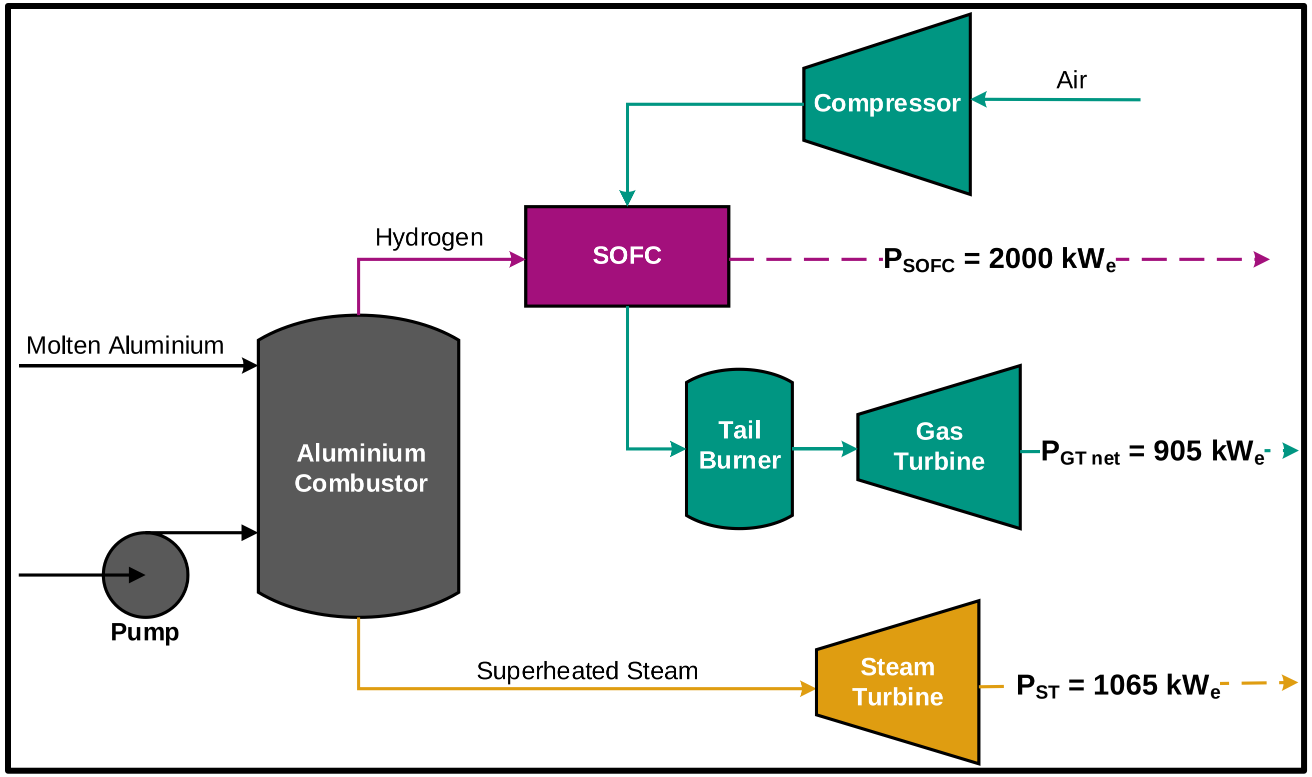
a) 600 °C, b) 750 °C, c) 800°C, d) 850 °C, e) 900°C
water flow rate: 60 g/h; 0.2 g loaded Aluminum
(with backscattered detector in the second column)

g-Al2O3 83.4 % while **Al 16.6 %**
(by Rietveld method)





L. Barelli et al., “Aluminum steam oxidation in the framework of long-term energy storage: experimental analysis of the reaction parameters effect on metal conversion rate”
Energy Technology (under review)



$\dot{m}_{AL}$ (kg/sec) Al powder	0.275
P_{tot} (kW)	3,892
$\eta_{P\text{-}P}$ (%)	35.6

$E_{smelting}$ fixed at 39.63 kJ/g_{Al}

-15% with respect to the state of the art smelters specific consumption.

It considers[3]:

- ✓ Use of wettable drained cathode technology (energy savings estimated at 15-20%)
- ✓ Use of inert and dimensionally stable non-carbon anodes.

---

[3] Energy Efficiency and GHG Emissions: Prospective Scenarios for the Aluminium Industry, (n.d.). https://setis.ec.europa.eu/sites/default/files/reports/energy_efficiency_and_ghg_emissions.pdf

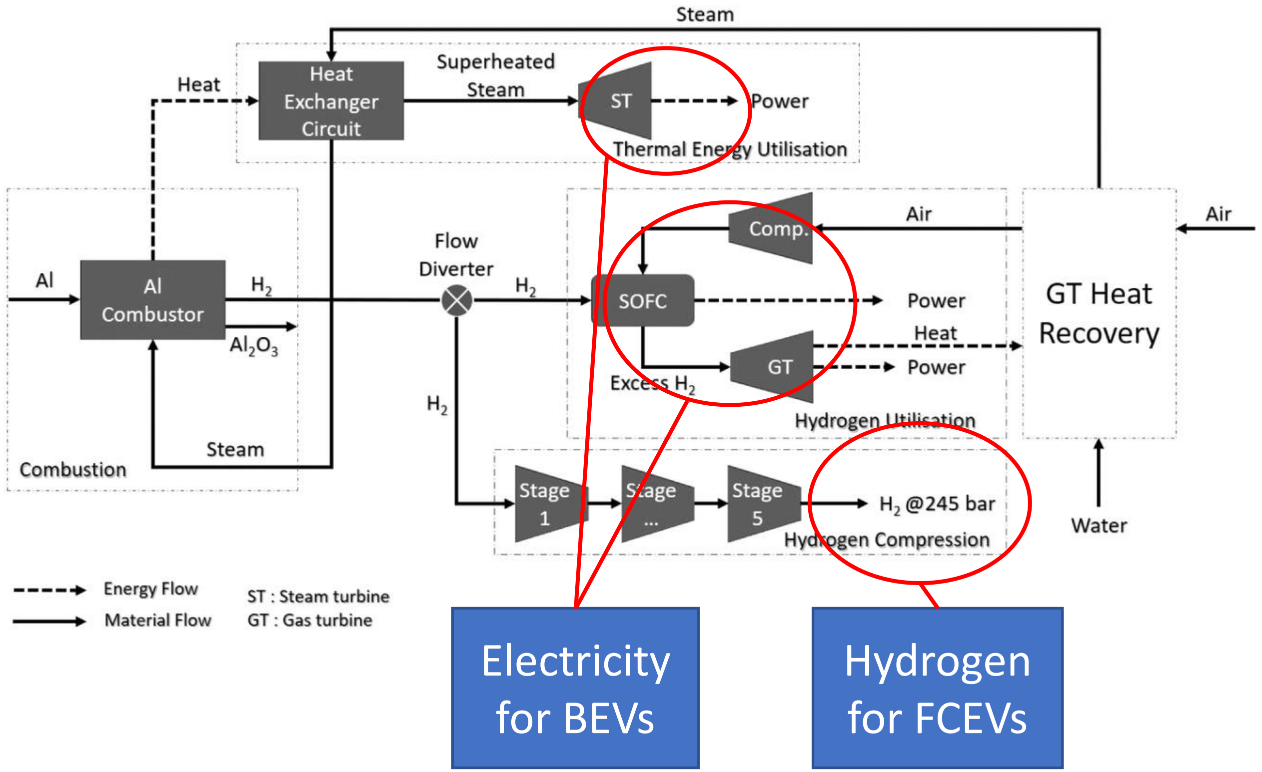
RTE, vol. energy density for different technologies and energy carriers in Power-to-Power applications

Energy Carrier	Conversion Technology	Round Trip Efficiency (RTE)	Energy Density [kWh/L]
Al	Aluminium Wet – Combustion (ST,GT, & SOFC)	35.6 %	23.5
H_2	PEM Electrolyzer – PEM Fuel Cell (PEMFC) Reversible – Solid Oxide Cell	30% (H_2@200 bar) 48% (H_2@70 bar)	0.53 0.2
Methanol / DME	Solid Oxide Electrolizer (SOE) / H_2 to methanol-DME / Solid Oxide Fuel Cell (SOFC)	36% (26.5%)	5.5
Gasoline	SOE/ H_2 to gasoline/SOFC	27% (20%)	8.8
LNG	SOE/TSA dehydration, H_2 and CO_2 membrane separation/SOFC	28% (23%)	5.8

The RTE values in brackets include the thermal (1750 kWh/tCO_2) and electric (250 kWh/tCO_2) specific consumptions for CO_2 direct air capture for low-temperature solid sorbent technologies

Barelli, L.; et al.. Reactive Metals as Energy Storage and Carrier Media: Use of Aluminum for Power Generation in Fuel Cell-Based Power Energy, Energy Technology 2000233 (2020)

Case study:
multi-technology refueling/recharging stations for EVs[6]



Technical features of the station

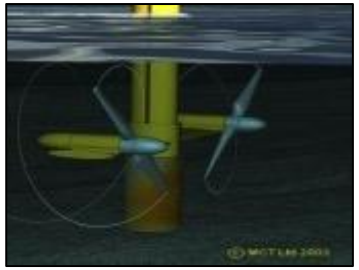
SOFC Partial Loads	Produced P_{el}	Produced H2	$\eta_{Power\text{-}to\text{-}X}$
100%	~4 MW	-	35.6%
80%	3.1 MW	28 kg/h	38.8%
65%	2.6 MW	46.8 kg/h	40.7%

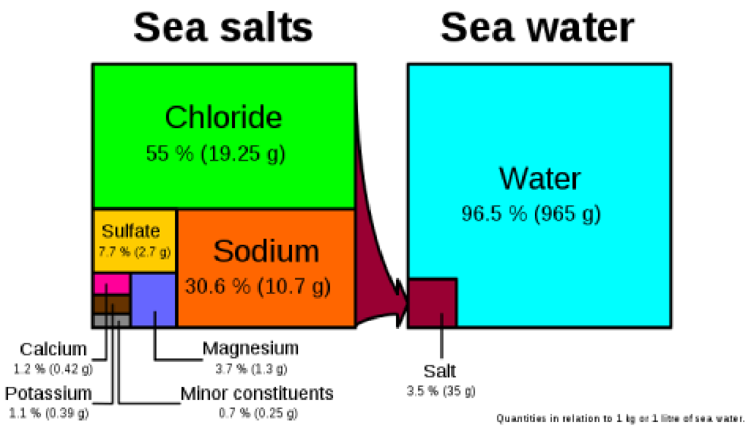
- Feeding Al stream: 0.275 kg/s
- CAPEX: 4200–6200 €/kW

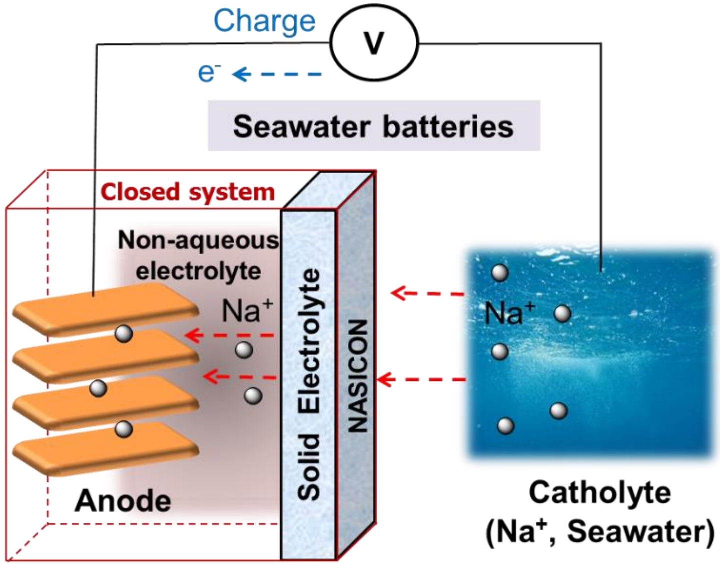
H. Ersoy et al., “Hybrid Energy Storage and Hydrogen Supply Based on Aluminum—a Multiservice Case for Electric Mobility and Energy Storage Services”
Advanced Materials Technologies, Jan. 2022, doi: 10.1002/admt.202101400

[6] International Energy Agency: *Net-zero by 2050 (https://www.iea.org/reports/net-zero-by-2050)*
Hydrogen Council: *Roadmap towards zero emissions: The complementary role of BEVs and FCEVs (https://hydrogencouncil.com/wp-content/uploads/2021/10/Transport-Study-Full-Report-Hydrogen-Council-1.pdf)*

Na & electrochemical conversion: Na/seawater batteries







	Negative electrode	Positive electrode
Charge:	$Na^+ + (H) + e^- \rightarrow Na(H)$	$NaCl\ (aq) \rightarrow Na^+ + 1/2Cl_2\ (g) + e^-$ $NaCl\ (aq) + 2OH^-\ (aq) \rightarrow Na^+ + ClO^- + H_2O + 2e^-$ $2OH^-\ (aq) \rightarrow H_2O + 1/2O_2\ (g) + 2e^-$
Discharge:	$Na(H) \rightarrow Na^+ + e$	$2Na^+ + H_2O + 1/2O_2\ (g) + 2e^- \rightarrow 2NaOH\ (aq)$

- Seawater (Unlimited resource!) is exploited at the cathode
- Stored energy is proportional to the amount of stored Na

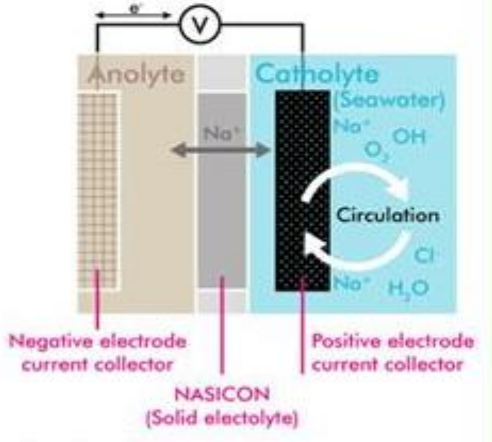
Implementing Scenario: Decarbonisation @2050 – Na/seawater batteries

- **Energy storage in stationary applications in the sea environment**

  Further functionalities
  Na production
  Industrial & tap water
  Cl-based chemicals production

- **Further application in the transport sector:**
  Propulsion for marine and sub.marine applications

charge $2\,NaCl + electricity \rightarrow 2\,Na + Cl_2$



discharge $2\,Na^+ + H_2O + ½O_2(g) \rightarrow NaOH + electricity$

NaOH

Air $\rightarrow$ $2NaOH + CO_2 \rightarrow Na_2CO_3 + H_2O$

CO_2 absorption rate of 20% at pH 8

SBAM project
funded by MITE (Italian Minister of Ecological Transition)

NSB architectures to be investigated

1) open cathodic compartment (*Na* internal storage)
2) open battery (*Na* external storage) - *Optional*

Activities:

Material optimization to enhance battery performances
Development and test of prototype at coin cell scale
<u>Stack development and optimization</u>
<u>Development & test of prototype at pre-commercial scale (tens of cm^2)</u>

Implementing Scenario: Decarbonisation @2050 – Na/seawater batteries

Business case: Sardinia

Energy features

- Absence of the natural gas distribution infrastructure;
- Electric grid to be improved;
- Large RES potentials

Annual energy demand:

- Primary TOTAL 2023,5 ktep (23,5 TWh)

- <u>electricity 8,47 TWh</u>

Seawater Battery

Seasonal energy storage demands:

- 4,43 TWh (69 km² PV)
- <u>1,59 TWh (25 km² PV)</u>

High storage capacity with external Na storage

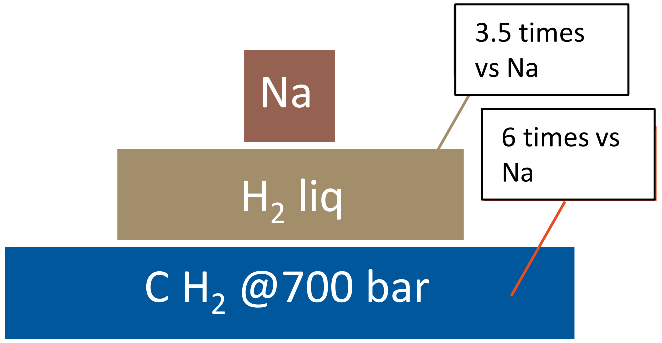
High RTE

Cl_2 production

Desalinized water production

CO_2 sequestration

Advantages



Confronto volume di accumulo per diverse tecnologie.

<u>131 mil m³</u>
(needs of 1.64 million inhabitants)

<u>57.700 tonnes of CO2</u>
36,2 g CO_2 per stored kWh

Biomass: the natural link between energy storage and hydrogen

V. Mulone

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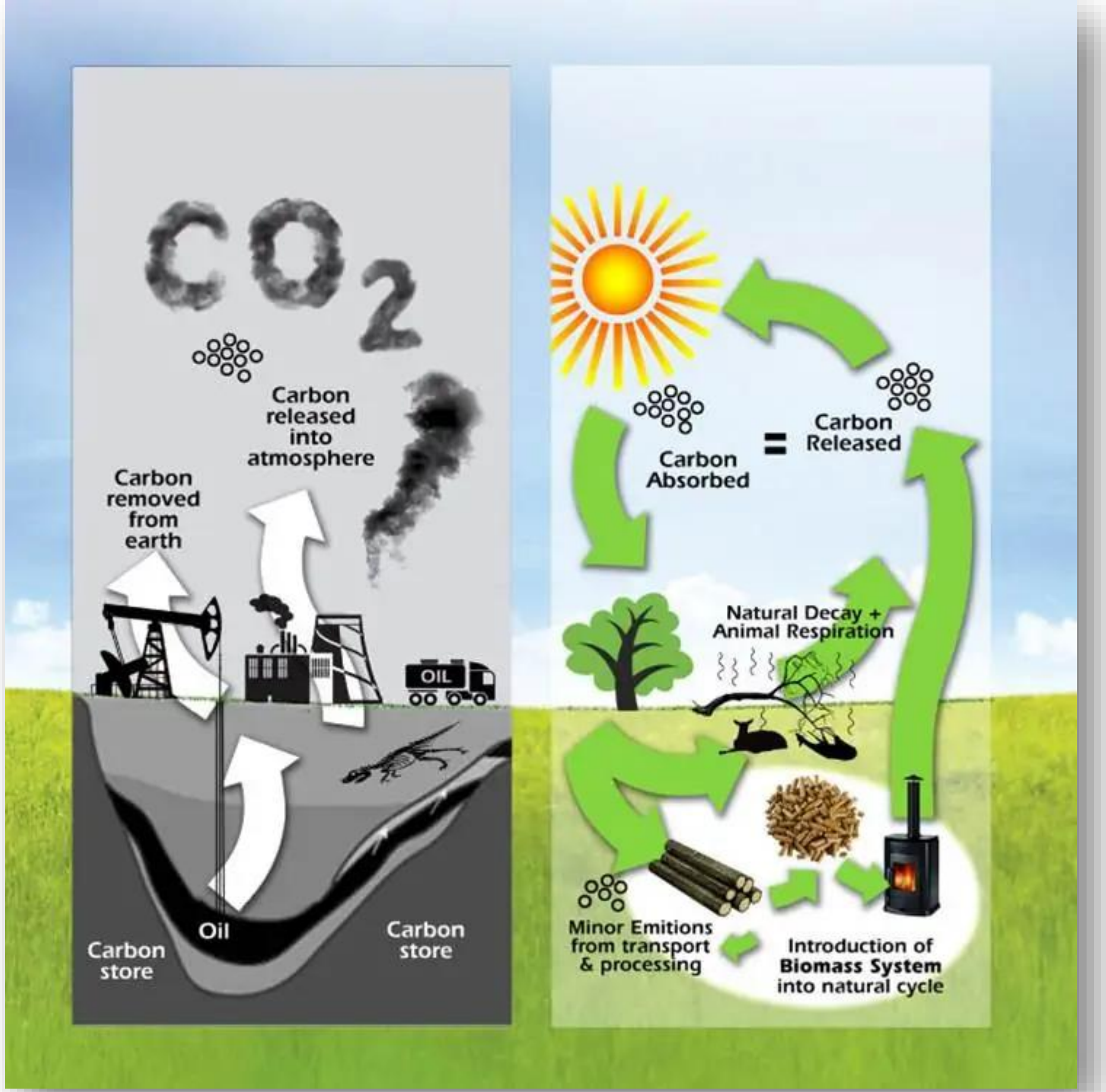
Biomass

- Biomass is renewable organic matter
- It is the biodegradable fraction of products, waste and residues from biological origin from agriculture including vegetal and animal substances, from forestry and related industries, including fisheries and aquaculture, as well as the biodegradable fraction of waste



Biomass for energy

- Bioenergy is the main contributor in the distribution of renewable gross final energy consumption in EU28
- Solid biomass, biofuels, biogas and renewable municipal waste are currently more common in the heating and transport sectors
- Biomass is then used commonly in low efficiency, low energy density systems, in competition with food and material supply, and with high pollutant emissions

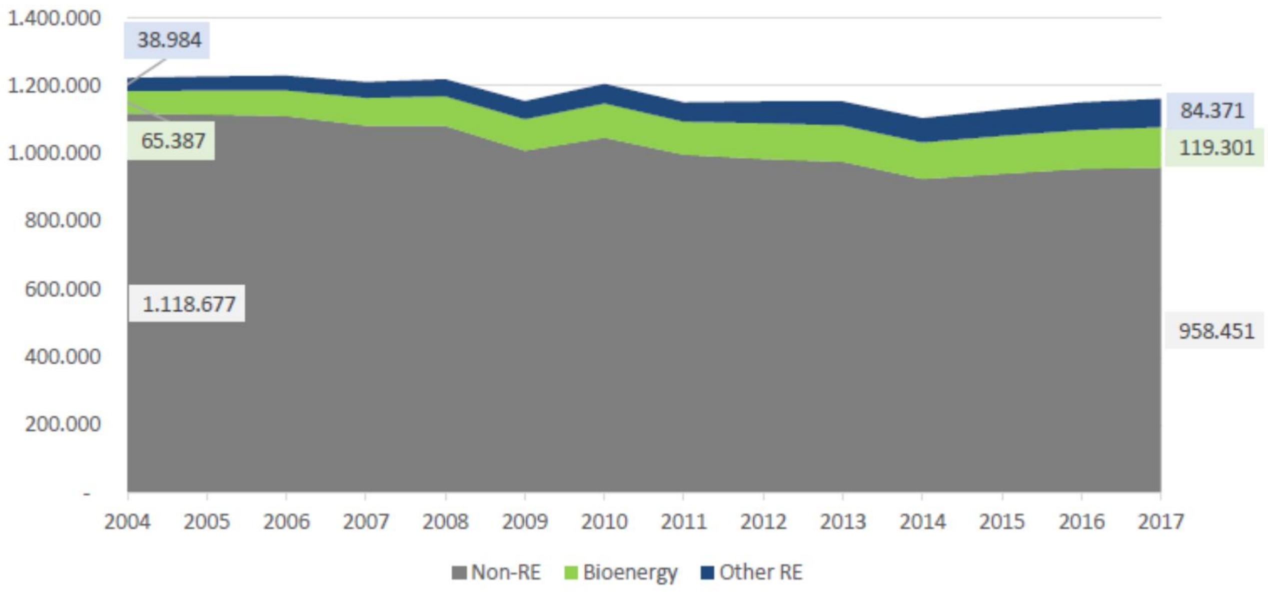
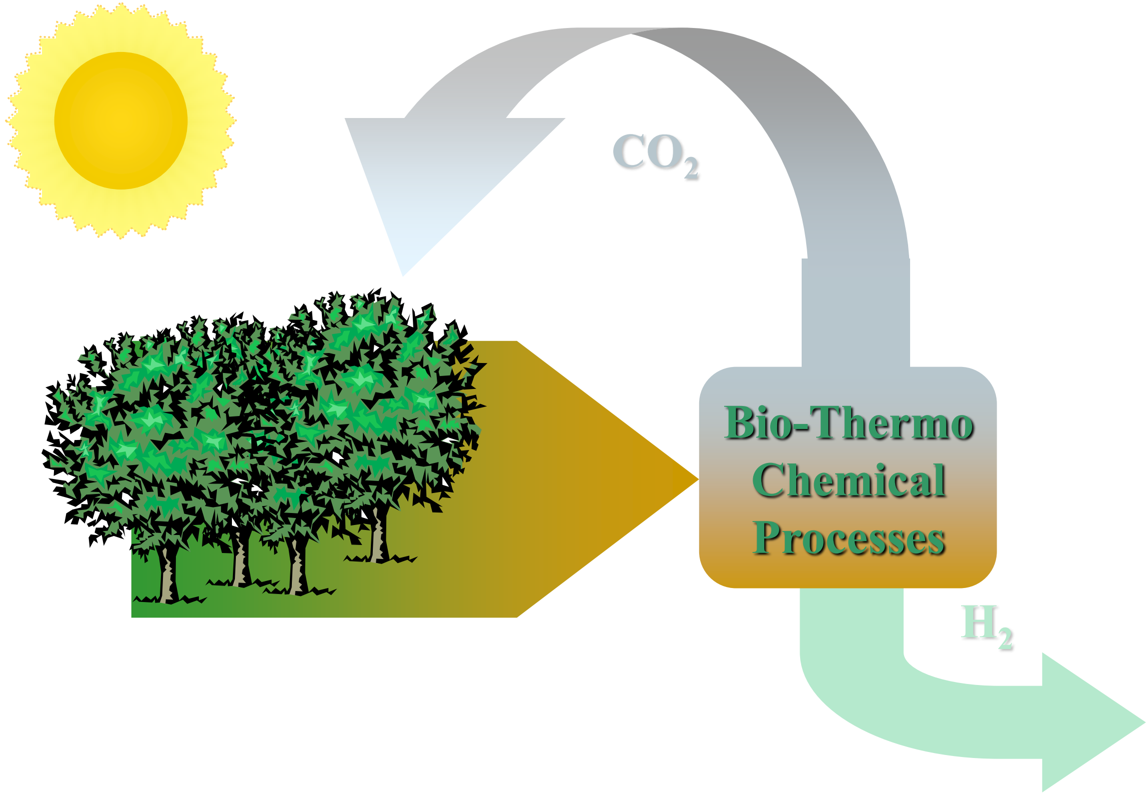


Figure 2: Gross final energy consumption by fuel type in EU28 (ktoe), Source: Bioenergy Europe, Eurostat

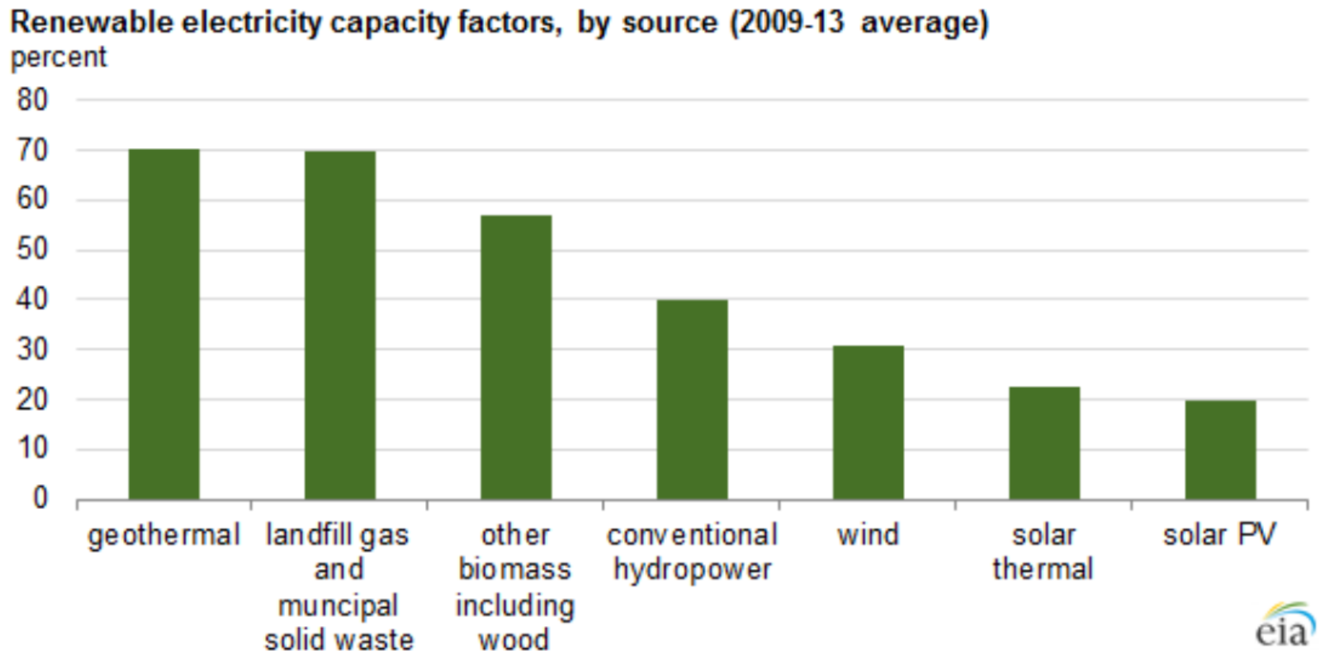
Residual biomass: the availability

- Residual biomass is the key
- In EU there are available
  - 265 Mt/y agriculture residues
  - 168 Mt/y forestry residues
  - 131 Mt/y industrial residues
  - 88 Mt/y municipal waste residues
  - 26 Mt/y digestate residues
- Residual biomass can be used to produce H_2 and e-fuels (or both), with no competition with food and materials, by investing in innovative technological solutions



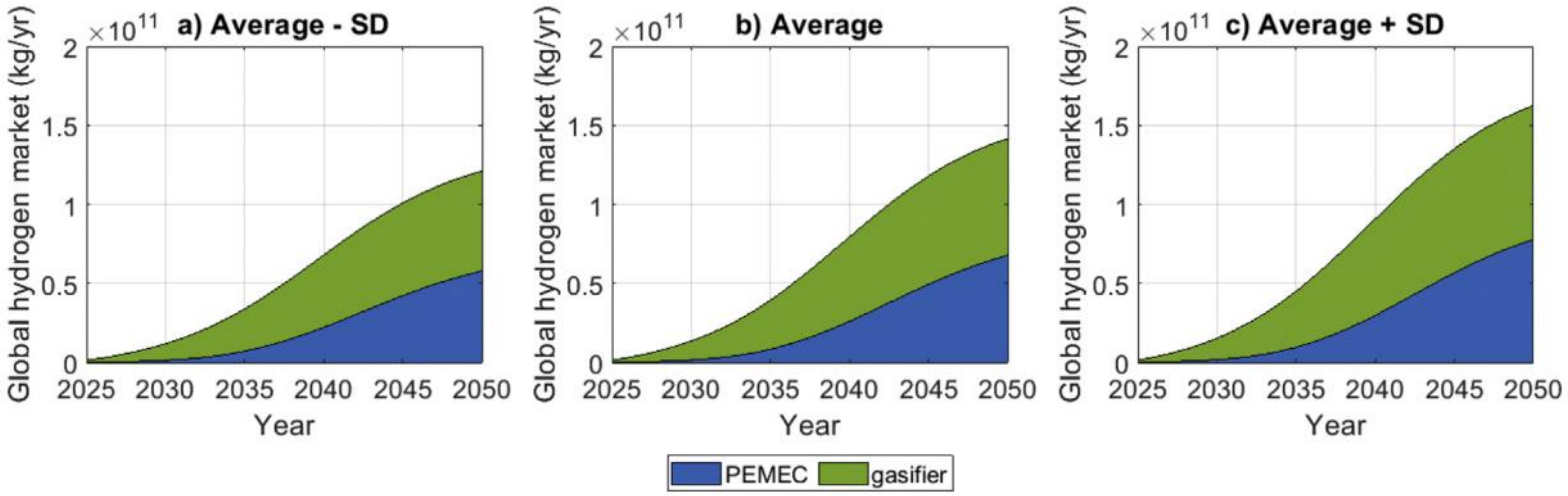
Biomass capacity factor

- Biomass suffers less than other RES from seasonal fluctuation
- Feedstock storage capacity is a key aspect
- The transition toward high RES penetration can be better managed thanks to the high capacity factor



Source: U.S. Energy Information Administration,

Green H_2 from biomass: market perspective



B. Lane et al. Int. J. Hydrogen Energy, 2021

Green H_2 from biomass: techno-economic perspective

- With residual biomass cost at 0.07€/kg, H_2 from biomass is economically sustainable
- Learning curves of technologies are different, and feedstock costs will evolve differently too

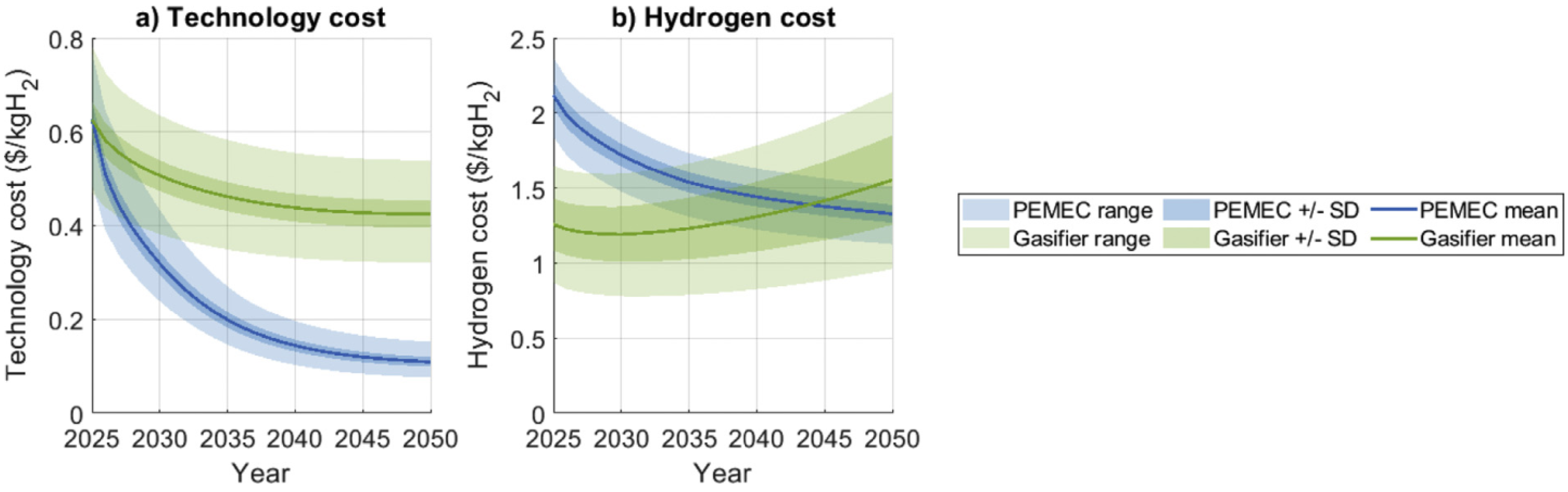


Fig. 6 – Projected a) hydrogen production technology cost and b) produced hydrogen cost.

Biomass conversion: the conventional routes

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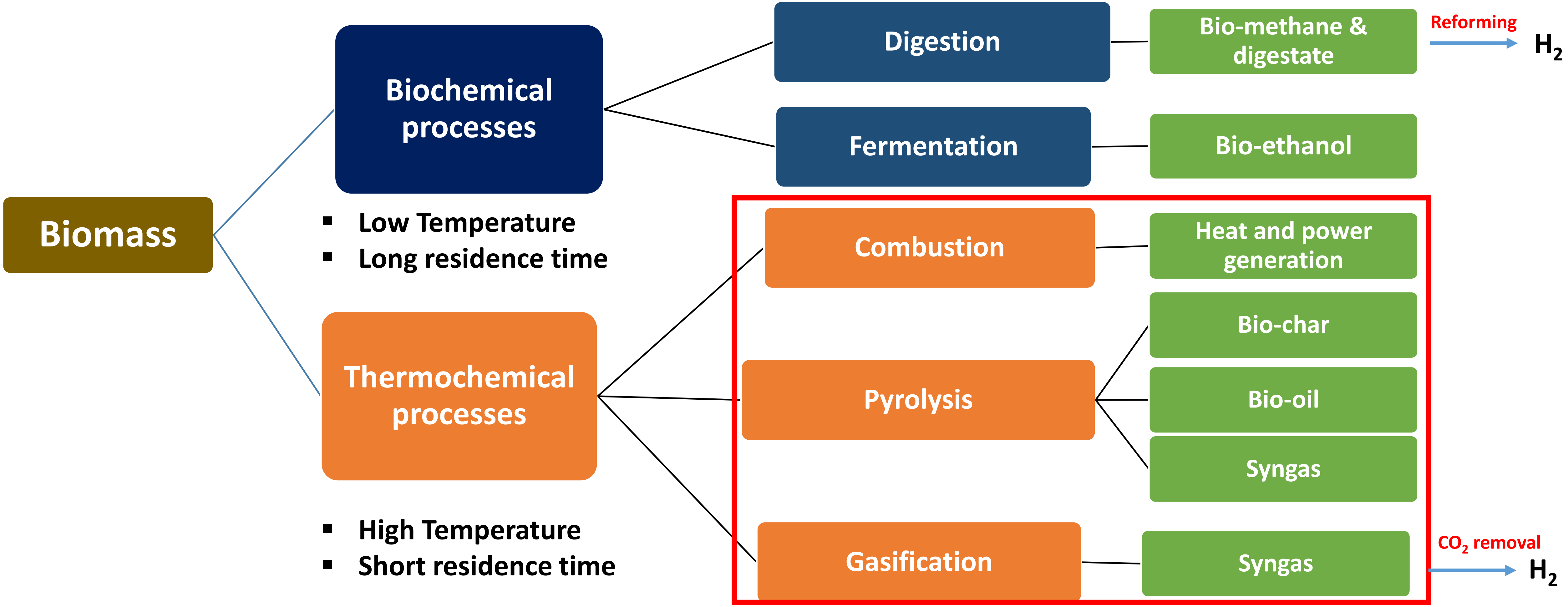
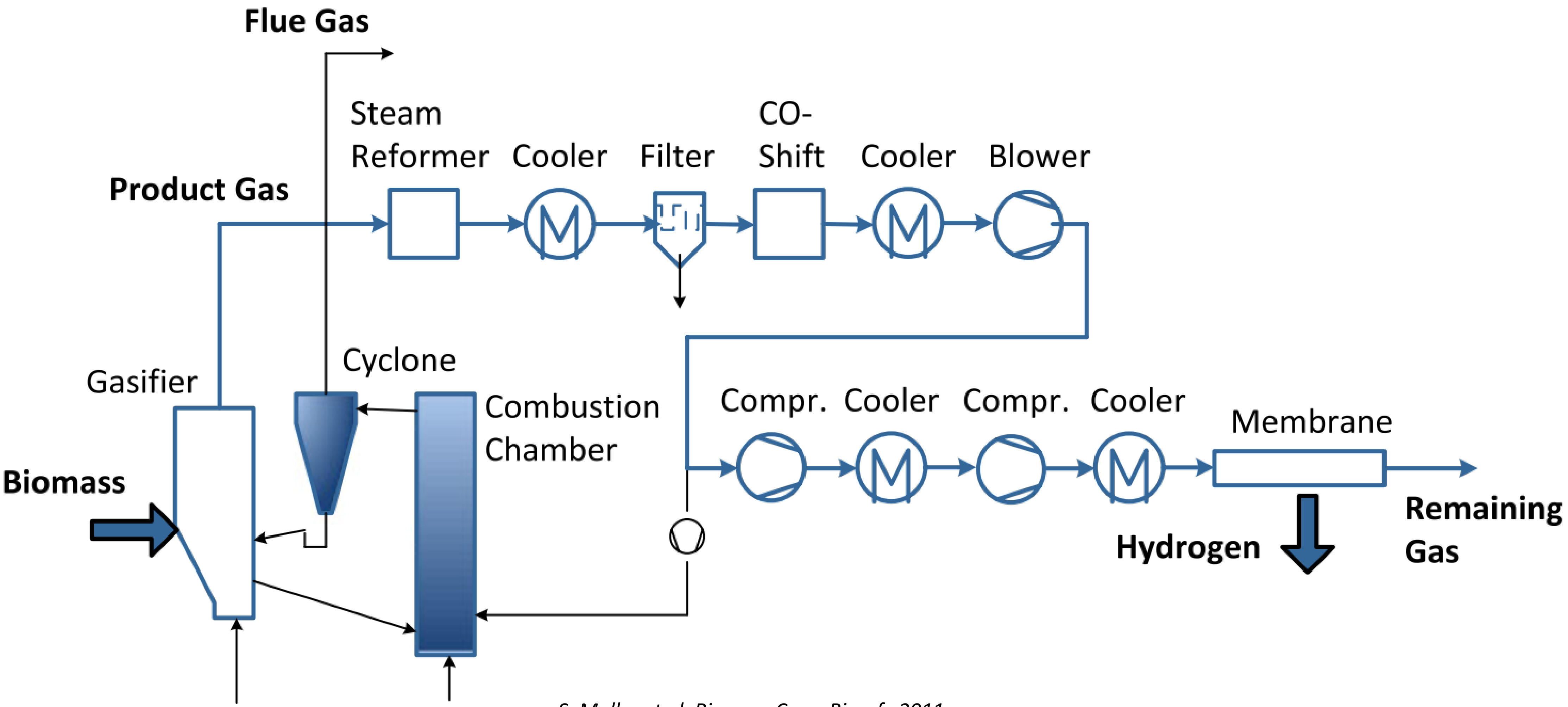


Dual-fluidized bed gasifier for H_2 production



S. Muller et al. Biomass Conv. Bioref., 2011

Dual-fluidized bed gasifier: TUWien 100kW$_{th}$ pilot plant

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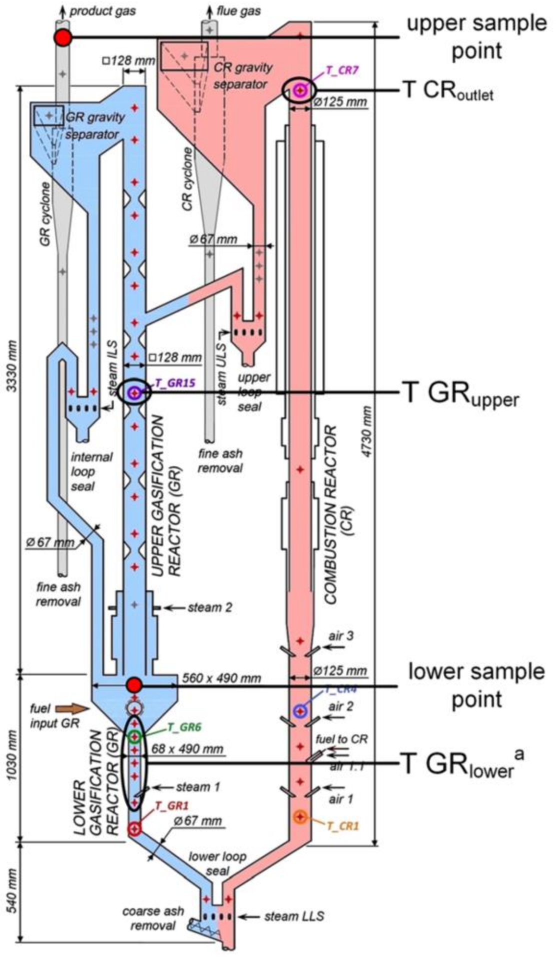
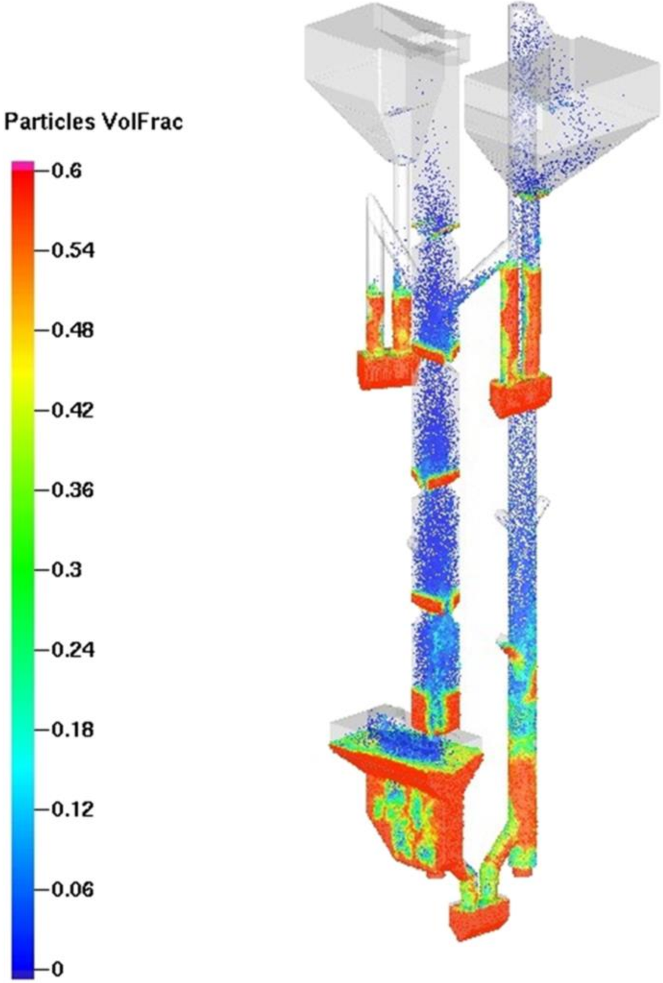
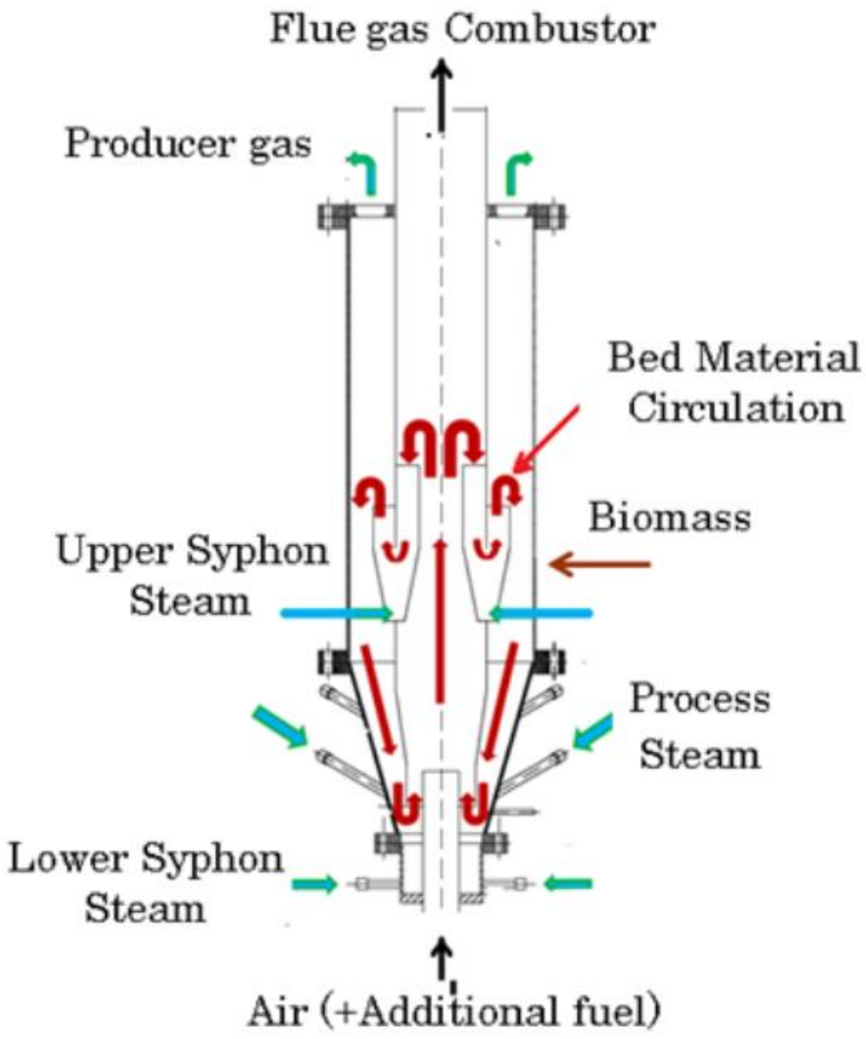
Fig. 3 Upper part of the 100 kW$_{th}$ gasification pilot plant, TU Wien [28]





A.M. Mauerhofer et al. Biomass Conv. Bioref., 2021

Dual-fluidized bed gasifier: HBF2.0 100kW$_{th}$ pilot plant



A.Di Carlo et al. Chemical Engineering Journal., 2019

Steam Gasification of hydrochar from food waste

- H_2 yield depends on:
  - Feedstock characteristics
  - Reactor operating temperature
  - Steam-to-biomass ratio
  - Gasifier design (residence time, thermal history)
  - Bed material – inert, catalysts, CO_2 sorbents
  - Energy efficiency depends highly on thermal management of the system through integration

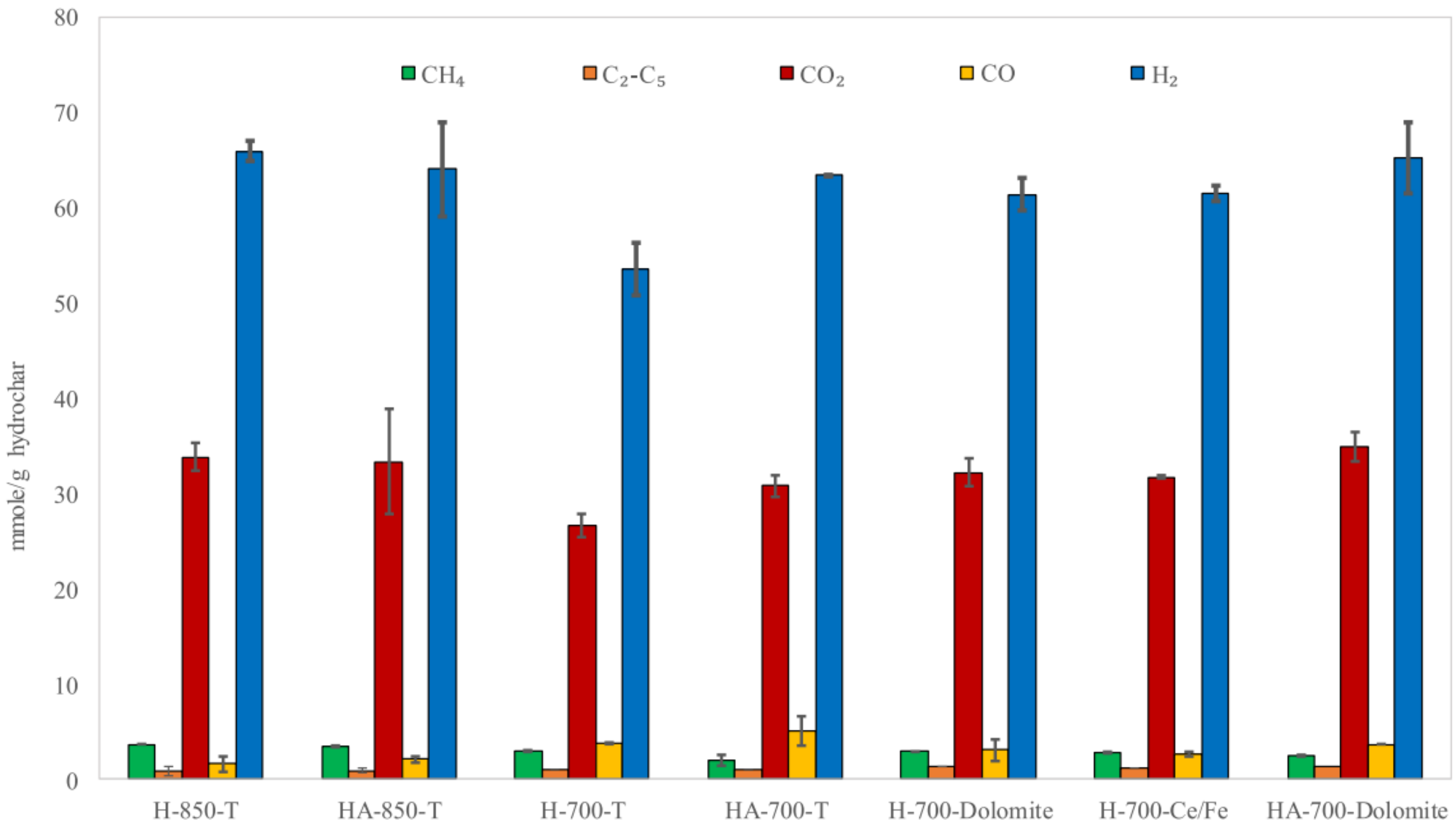


Fig. 4 – Gas yields from steam gasification of hydrochar derived from food wastes.

G. Duman et al. Int. J. of Hydrogen Energy, 2018

Two-stage gasification process

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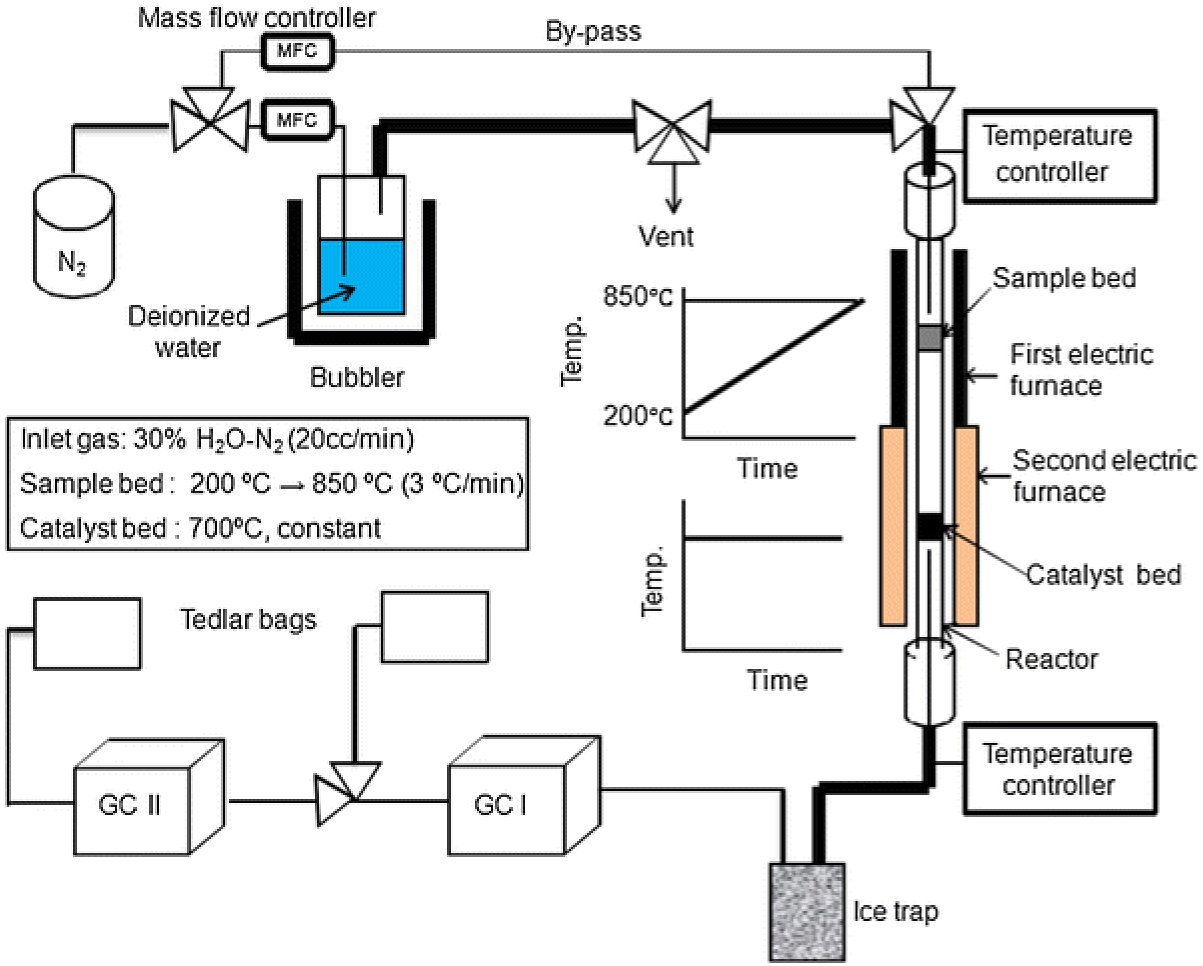
- Two stage gasification is a promising technology
- Temperature are controlled separately, the second one is a catalyst bed



H. Cay et al. Energy & Fuels, 2019

Feedstock pretreatment

- Two stage gasification reactors have better performance towards H_2 production
- Pretreatment is important too
- HTC (HC label) is a promising technology
- Pyrolysis (P label) is even more impacting the H_2 production
- Pretreatment of spent coffee grounds by HTC and Pyrolysis give better performance than RB=Raw Biomass

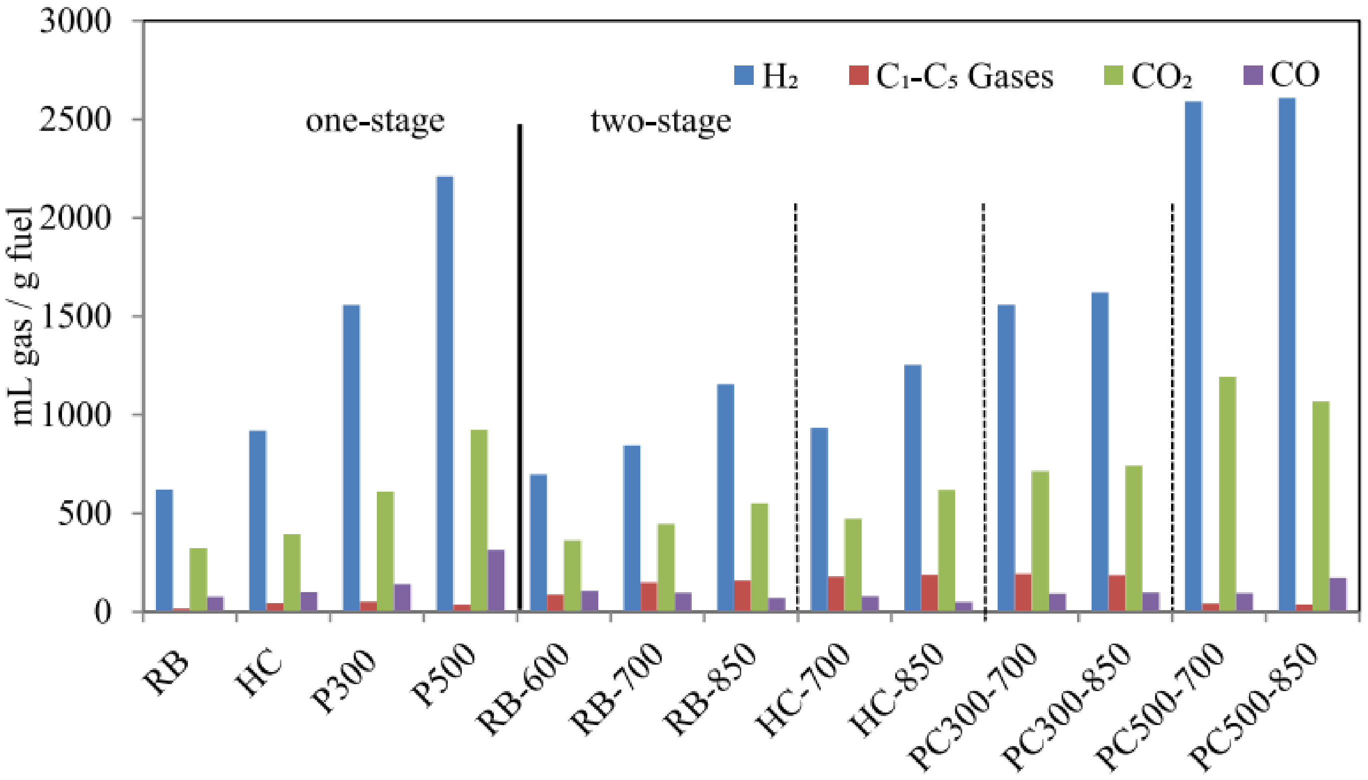
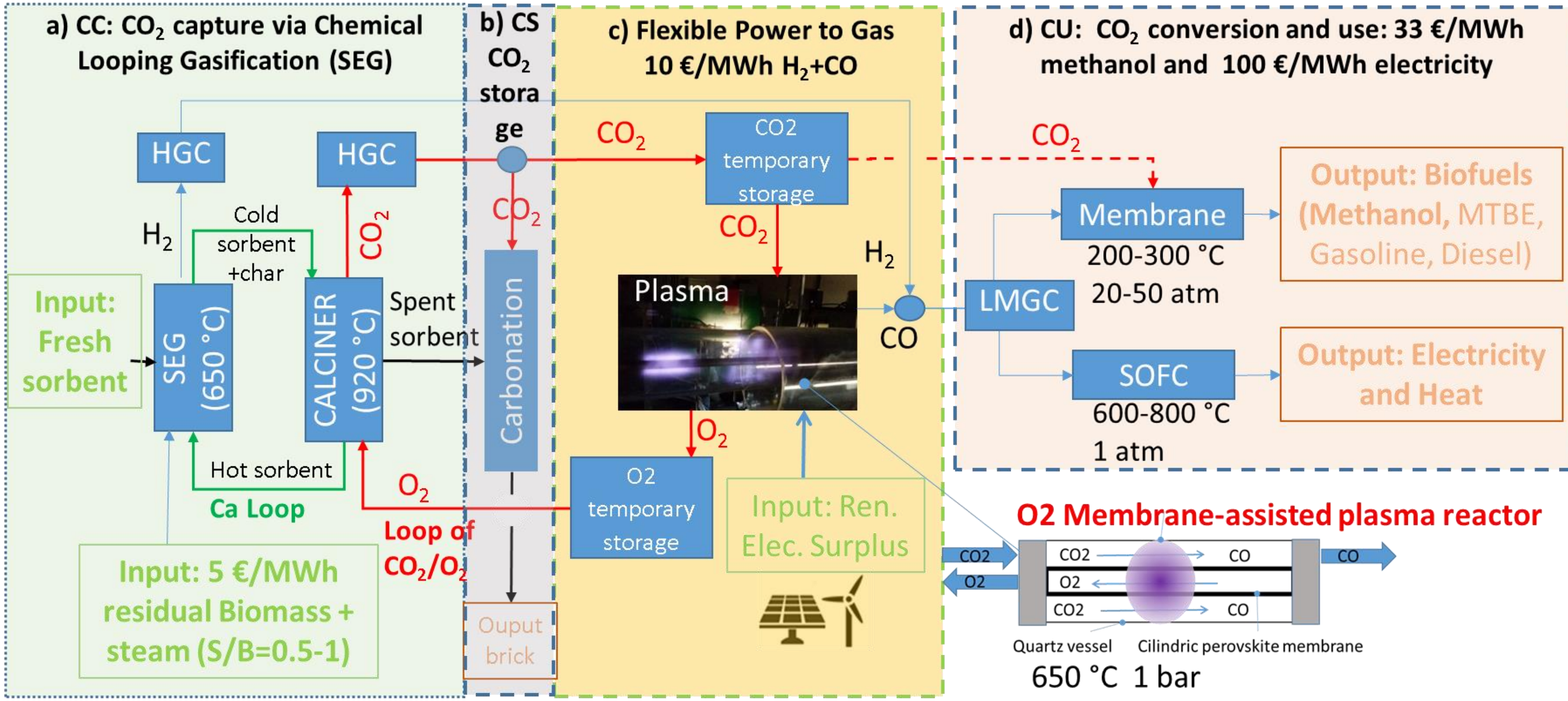


Figure 1. Gas yields from thermal steam gasification by one-stage and two-stage processes.

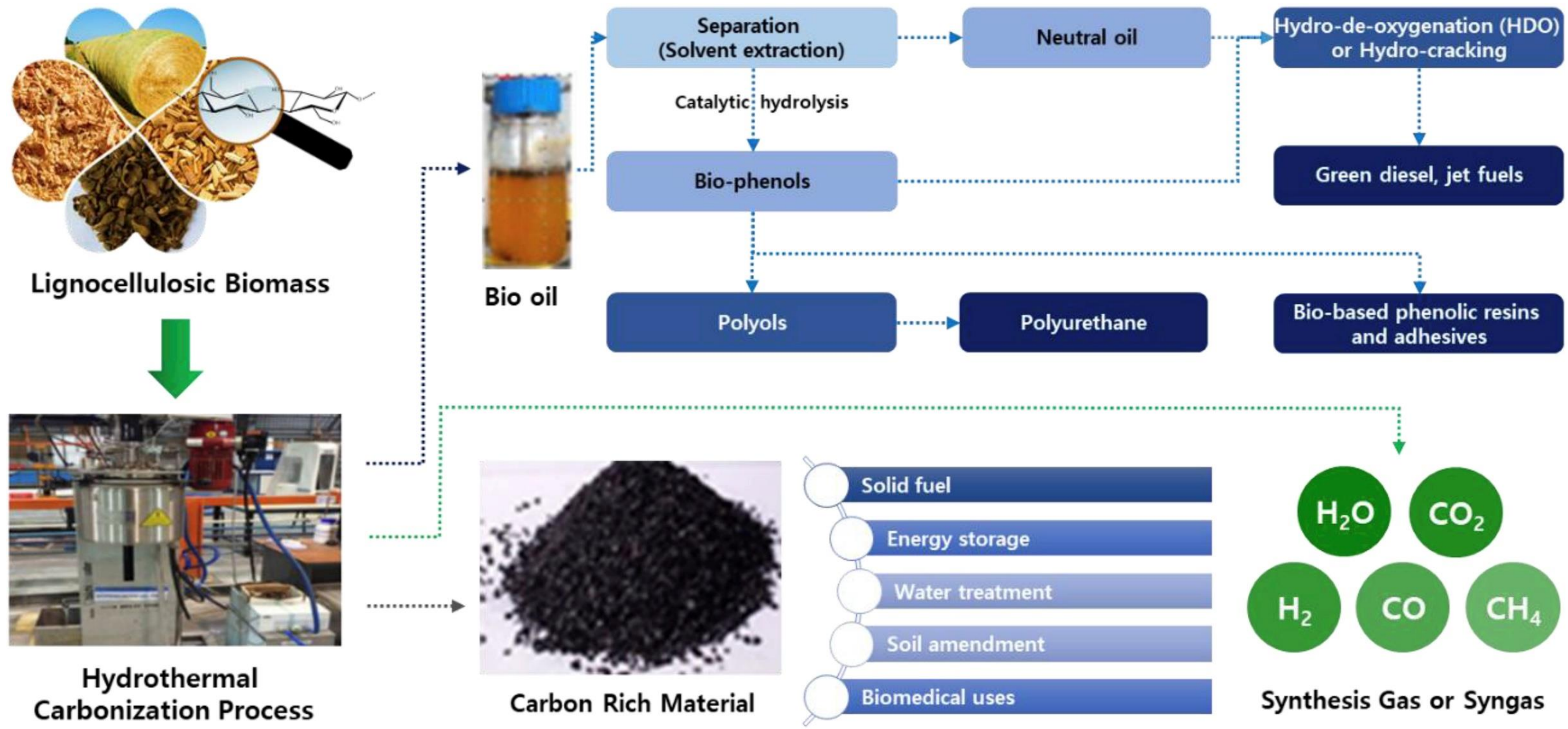
H. Cay et al. Energy & Fuels, 2019

Multi-Input Multi-Output Systems: GICO

- GICO is an advanced multi-input multi-output system for (H_2), e-fuels, electricity and heat production
- Energy storage can help in managing the input RES surplus, to couple the production to the utilization of H2, e-fuel, electricity and heat



HTC pretreatment



T.A. Khan et al. Biomass and Bioenergy, 2019

Pyrolysis thermal pretreatment

SWP

SCG

Feedstock Drying

(12 H @ 105°C)

Biomass

Feeding

0.5 kg/h

Inert Gas Supplying

Nytrogen (N2) or carbon dioxide (CO2)

Heating

Electric

Resistor

(300 W)

INTEGRATION TO THERMAL STORAGE

Quenching

Product

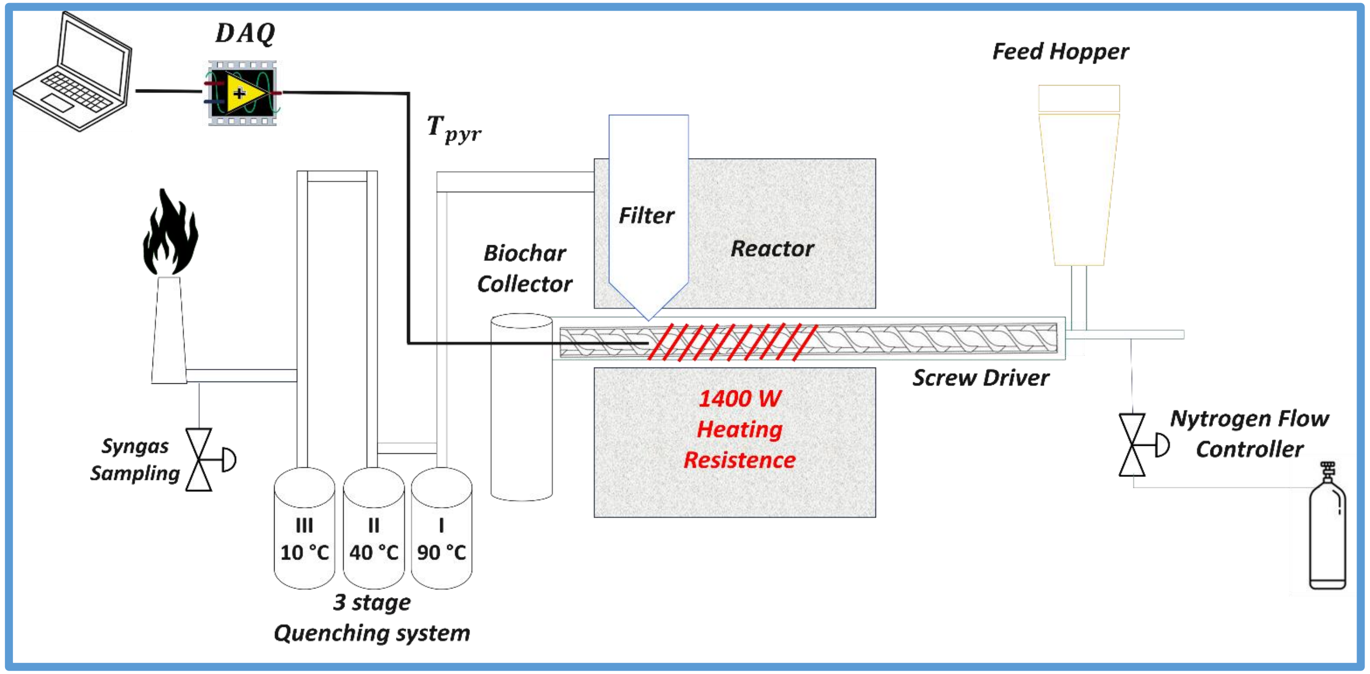
Collecting

BIO-CHAR

BIO-OIL

SYNGAS

SCERG experimental setup

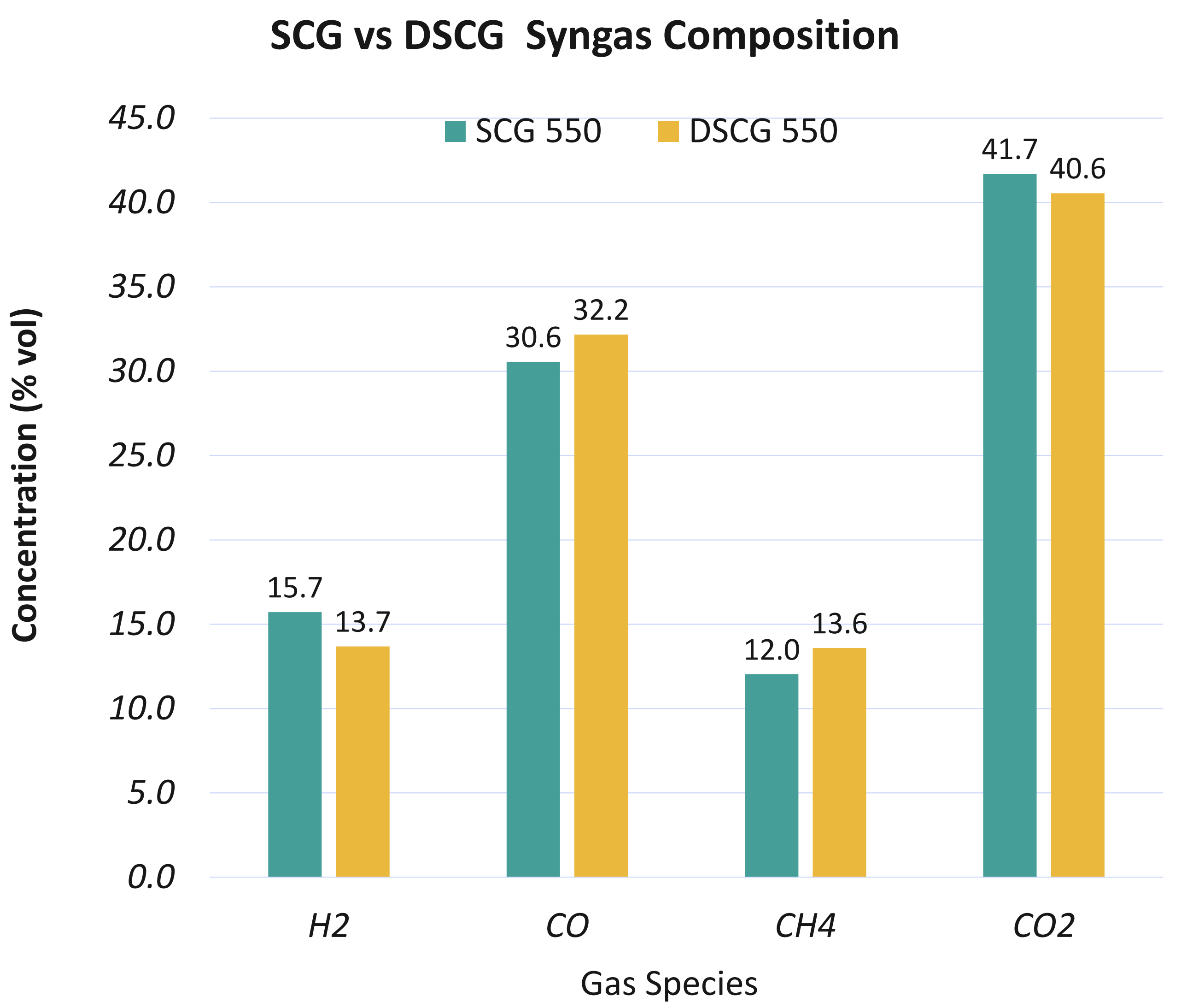


OPERATING CONDITIONS	
Residence Time :	~ 10 s.
Particle Size:	500 - 850 μm
N_2 flow rate:	0.5 NL/min
Biomass Processing Capacity:	150 -250 g/h
Temperature:	350-550°C

SCERG pyrolysis: Spent Coffee Grounds vs Defatted

- The increase in methane production is related to the increase of lignin in DSG compared to SCG

- Lignin, which consists of highly branched, substituted, mononuclear aromatic polymers; its cracking and deformation releases the largest fraction of hydrogen and methane.



Conclusions

- Residual biomass is cheap and abundant
- Currently low efficiency and low power density technology are considered
- The investment on innovative technologies can pay back with compact plants and high H_2 yield
- There is a common ground between H_2 and ES JPs through biomass, looking at system level innovation
- Pretreatment and multi-input multi-output systems are some of the options with advantages on efficiency and capacity factor

Biomass EU projects and stakeholders

- TO-SYN-FUEL, GREENSYNGAS, UNIFHY
- FLEXGAS, FUEL-FROM-WASTE, UNIQUE
- AMBITION, GICO, BLAZE, WASTE-2-H2

- NEXT-CHEM/ENERECO
- ENI ENEL-GP
- JOHNSON-MATTHEY, HALDOR-THOPSOE
- CALIDA

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EERA European Energy Research Alliance

Energy Storage

"Energy storage, Fuel Cells & Hydrogen. Bringing research and industry closer: accelerating innovation and uptake of new technologies"
Palazzo della Salute, Padova – 10 May 2022

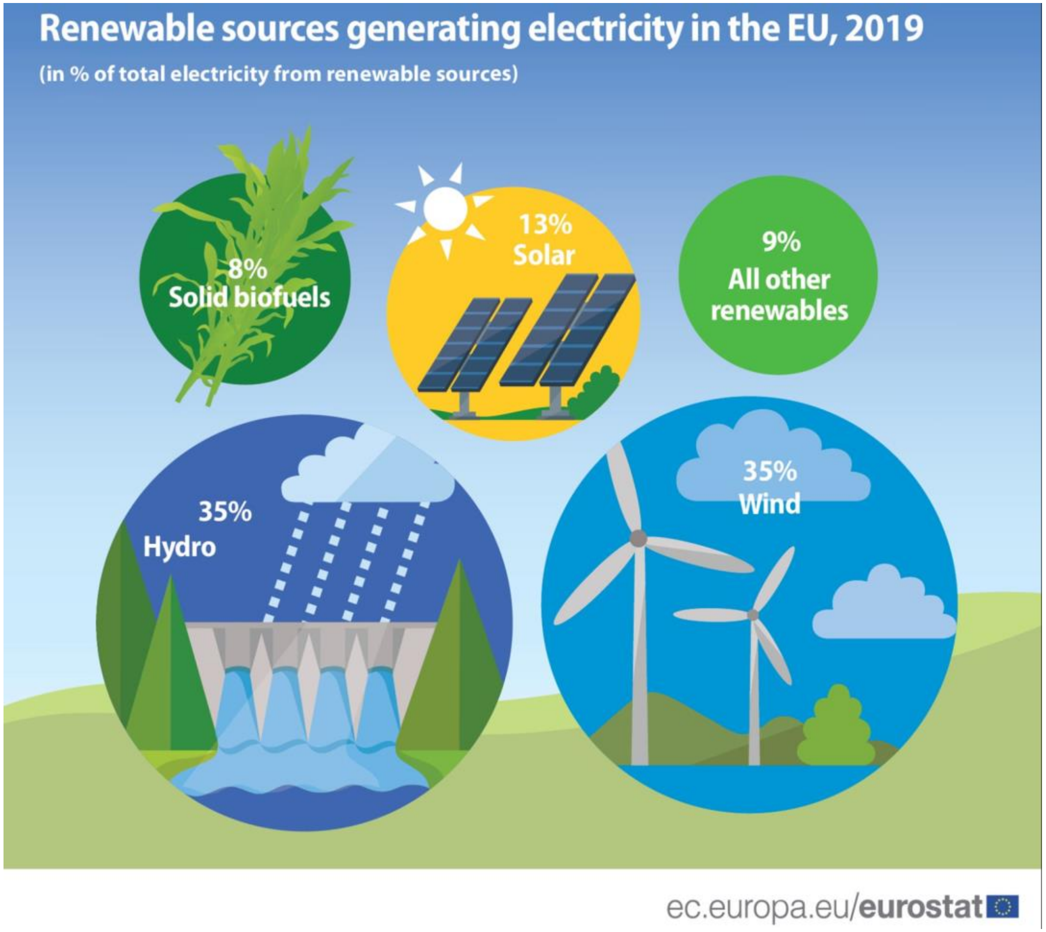
Pumped Hydropower Energy Storage

Prof. Giovanna Cavazzini

Interdepartmental Centre Giorgio Levi Cases
for Energy Economics and Technology

SUPEERA

Levi Cases



Hydropower is the largest renewable energy source in Europe (334 TWh/year).

10% of the renewable electricity generation in the world

35% of the renewable electricity generation in EU. Similar to wind but..

…hydropower is predictable, flexible and stores large amounts of renewable energy

Key role in the CET

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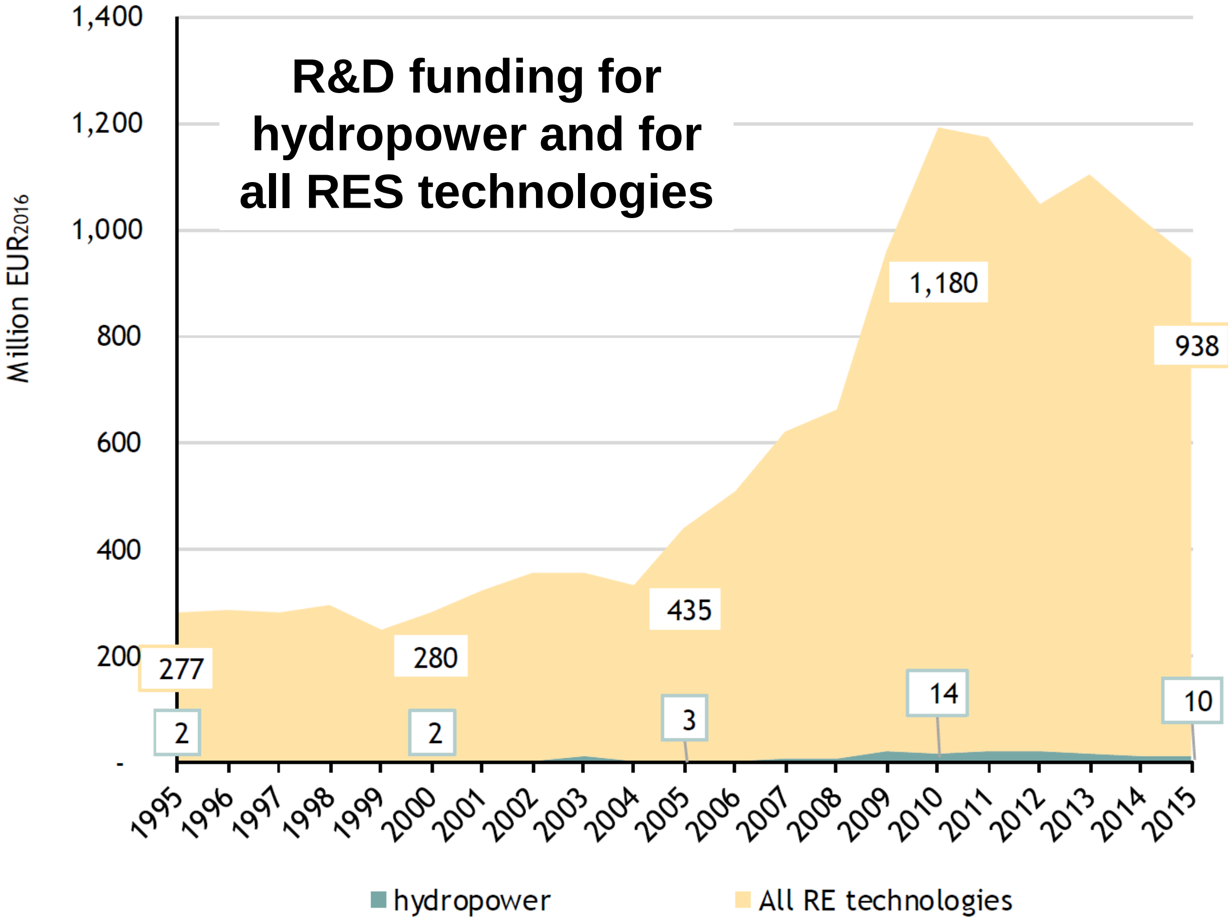
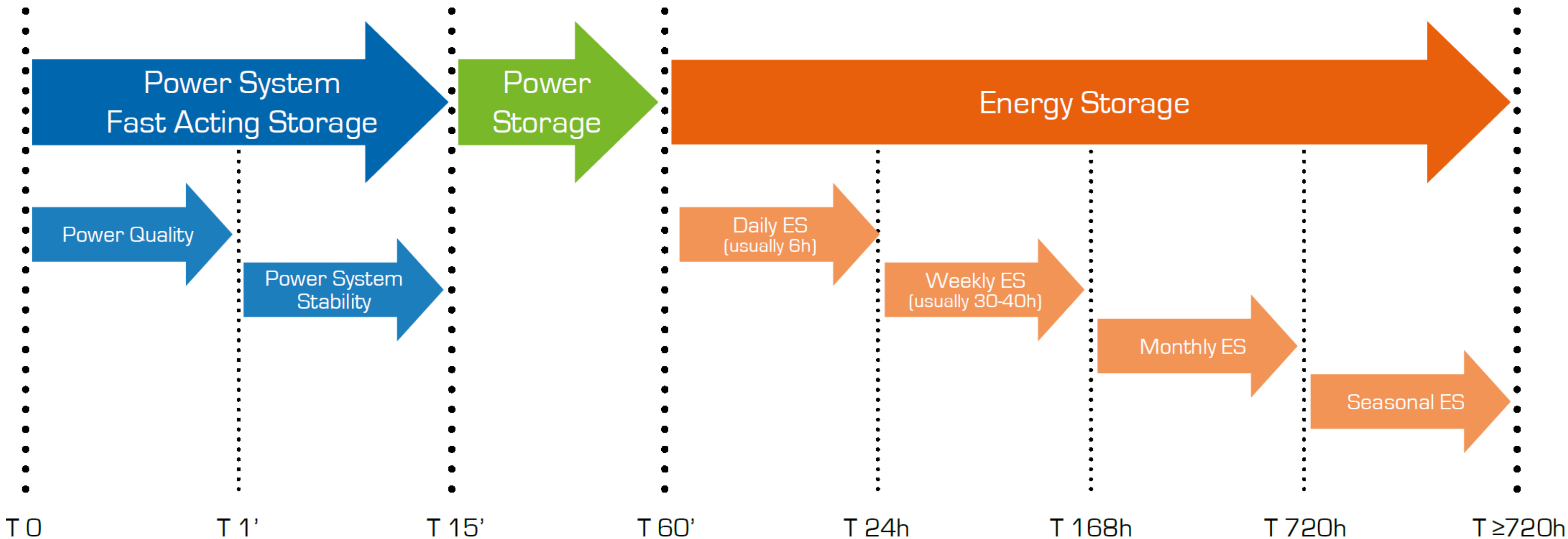
EERA European Energy Research Alliance
Energy Storage



Source: Based on data from OECD/IEA (2018).
Note: Data for 20 EU countries was available in this source: The EU15 plus Czech Republic, Estonia, Hungary, Poland, Slovakia. Data for Italy was not available for 2015, for the Netherlands for 2004 and data for Poland was not available before 2009 for any RE technologies.

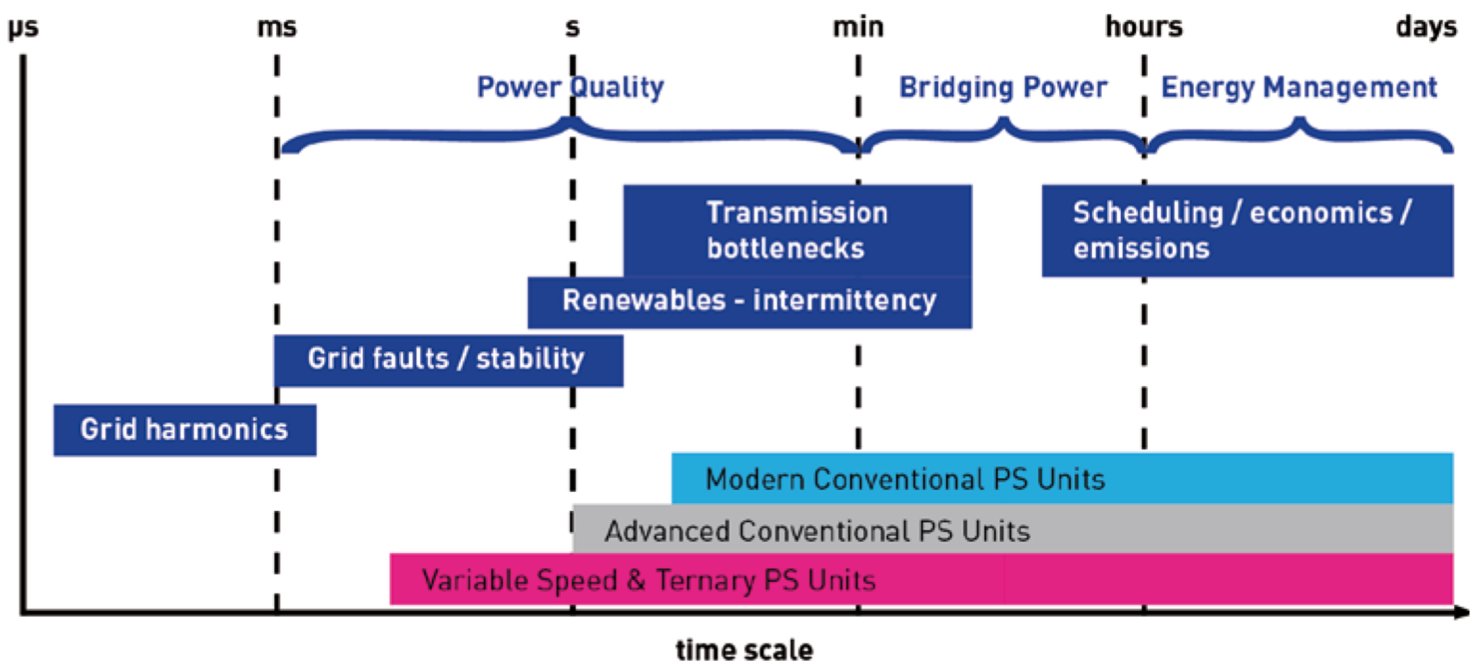
R&D funds in 2015 about 1%

Is hydropower a «mature technology»?



Depending on the application, there are different storage needs requiring different discharge time.

Pumped-hydro can certainly face energy storage needs……..



From a technical point of view, the new generation of PHES can offer power storage services, but these services will require:

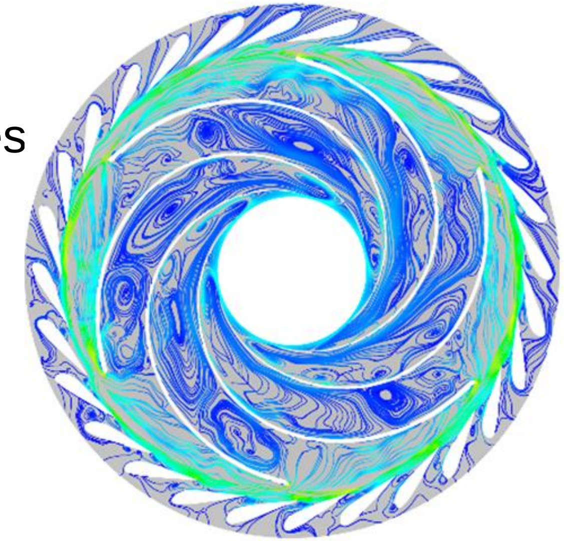
- Flexible operation
- Frequent start&stops and power ramp up/down

..at what cost?!

Research challenges

1. INNOVATIVE DESIGN STRATEGIES

UNIPD research collaboration with industries (turbine manufacturers)



2. INNOVATIVE CONTROL STRATEGIES

UNIPD research collaboration with industries (utilities) and academia

PHES

Hybrid energy and energy storage system

Hybrid Energy Storage System

Sea Water Pumped Hydro

Flywheel

Batteries

Techno-economic optimization of the control strategy and size

Electric grid

Research Fund for the Italian Electrical System

RSE Ricerca Sistema Energetico

Market & Grid

Università degli Studi di Padova

PHES: modelling & experimental characterization

EERA European Energy Research Alliance Energy Storage

Mobility Scheme

Universidad Politécnica de Madrid

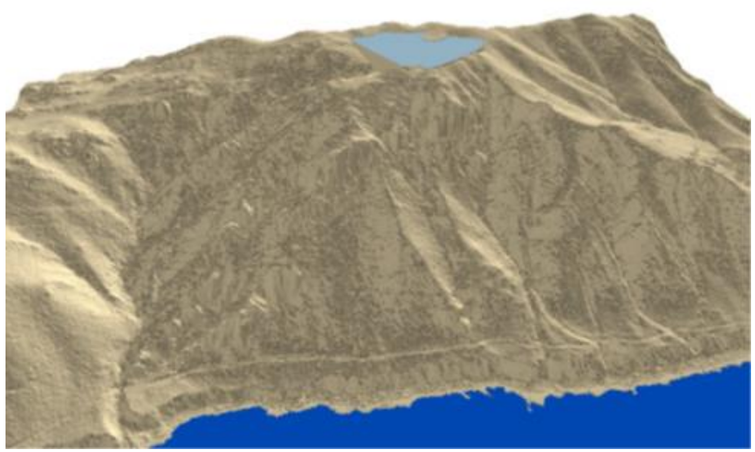
Dynamic control strategy

Ciemat Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

Flywheel & experimental validation of the control strategy

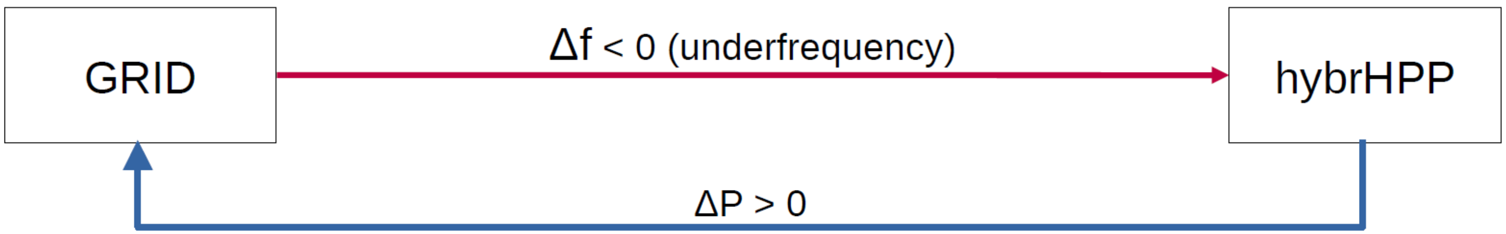
Case study: Foxi Murdegu pumped hydropower plant

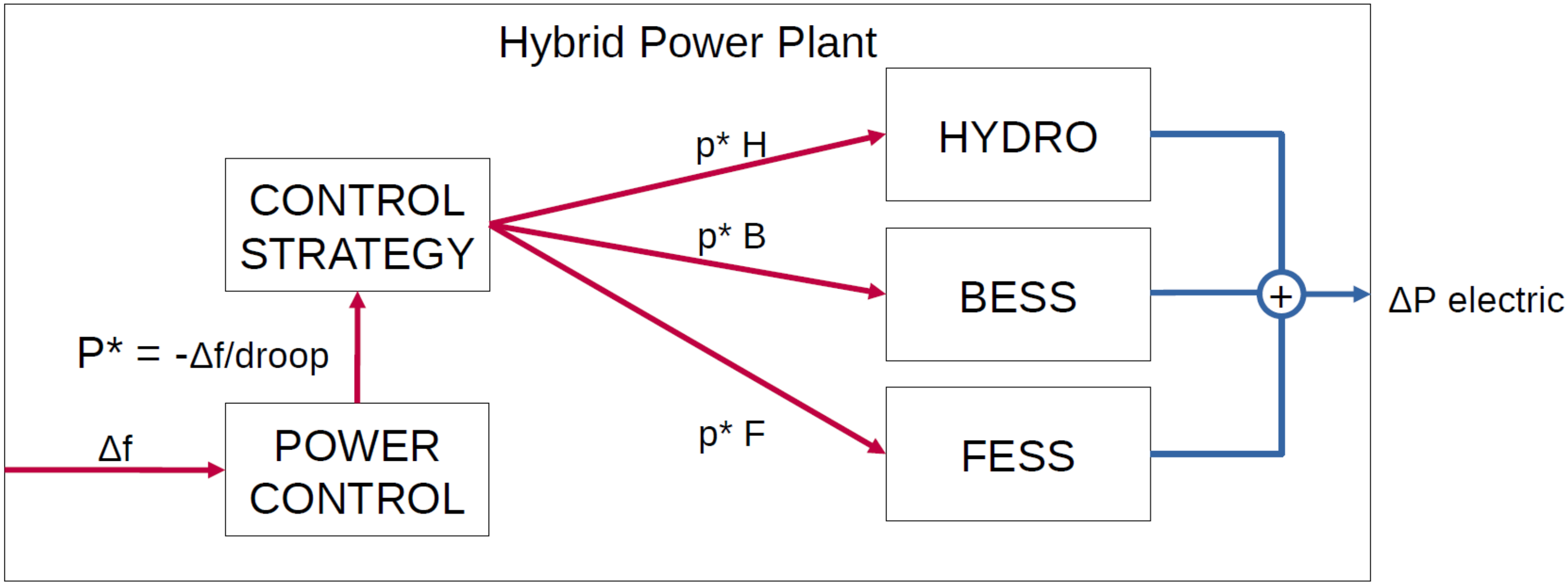
- 1,200,000 m^3 upper reservoir,
- 345m – 367m a.s.l.
- 700m penstock
- 1x150MW variable-speed pump-turbine



M. Meghella, J. Alterach, E. Gobbi, G. Gardini, and R. Marazzi, “Studi e analisi di pre-fattibilità per l’integrazione ottimale in rete dell’energia prodotta da fonti rinnovabili mediante sistemi di pompaggio marino,” Ricerca sul Sistema Energetico, Jan. 2013.

Hybrid energy storage system: the control scheme





Hybrid energy storage system: the control strategy

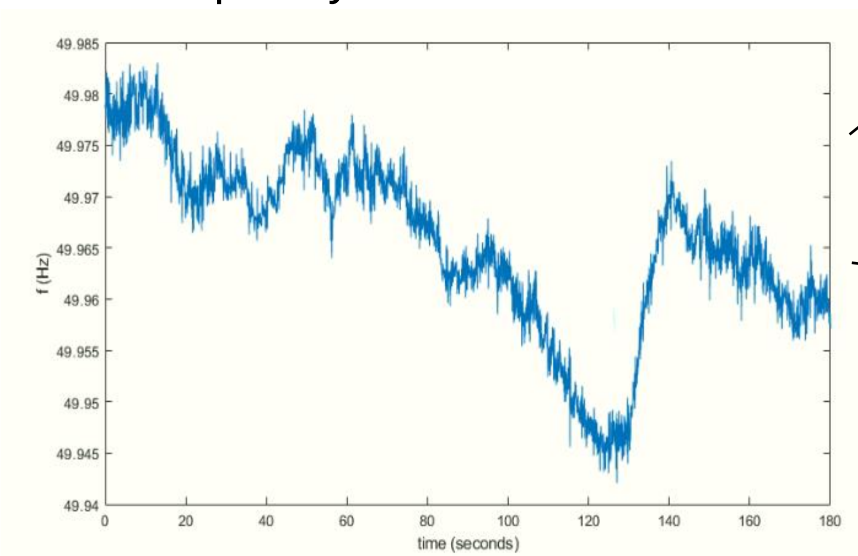
- BESS and FESS in order to relieve PHES fatigue/stress due to fast power adjustments
- The PHES controls the SOC of BESS and FESS

Different control strategies for the regulation split between hybridized technologies were considered but the best resulted to be:

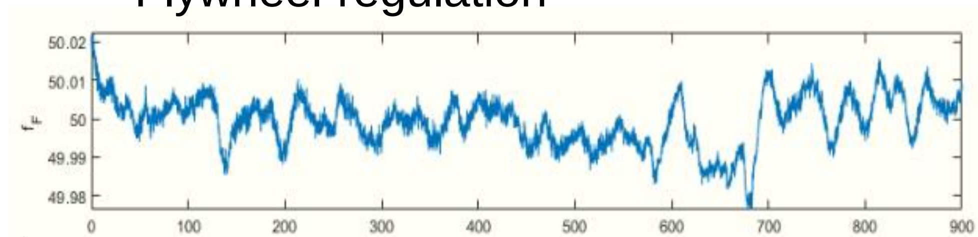
- **Frequency split**: the regulation is splitted among all technologies depending on the frequency values

Frequency split regulation strategy

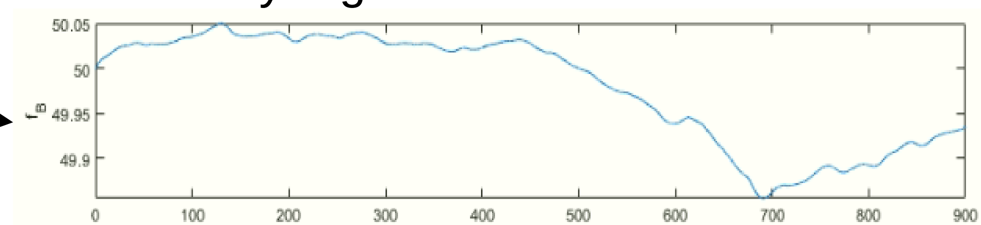
Grid frequency



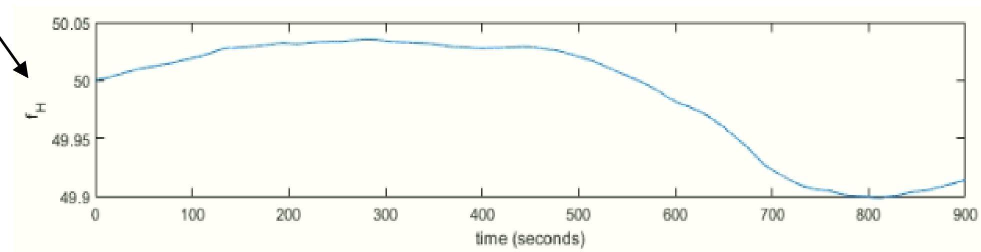
Flywheel regulation



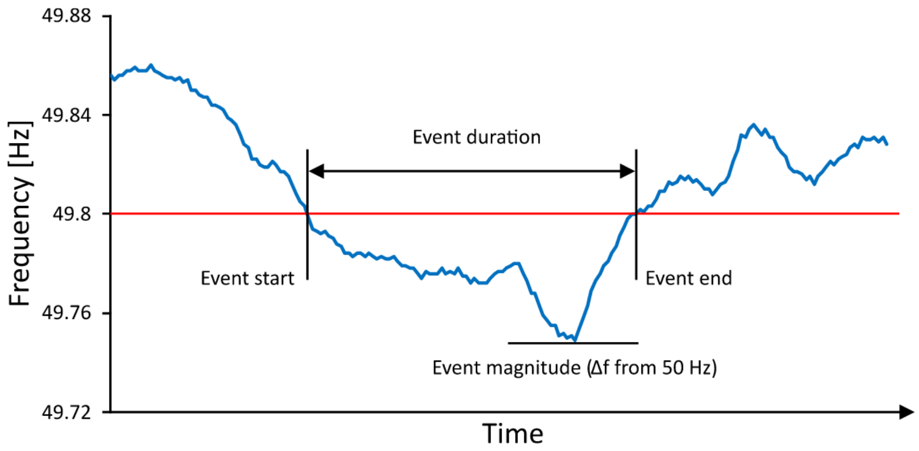
Battery regulation



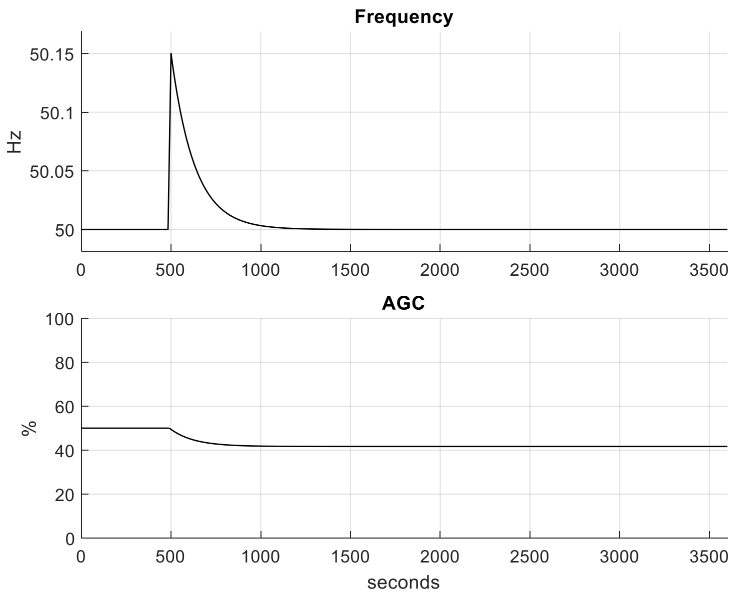
Pumped-hydro regulation



Optimization of the control strategy



The optimal control parameters depend on the event characteristics



The control parameters were optimized considering:

- 17 different events
- Starting operation both in turbine and in pumping modes
- Remuneration scheme

To evaluate the techno-economic sustainability of hybridizing an existing pumped-hydropower plant with fast storage systems (BESS/FESS)

Objective function: maximization of the NPV (Net Present Value)

Fixed Costs/Revenues
(–) Investment costs (BESS, FESS)
(–) Fixed O&M costs (BESS, FESS)
(+) Fast reserve revenues (BESS, FESS)

→ depend on MW BESS/FESS
↓
Different configurations tested

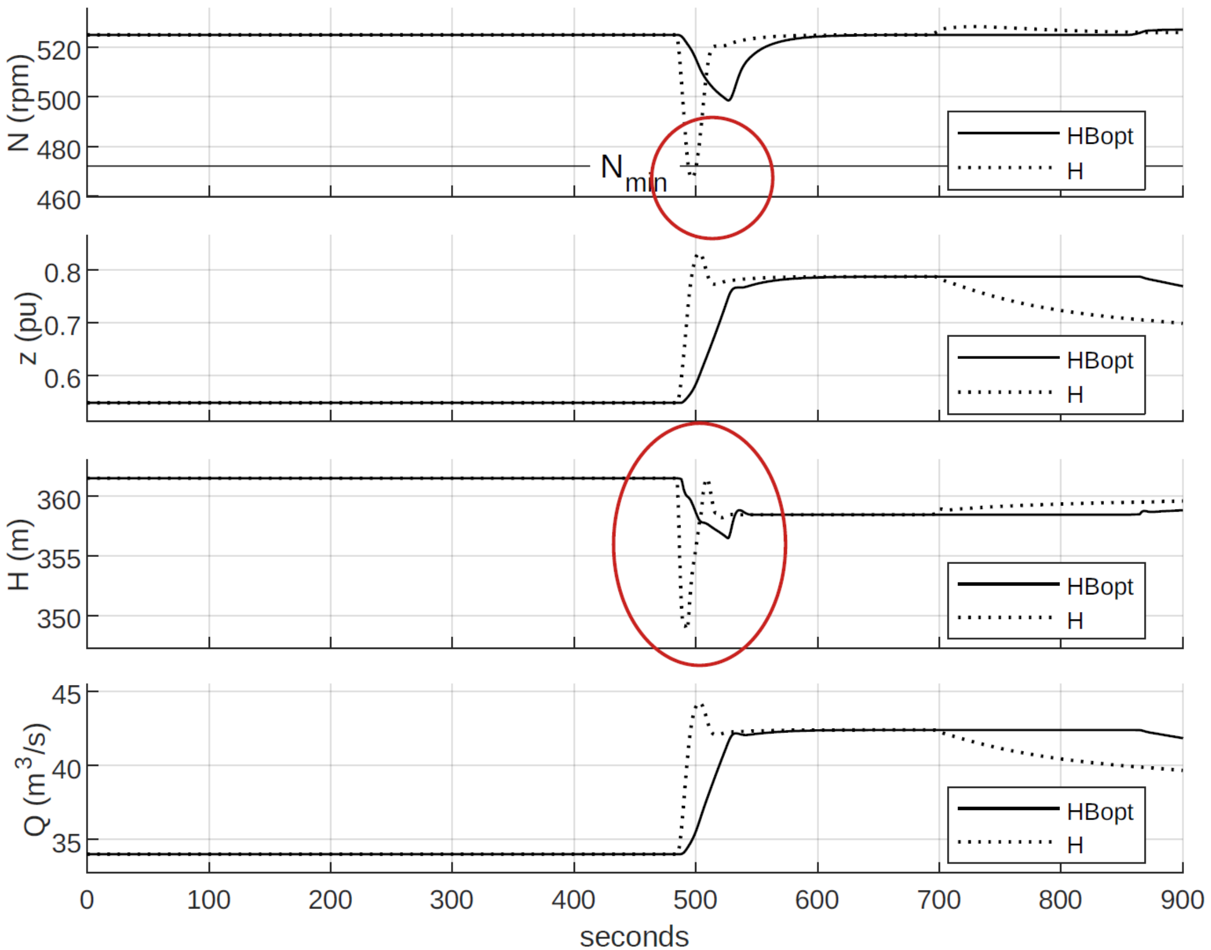
Variable Costs/Revenues (depend on control strategy)
(–) Variable O&M costs (HPP, BESS, FESS)
(–) Wear and tear costs (HPP, BESS, FESS)
(+) Revenues (primary, secondary)

PHES= 150MW

P_{BESS} [MW]	P_{FEES} [MW]	Strategy	NPV [M€]
0	0	-	5,614
25	0	FS	12,65
24	1	FS	12,044
23	2	FS	11,43
20	0	FS	11,297
30	0	FS	11,012
22	3	FS	10,638
21	4	FS	10,179
20	5	FS	9,543
10	0	FS	8,816
15	5	FS	8,124
25	5	FS	7,918
5	0	FS	7,319
10	5	FS	6,905

Best configurations

- Higher investment costs of FESS
- Important revenues: Fast reserve (~60 k€/MW installed, fixed) up to 25 MW
- Slow down HPP as much as possible (less power ramps)



Intense events can be unbearable for the PHES

Hybridization with the proper control can avoid high pressure waves

The accuracy of the optimization procedure results

Cost data and equations taken from the literature

Wear and tear: very few information in literature! → estimated under several assumptions

Results depend on the input data (scenarios, prices, initial conditions, …)

BEST NPV ≠ BEST ABILITY TO CONTAIN FREQUENCY DEVIATION

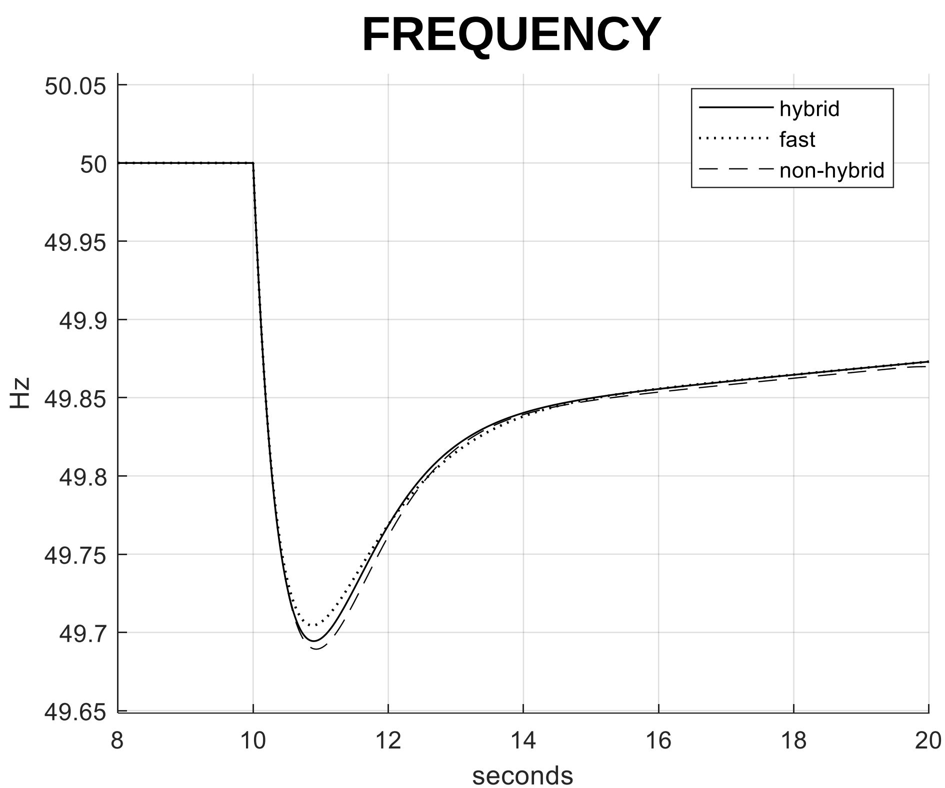
Detailed model of the Sardinian power system
(developed by RSE)

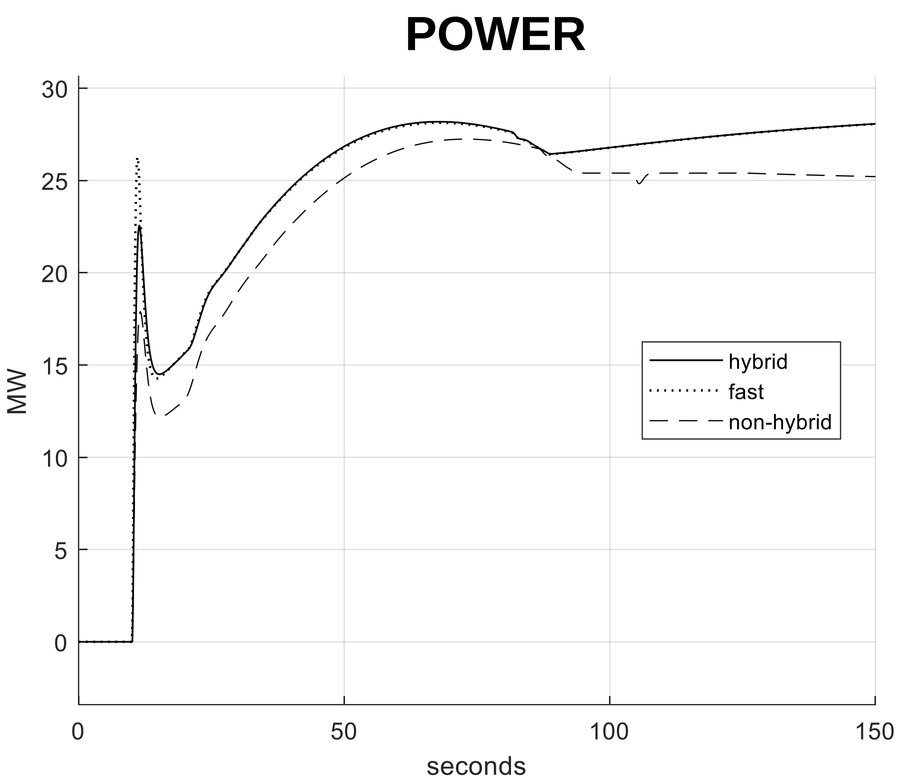
10 programmable plants + 2 HVDC cables + RES (wind/solar)

Assuming the loss of 256 MW of turbogas power plant, three cases were simulated:

- PHES non hybridized
- Hybrid PHES, optimal
- Hybrid PHES, optimal, no delays (fast)

Hybrid plant in fast mode minimizes the frequency deviation





BEST NPV ≠ BEST ABILITY TO CONTAIN FREQUENCY DEVIATION

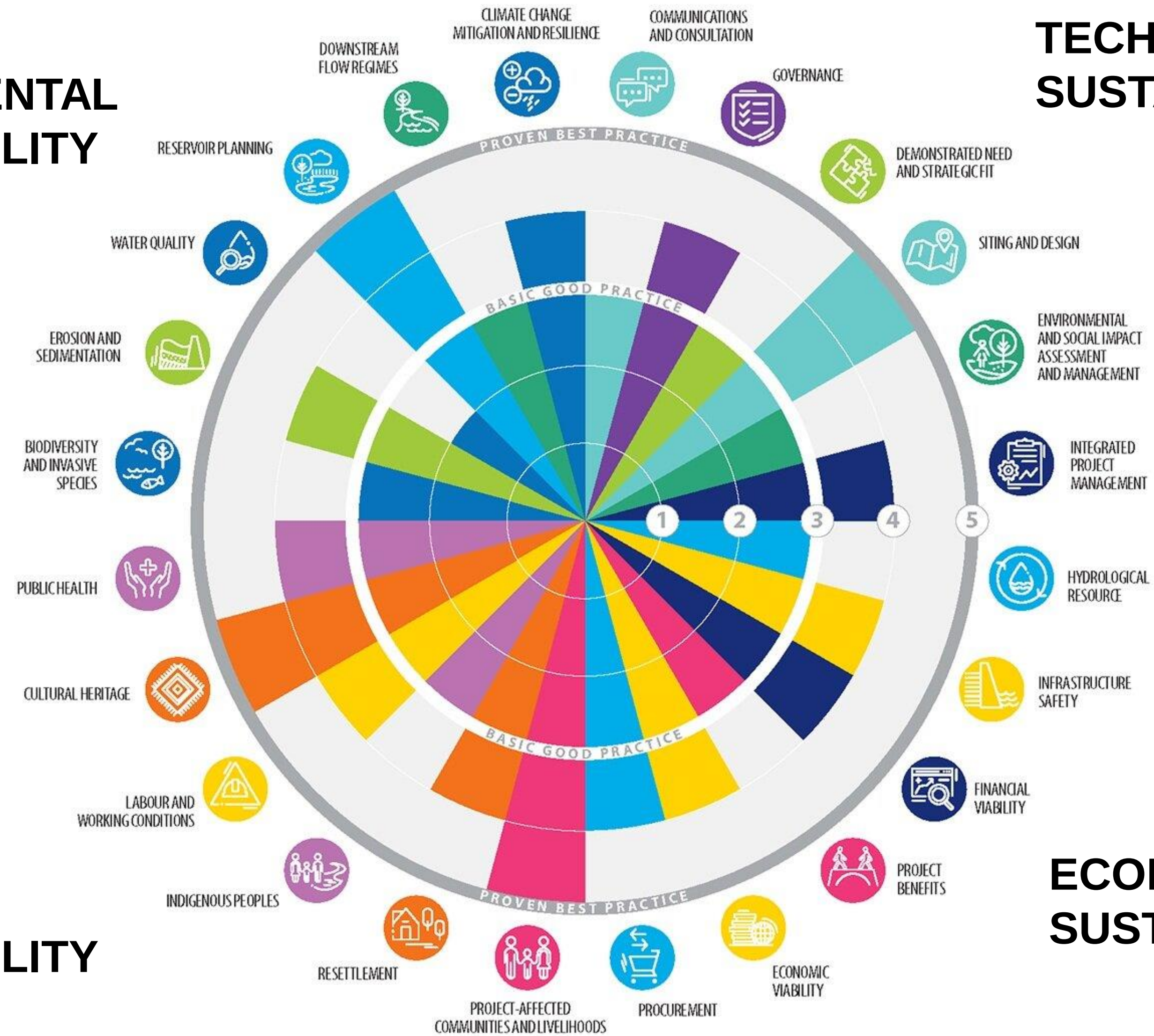
Hydropower Sustainability Assessment Protocol

Università degli Studi di Padova

EERA European Energy Research Alliance — Energy Storage

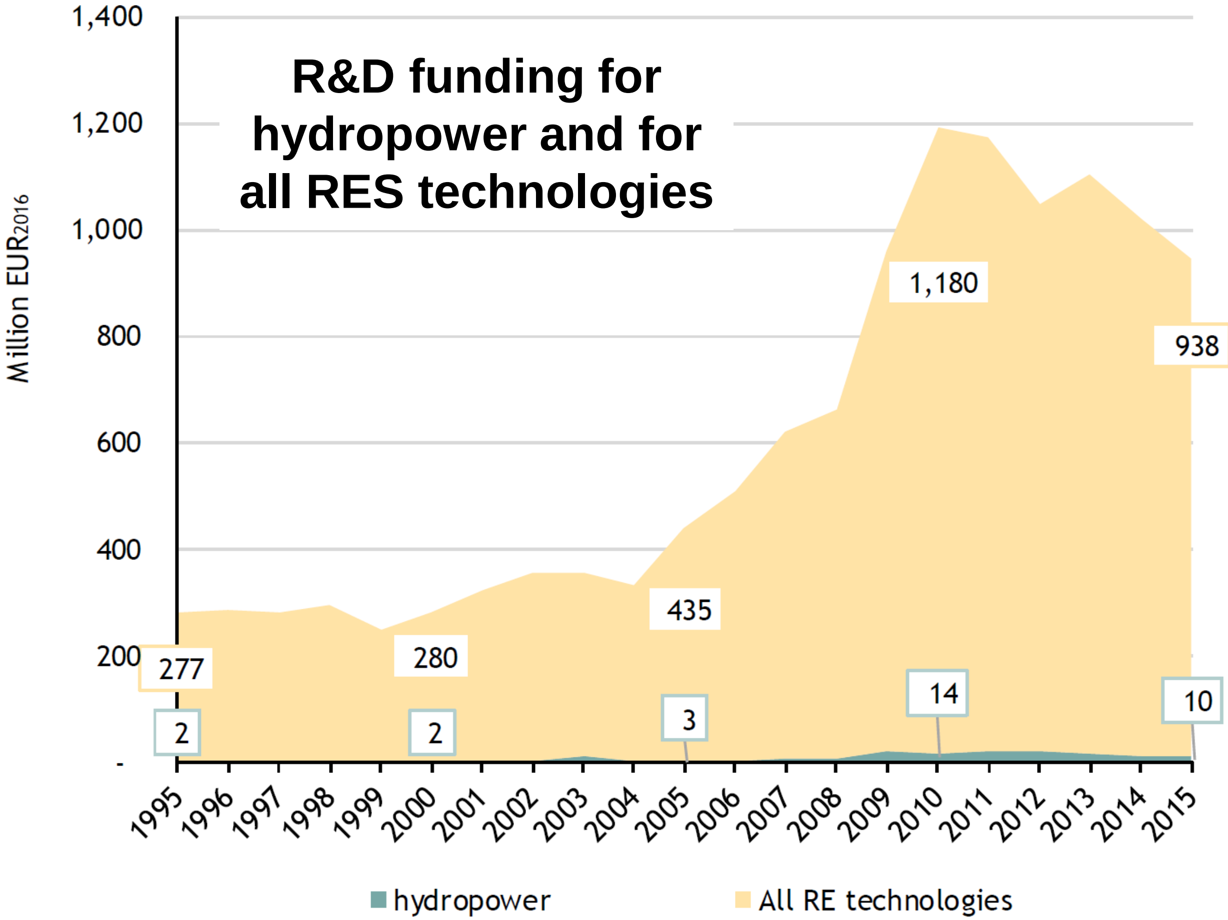
ENVIRONMENTAL SUSTAINABILITY

TECHNICAL SUSTAINABILITY



SOCIAL SUSTAINABILITY

ECONOMIC SUSTAINABILITY



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R&D funds in 2015 about 1%

Is hydropower a «mature technology»?

NO!

Hydropower sustainability is a new and challenging goal

Thank you!

Prof. Giovanna Cavazzini

Interdepartmental Centre Giorgio Levi Cases
for Energy Economics and Technology

JP FCH SP7 Hydrogen Storage SoA in Underground storage, liquid organic hydrogen carriers, compression

Energy storage, Fuel Cells & Hydrogen, 10.5.22, Padova, Italy

Klaus Taube
Institute of Hydrogen Technology

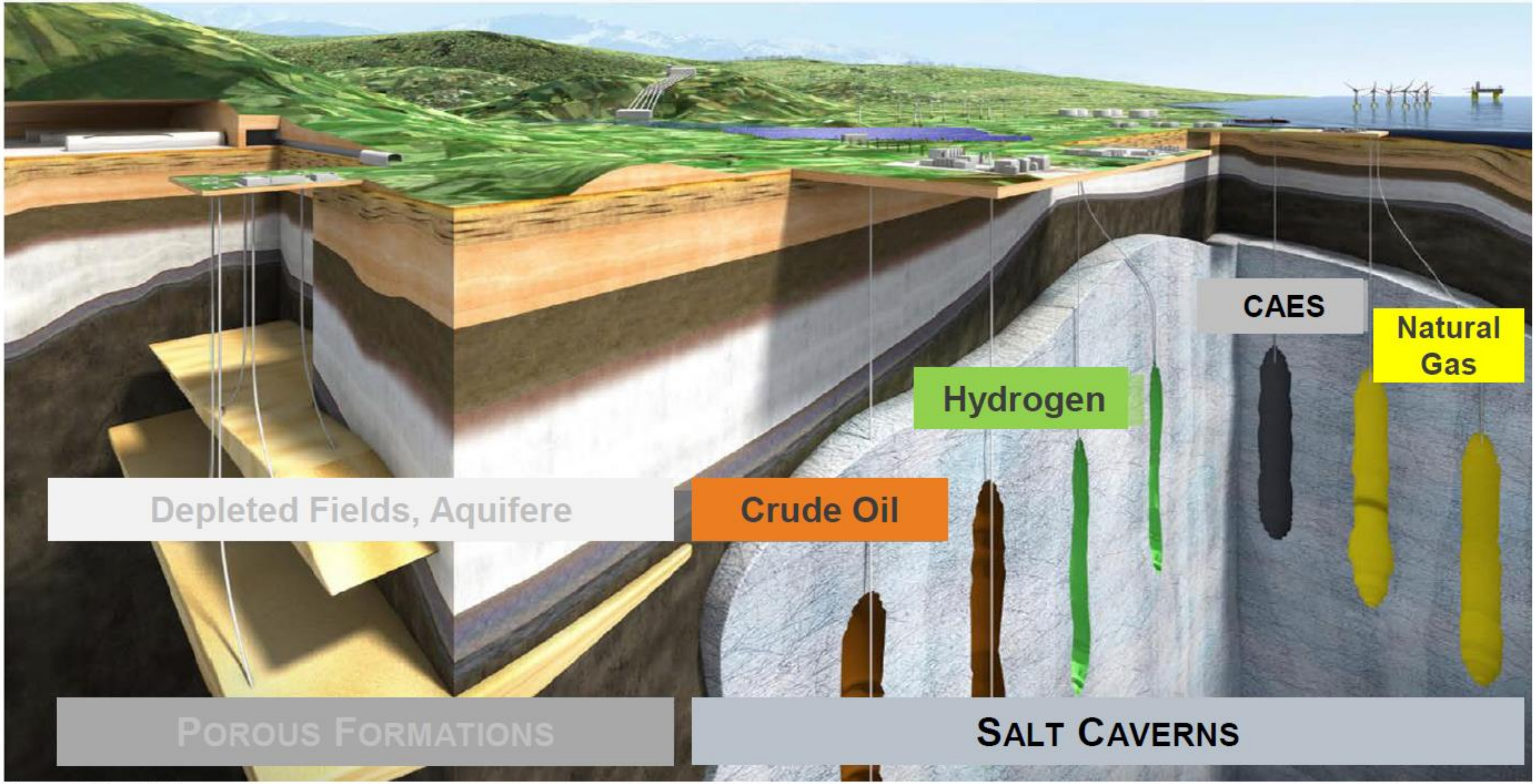
Slides from
Karsten Peter, STORAG ETZEL, Etzel
Joachim Hoffmann, SIEMENS Energy, Erlangen
Julián Puszkiel, Helmut-Schmidt-University, Hamburg

Helmholtz-Zentrum
hereon

Underground Storage

(slides kindly provided by Karsten Peter, STORAG ETZEL GmbH)

Types of Underground Storages



Picture: DEEP.KBB

CAES: Compressed Air Energy Storage

Gas Storage for Security of Supply

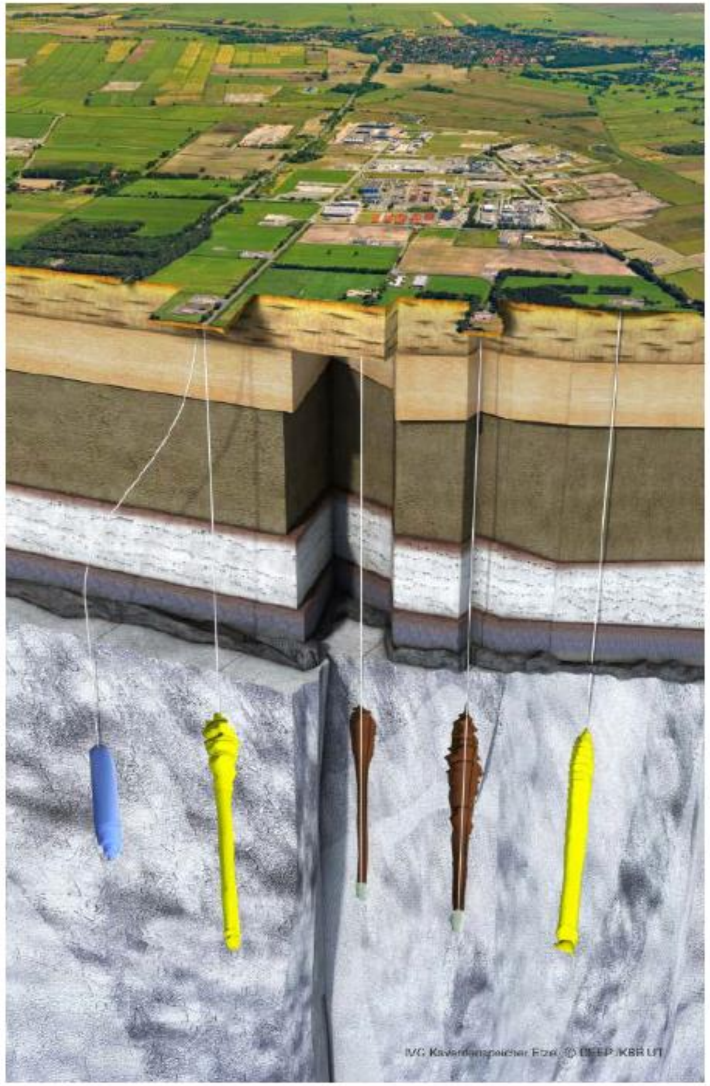
Facts

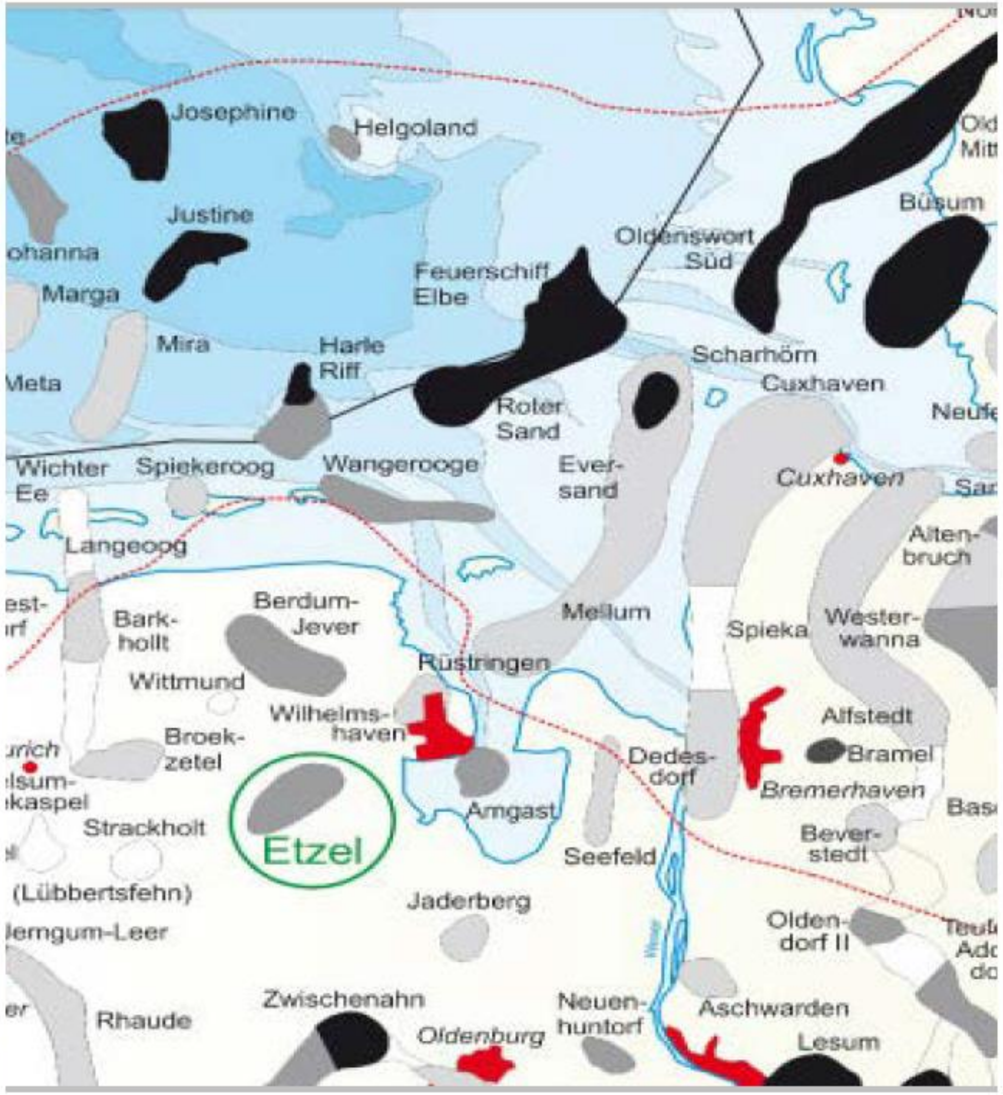
- **51 caverns for natural gas** in operation
- **total working gas capacity of 4,3 bcm**
- Some 4% of Germany´s annual gas consumption
- The gas storage is capable to balance seasonal supply fluctuations as well as instant peak demand

Tenants:

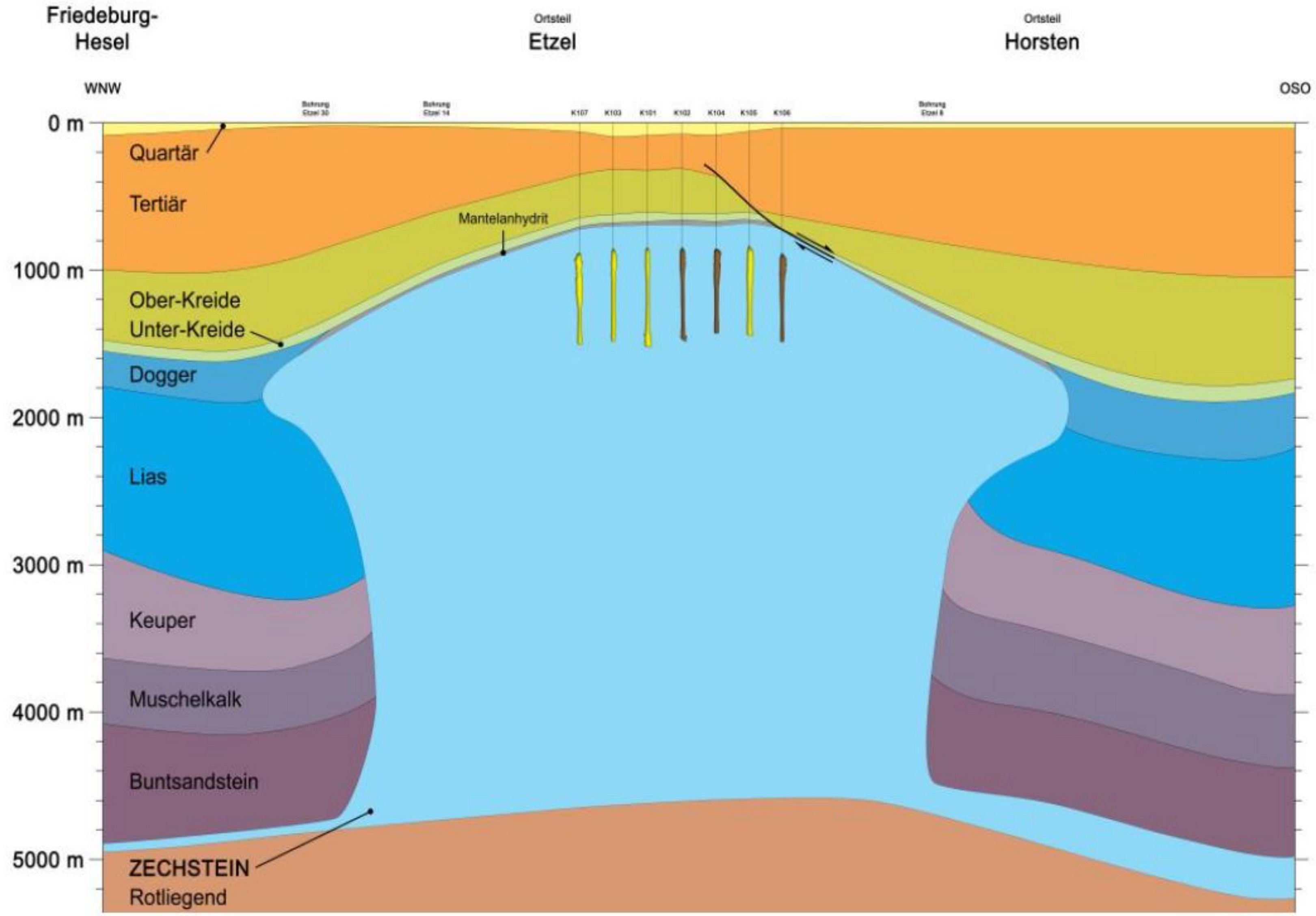
crystal	etzelgas-lager	EKB STORAGE	ESE erdgasspeicher etzel
EnBW, EDF	uniper, equinor	GAZPROM Germania, bp, Ørsted	uniper, OMV, VNG Gasspeicher GmbH

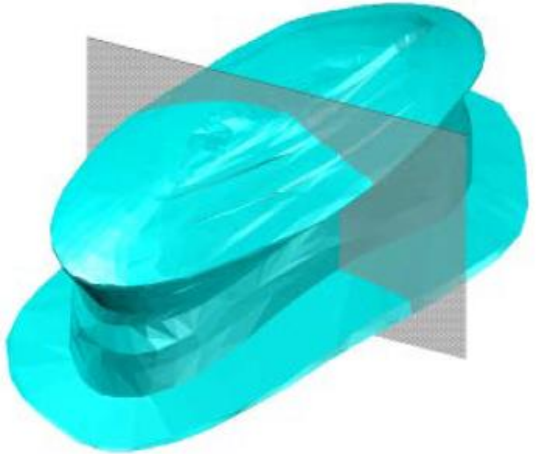
Potential underneath the Surface





Cross-section through the Etzel Salt Diapir

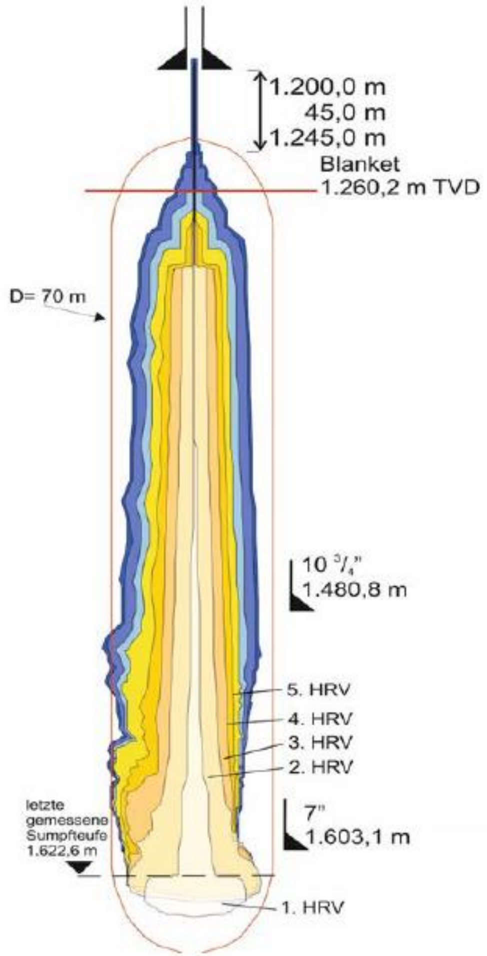




- Caverns are situated at the top central part of the salt structure
- Overburden above the diapir consists of flexible to unconsolidated deposits

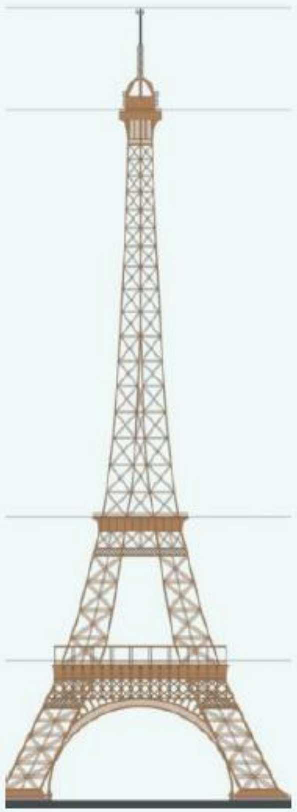
Construction of Caverns

› Cavern Design



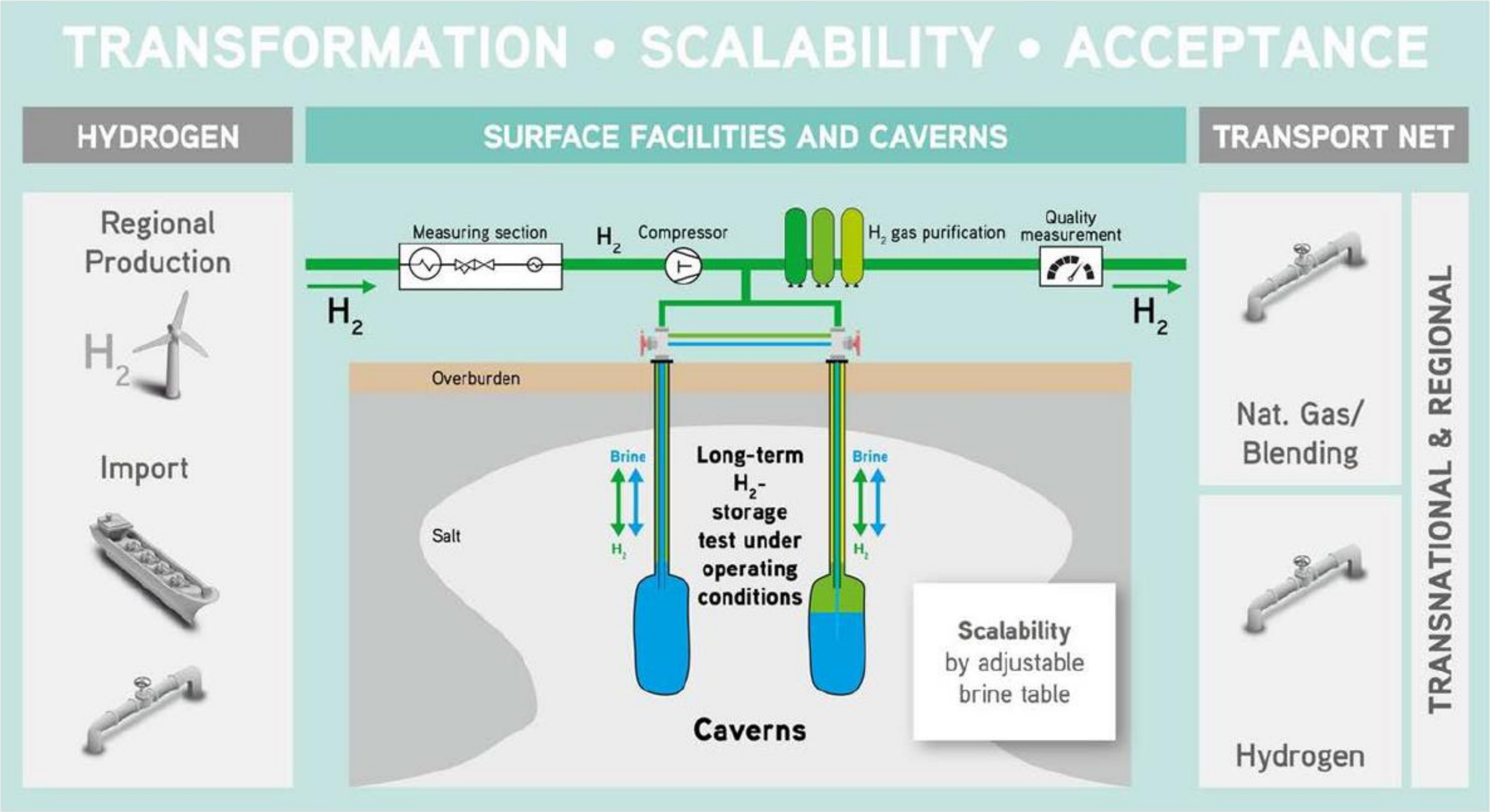
› 3-D Model

› ??



In-practice Test for the Conversion of Existing Caverns

in combination with above-ground H2 processing facility



H_2CAST Etzel

The H2CAST Schedule

- **Project to start** first quarter **2022**
- In **2023** two caverns shall be equipped with a **subsurface completion suitable for H2**
- The **injection of 5.000 tons or 1 Mio Nm³ hydrogen** into caverns is scheduled for **2024** following extensive material and safety tests until end **2026**

H_2CAST Etzel

Thank you for your attention!

STORAG ETZEL GmbH
Karsten Peter
Business Development
Beim Postweg 2
26446 Friedeburg

www.storag-etzel.de
www.h2cast.com

Hydrogen Storage and Transport by LOHCs

(slides kindly provided by Joachim Hoffmann, SIEMENS Energy GmbH)

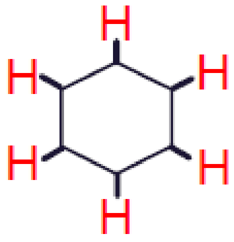
LOHC - Liquid Organic Hydrogen Carrier
Chemistry behind it

Concept ➔ reversable storage of hydrogen on an Organic Carrier

e.g. $CH_2 = CH_2 + H_2 \xrightarrow[\text{Catalytic Charging}]{\text{Heat released}} \overset{H}{|}\hspace{-0.5em}CH_2 - \overset{H}{|}\hspace{-0.5em}CH_2$ (Addition of hydrogen to „double bonds“)

$\overset{H}{|}\hspace{-0.5em}CH_2 - \overset{H}{|}\hspace{-0.5em}CH_2 \xrightarrow[\text{Catalytic Unloading}]{\text{Heat required}} CH_2 = CH_2 + H_2$ (relief of bonded hydrogen)

Typical compounds:
Benzene-like structure

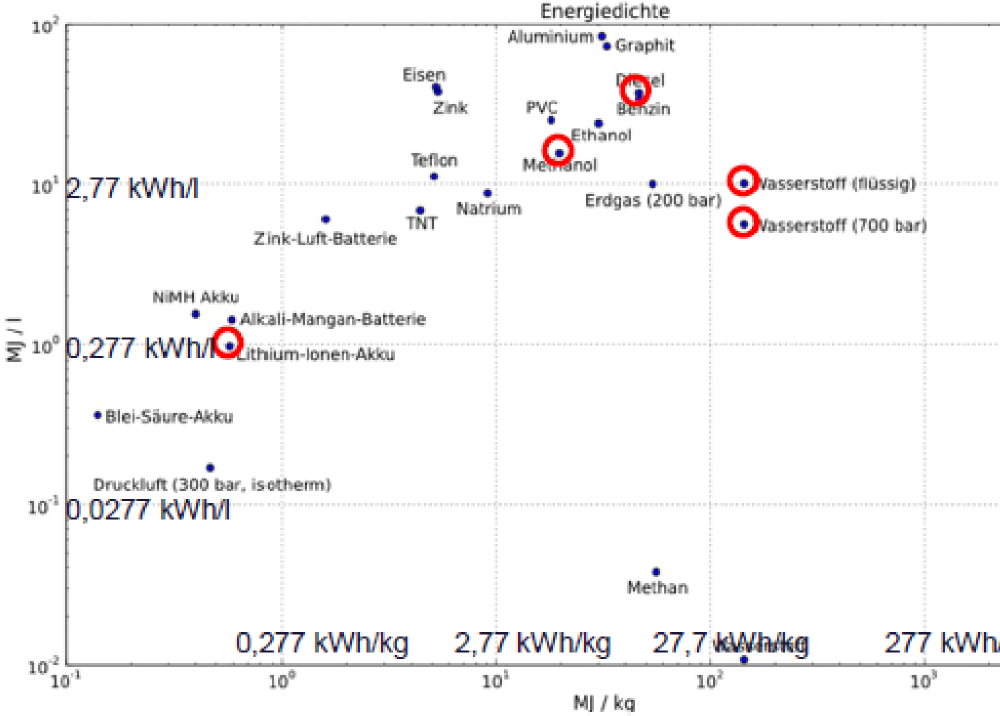
 $+ 3\ H_2 \longleftrightarrow$ 

LOHC - Liquid Organic Hydrogen Carrier
Chemistry & Physics behind it

SIEMENS energy

Storage Capacity

	kWh per m3	kWh per kg
Diesel	9700	11-12
Methanol	4300	5,5
LNG	5460	13,9
Hydrogen @ 200 bar	~612	33,3
Hydrogen @ 350 bar	~730	33,3
Hydrogen @ 500 bar	~1000	33,3
Hydrogen @ 700 bar	~1350	33,3
Hydrogen liquid	2360	33,3
LOHC (DBT)	~1800 (as H2)	~1,9 (as H2)
Li-Battery		0,05-0,26



1 MJ = 0,277 kWh

LOHC has a quite high volumetric storage capacity

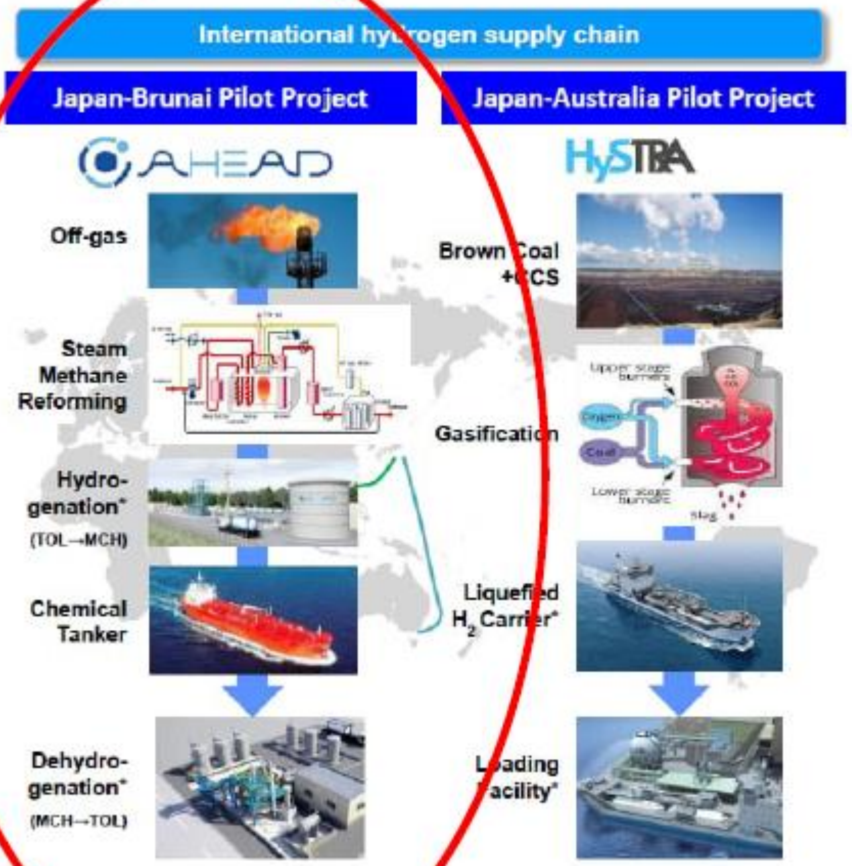
Metal hydrides:	1600 – 4800	0.4 – 3.3
NH3 @ 9bar, -33.3°C, liquid:	4062	6

LOHC - Liquid Organic Hydrogen Carrier
Current and Future Applications

SIEMENS energy

Japan Hydrogen Snapshot II

Source METI



Helgoland 15.04.2021 / 11:15

AquaVentus-Project on Helgoland

Gigantisches Wasserstoff-Projekt: Diese Nordsee-Insel wird zu einem Kraftwerk!

Source Hamburger Morgenpost

Offshore produced H2 will be stored as LOHC.
The process heat from loading the LOHC will replace Helgoland's existing fossil powerplant.
The LOHC shall be

- **distributed to Onshore applications**
- **used as fuel in maritime propulsion**

Source AquaVentus Förderverein

LOHC - Liquid Organic Hydrogen Carrier
Efficiencies with PEM Fuel Cell

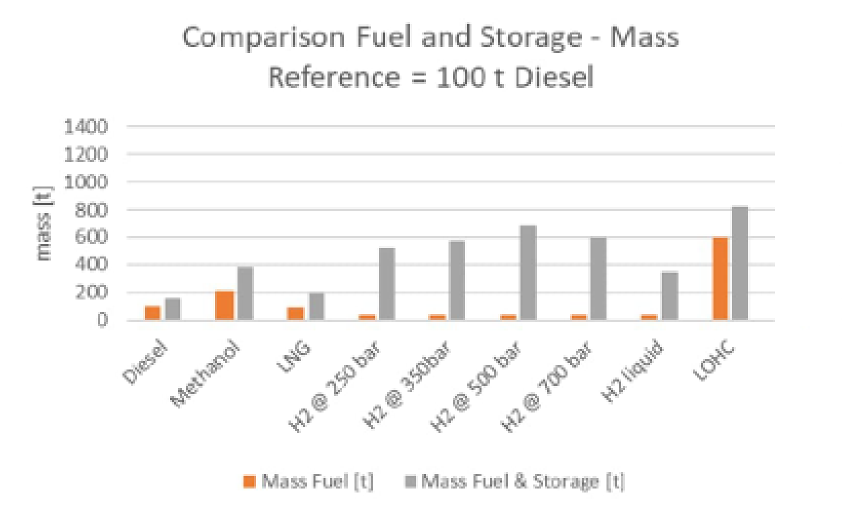
SIEMENS energy

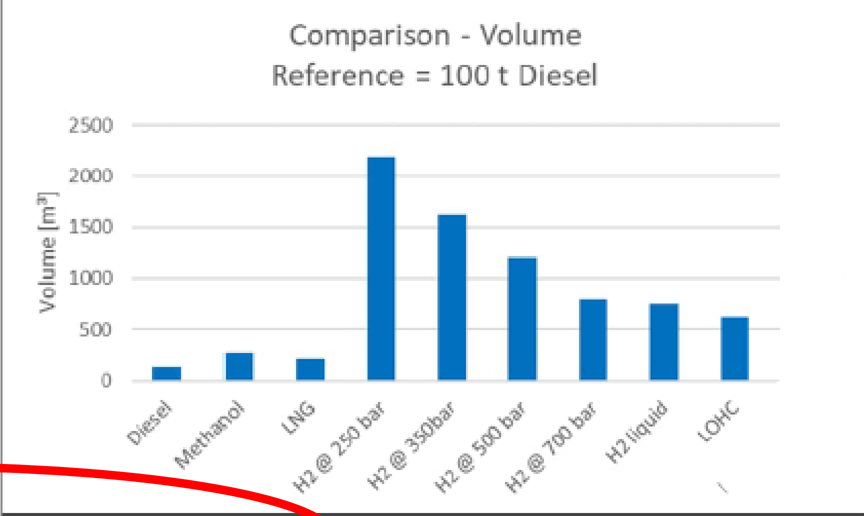
Heat requirements for un-loading H2 from LOHC+

➔ Part of hydrogen needs to be combusted to provide required heat

~ 1/3 of produced H2 is combusted

	kWh per m3	kWh per kg
LOHC (DBT)	~1800 (as H2)	~1,9 (as H2)
LOHC (DBT) - (incl. combustion)	~1200 (as H2)	~1,2 (as H2)





Tank to Propeller efficiency estimation

Demand on propeller & Hotel-load 1 MW @ 24 h	24	MWh
Efficiency of electrical equipment ~ 95%	~ 25	MWh
Efficiency of fuel cell process ~ 46% (without heat-util.)	~ 54	MWh
Efficiency of catalytic process = 66%	~ 83	MWh
Auxiliaries for LOHC Process ~ 1-2 MWh	~ 85	MWh

Total efficiency of LOHC/PEM-Fuel Cell ~ 28 % (Diesel Genset ~ 33 %)

Dr. Joachim Hoffmann | SE GP I SO MA

LOHC - Liquid Organic Hydrogen Carrier
Efficiencies with future SOFC

Heat requirements for un-loading H_2 from LOHC+

➔ Heat provided by process heat from SOFC
(SOFC = Solid Oxide Fuel Cell operating @ 600-800°C)

Tank to Propeller efficiency estimation

Demand on propeller & Hotel-load 1 MW @ 24 h	24	MWh
Efficiency of electrical equipment ~ 95%	~ 25	MWh
Efficiency of fuel cell process ~ 60% (without heat-util.)	~ 42	MWh
Efficiency of catalytic process = 100 % (heat from SOFC)		
Auxiliaries for LOHC Process ~ 1-2 MWh	~ 44	MWh
Total efficiency of LOHC/SOFC	~ 55 %	(Diesel Genset ~ 33 %)

LOHC - Liquid Organic Hydrogen Carrier
Summary

SIEMENS energy

Pros

Safety
- Nonexplosive
- Hardly flammable
- Controlled release of H2 on demand in small free H2-volumes

Liquid, which can be handled like Diesel
- Utilization of existing bunker systems

Stored at ambient conditions

High storage density in comparison with compressed H2 storage

High efficiency in case heat source for unloading is available (SOFC)

No consumption of the LOHC
- No carbon capture & CO2-Recycle required

Cons

High Volume

High weight → large displacement

LOHC supply chain for large quantities needs to be established

Poor efficiency if external heat source is required

Large installation for fuel processing

Purity of released H2

Life cycle management of LOHC
- Although a high cycle stability (loading/un-loading) is expected, after a certain period due to undesired catalytic side reactions LOHC needs to be re-conditioned

Thank you for your Attention

Schiffbautechnische Gesellschaft e.V.

Siemens Energy - Marine

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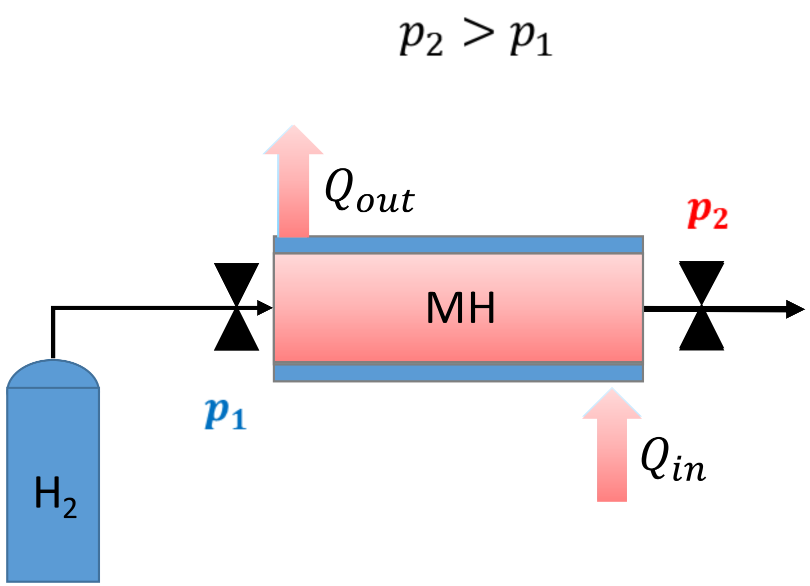
https://www.siemens-energy.com/marine

Hydrogen Compression by Metal Hydrides

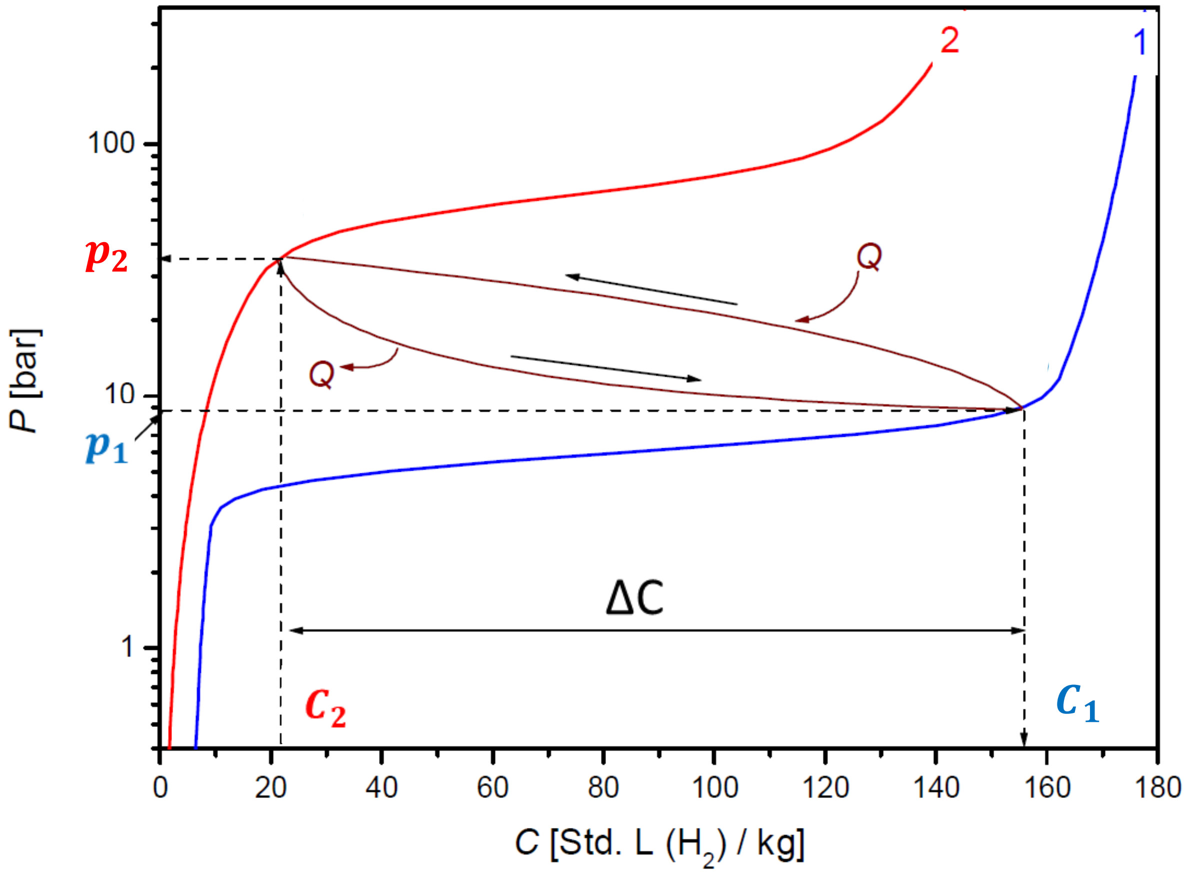
(slides kindly provided by Julián Puszkiel, Helmut-Schmidt-University)

1. Metal hydride compressors - principles of operation



Single compression step

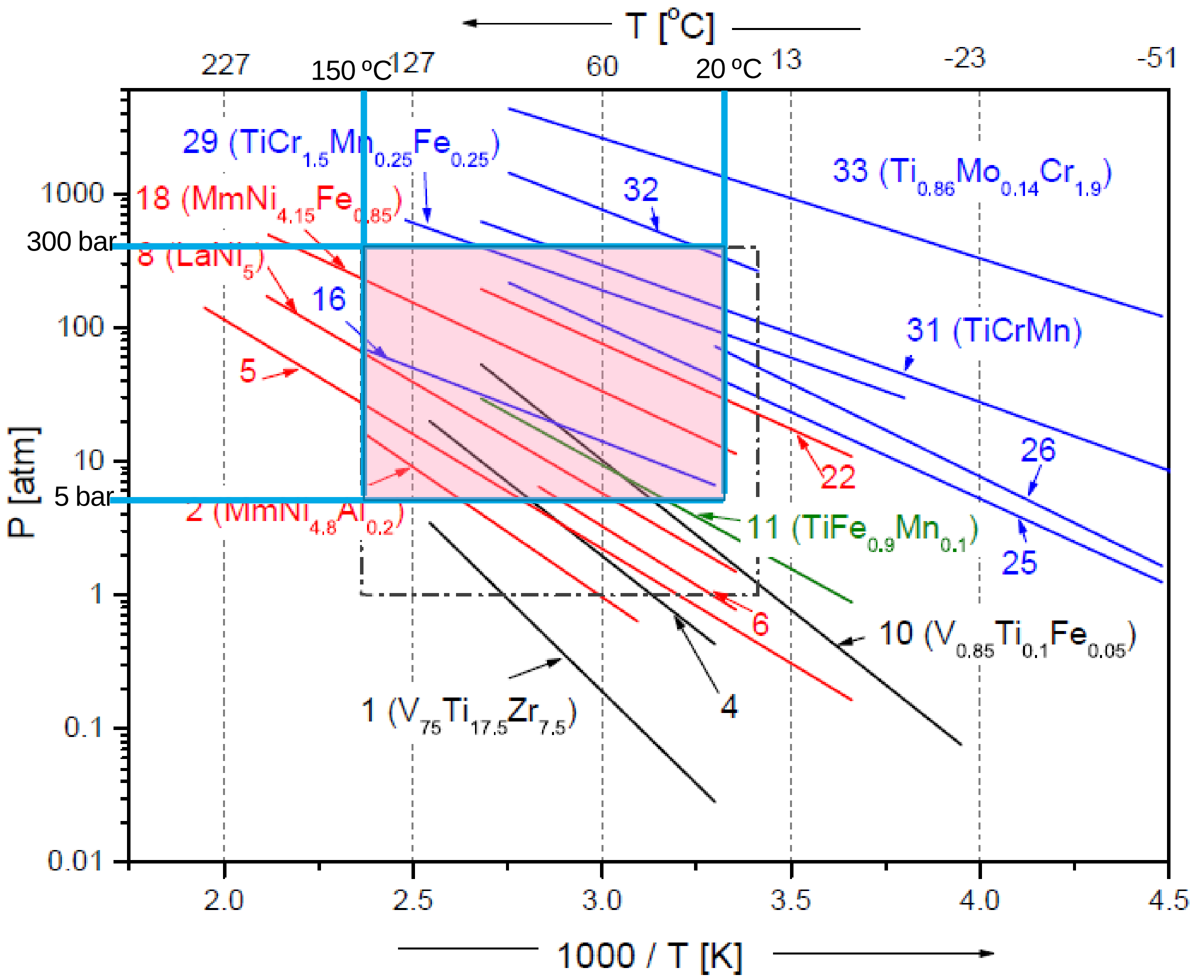
For H-$La_{0.85}Ce_{0.15}Ni_5$, T_1: 20 °C and T_2: 150 °C



M.V. Lototskyy, *et al.*, IJHE 39 (2014) 5818.

Hydride forming alloy for MH-compressor

Blue: AB2
Red: AB5.
Green: AB
Black: BCC



M.V. Lototskyy, et al., Metal hydride hydrogen compressors: A review, International Journal of Hydrogen Energy 39 (2014) 5818-5851

COSHMYC, COSHMYC XL, COSHMYC Demo

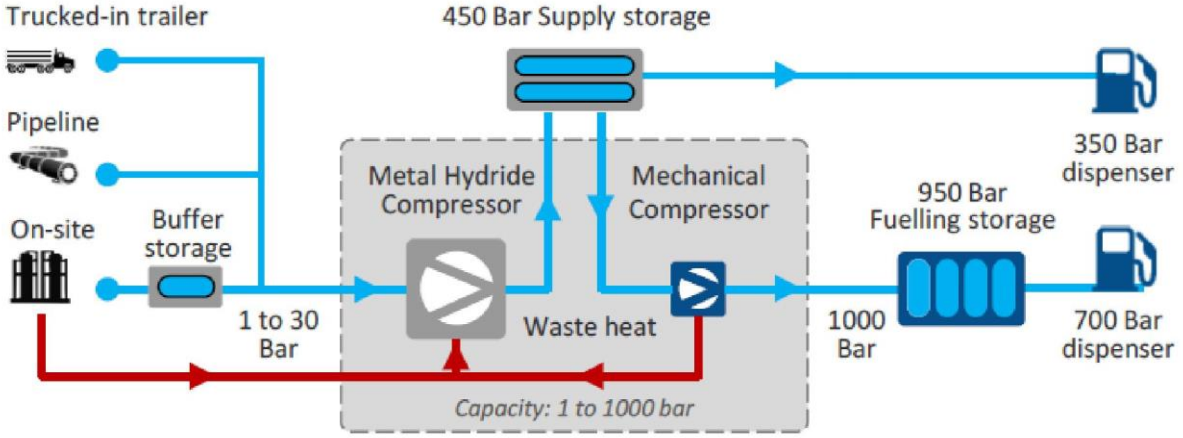


Figure 1- Concept COSMHYC project


Figure 3- COSMHYC Metal Hydride Compressor

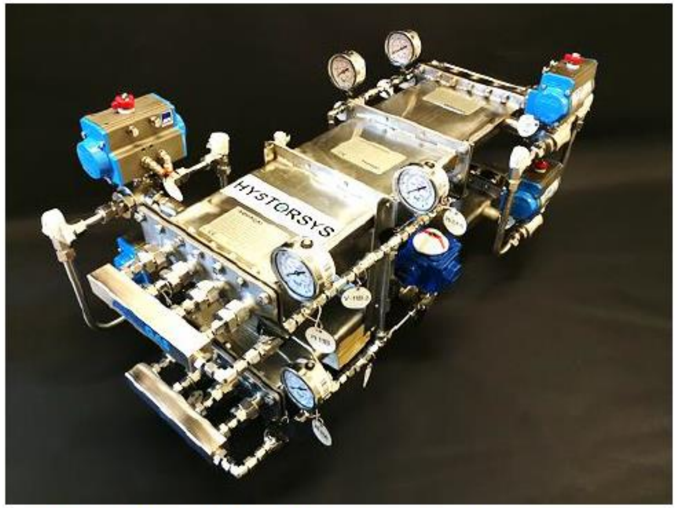
Tours, France Q3 2022	
Pressure:	30 bar → about 400 bar
Capacity (COSMHYC DEMO):	~ 25 Nm^3/h
Stages:	2
MH-Material:	free of rare earth metals

MAHYTEC nel EIFHYTEC European industry for Hydrogen technologies

Programme: H2020-JTI-FCH-2016-1
Topic: FCH-01-8-2016 - Development of innovative hydrogen compressor technology for small scale decentralized applications for hydrogen refueling storage
Start date of project: 01.01.2017
Duration: 50 months

Overview over companies offering MH compressors

Company	Country	$p_{out,max}$ [bar]	$\dot{V}_{out,max}$ [Nm³/h]
HYSTORSYS	NORWAY	250	12
CYRUS, HyStore Tech LIMITED	GREECE	300	1.5
MAHYTEC	FRANCE	400	25
GRZ TECHNOLOGIES	SWITZERLAND	200	0.096
University of the Western Cape, HySA Systems Hydrogen South Africa	SOUTH AFRICA	200	10



2-stage 1 Nm³/h hydrogen compressor. Inlet pressure 20 bar, outlet pressure 200 bar. © 2018

Helmholtz-Zentrum hereon

Research questions

- **Rare earth free metal hydride alloys ⇒ safety of supply of raw materials**
- **Reaction kinetics and cyclability of metal hydrides**
- **Optimisation of heat transfer ⇒ smaller containers for same capacity**
  - ⇒ minimal consumption of external heat
  - ⇒ less cost
- **System scale-up ⇒integration into hydrogen refuelling stations, gas grid, etc.**

Questions?

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Helmholtz-Zentrum
hereon

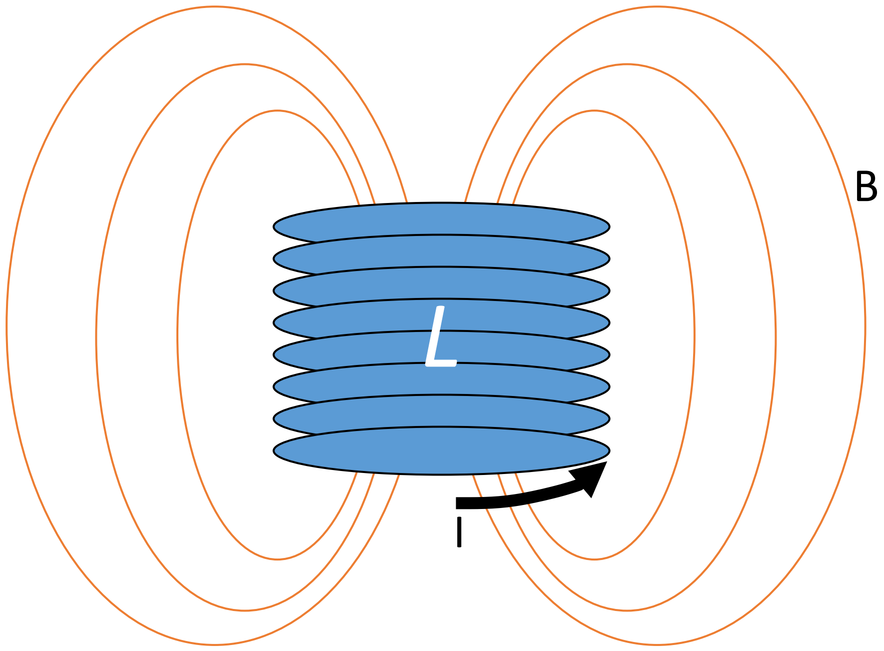
Magnetic Energy Storage?

Superconducting Magnetic Energy Storage
EERA JP ES SP5

Energy Storage: How do it

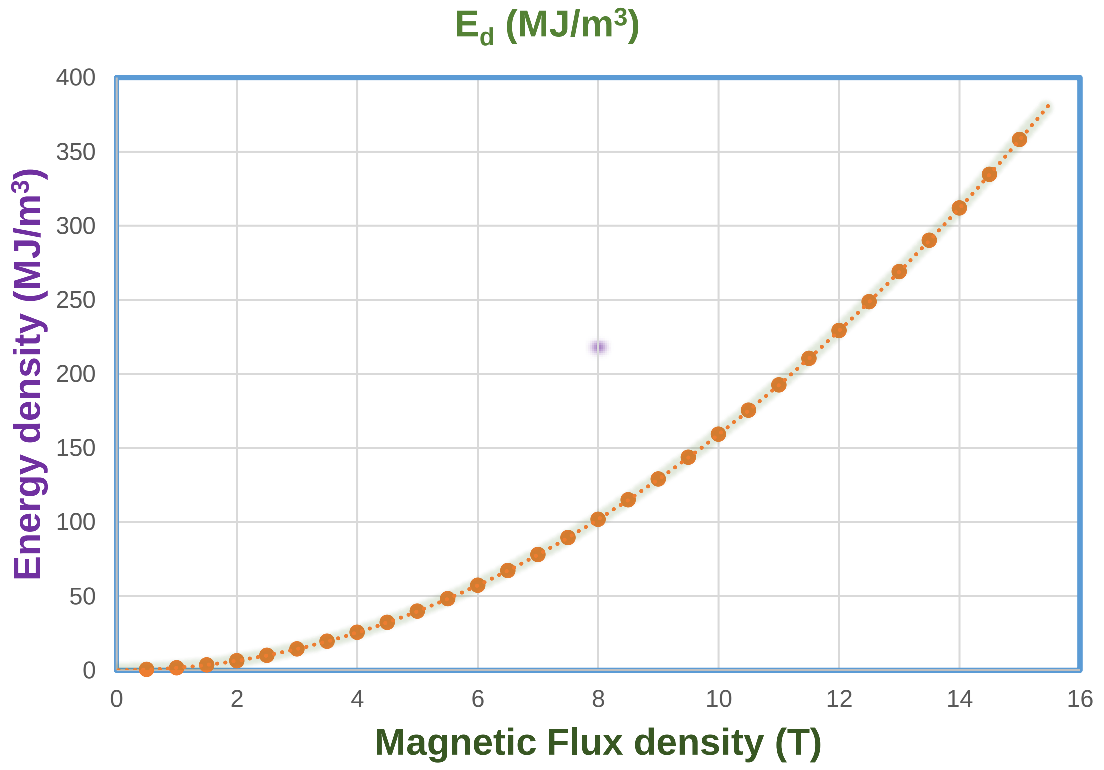
Electrochemical	Closed cycle Batteries, Li, Ca, Mg …… Flux Batteries …… Supercapacitors	Static and mobile applications
Chemical	Chemical vectors Chemical to chemical and reverse hydrogen , Aluminium…………	Charge: Static systems Discharge : Both static and movable
Thermal	Thermal mass, Phase change of salts	Static systems
	hybridation	
Mechanics	Water Pumping, CAES, ACAES, Flywheels	Static systems Movable (CAES)
Magnetic	SMES	Static systems Expected movable systems Hybrid and sinergic systems

Energy in a coil: Magnetic Energy Storage

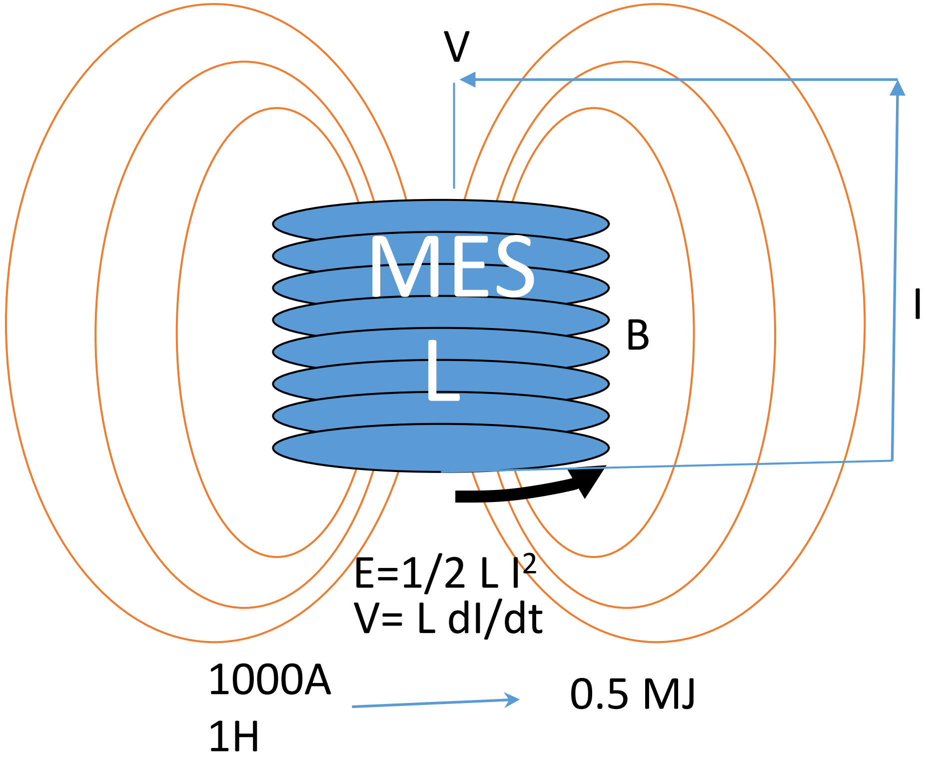


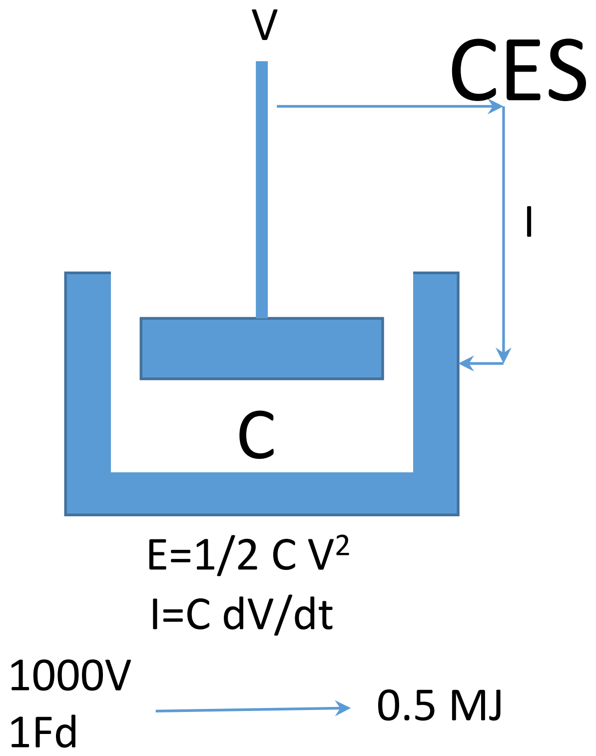
$$E_{max} = \frac{1}{2} L \cdot I^2 = \int_v \frac{B^2}{2\mu_0} dv$$

In a coil, each m^3 of magnetic flux with a density of 1T, has the same energy as a m^3 of water at 40.6 m high. I the flux density achieves 6T, the stored energy is 36 times higher: just at 1,461.6m high!



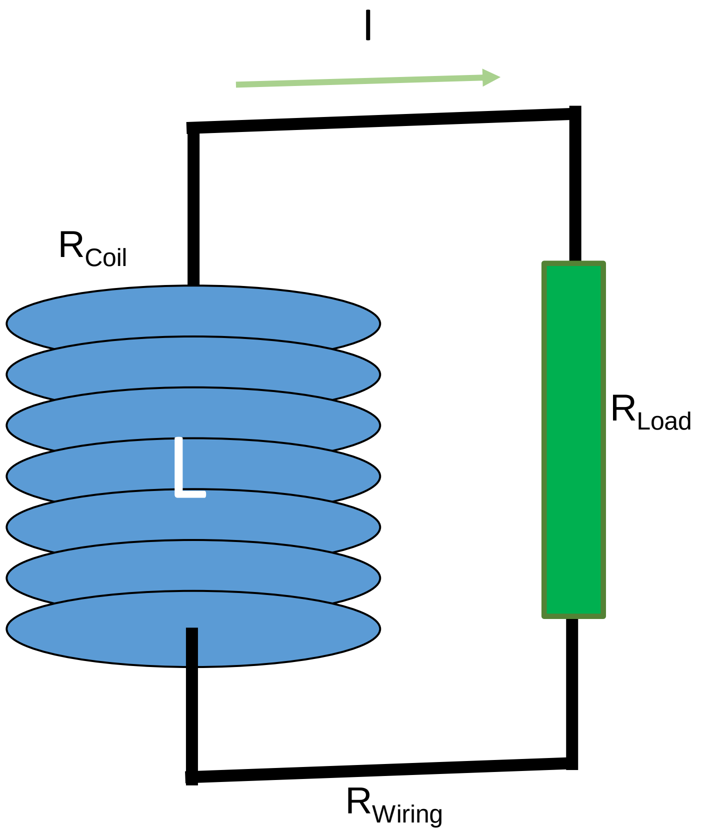
Coils instead Capacitors?





Current instead charge
Inductance instead Capacity
Magnetic Flux Density instead electrical field

MES: time decay?



$R_t = R_{Wiring} + R_{Coil} + R_{Load}$

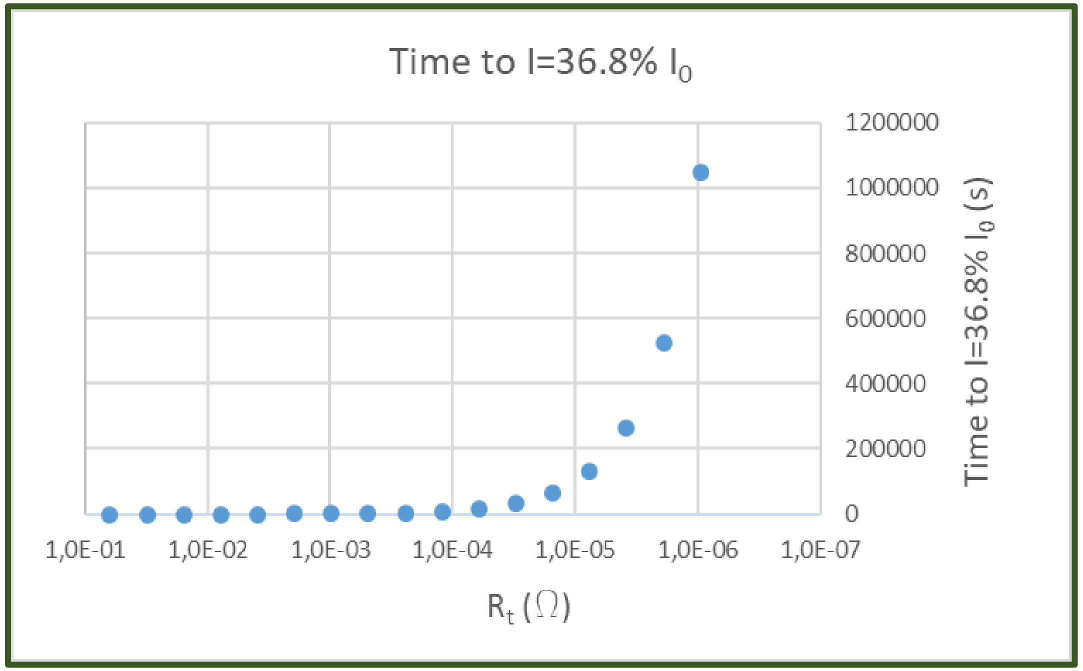
$\tau = L/R_t$

$I = I_0 \, e^{-t/\tau}$

$V = R_t \cdot I_0 \, e^{-t/\tau}$

$E = 1/2 \, L \, (I_0 \, e^{-t/\tau})^2$

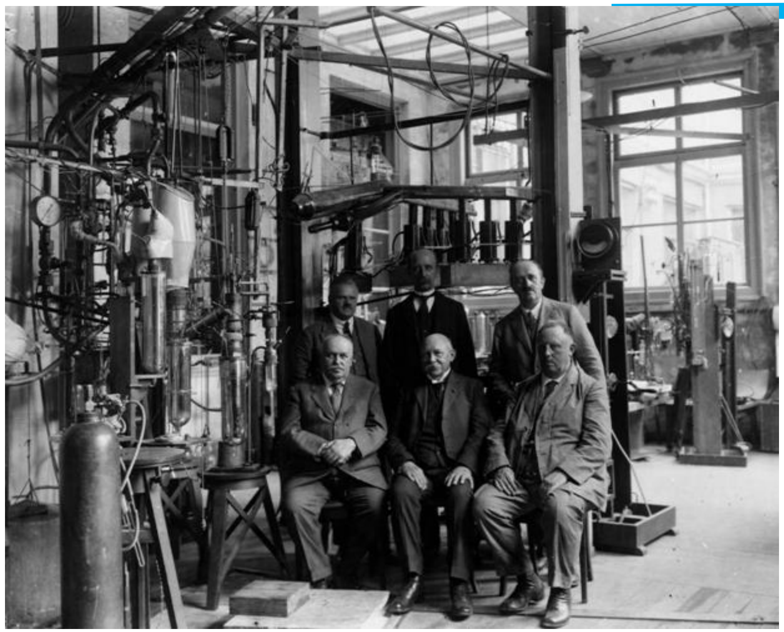
for $t = \tau$ ➔ $I = 36.8\%(I_0)$



Copper? ➔ Resistance!= loss of energy ➔ $\tau = L/R$

? ➔ $R_t = 0$? ➔ $\tau = \infty$

R=0 ?   Superconductors!



A new state of matter

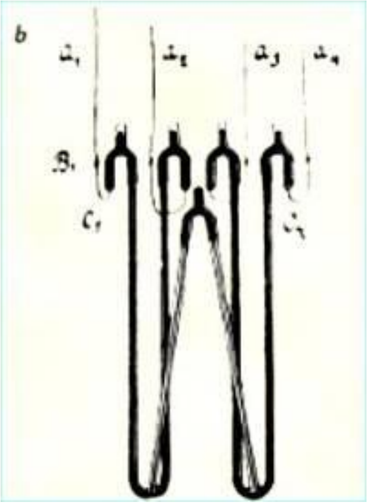
The Superconducting state

Superconducting coils can retain the magnetic field for large time:

Magnetic Energy can be stored within Superconducting coils:

SMES is feasible

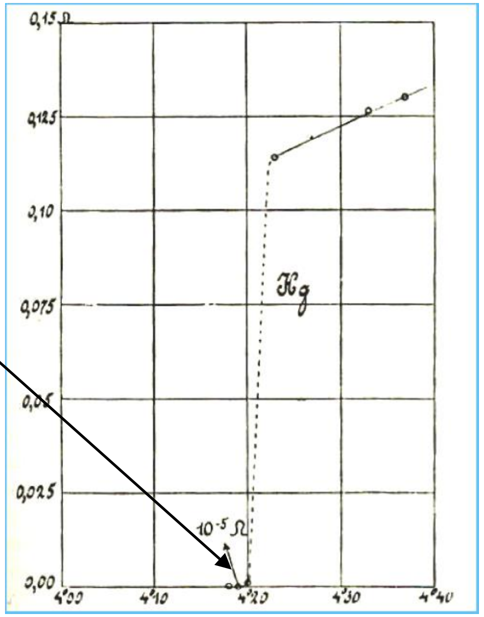
Mercury test



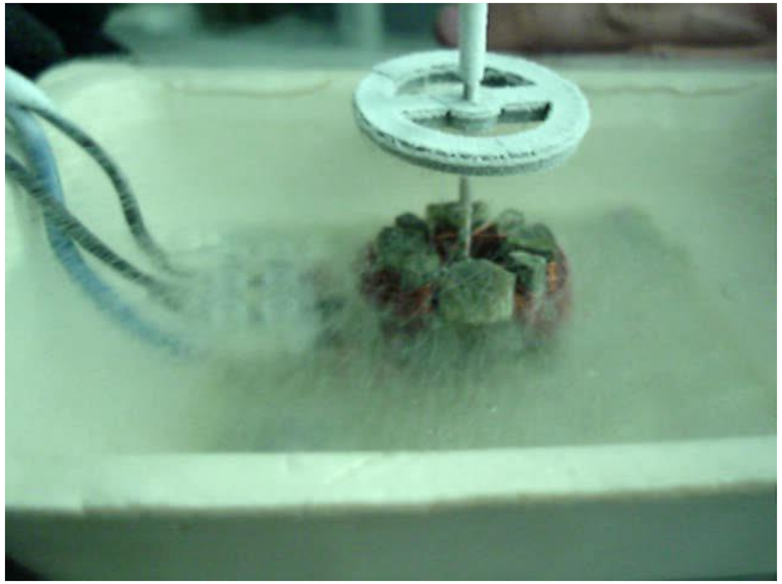
1911

Resistance dropped to zero at

4.2K



R=0 Superconductors



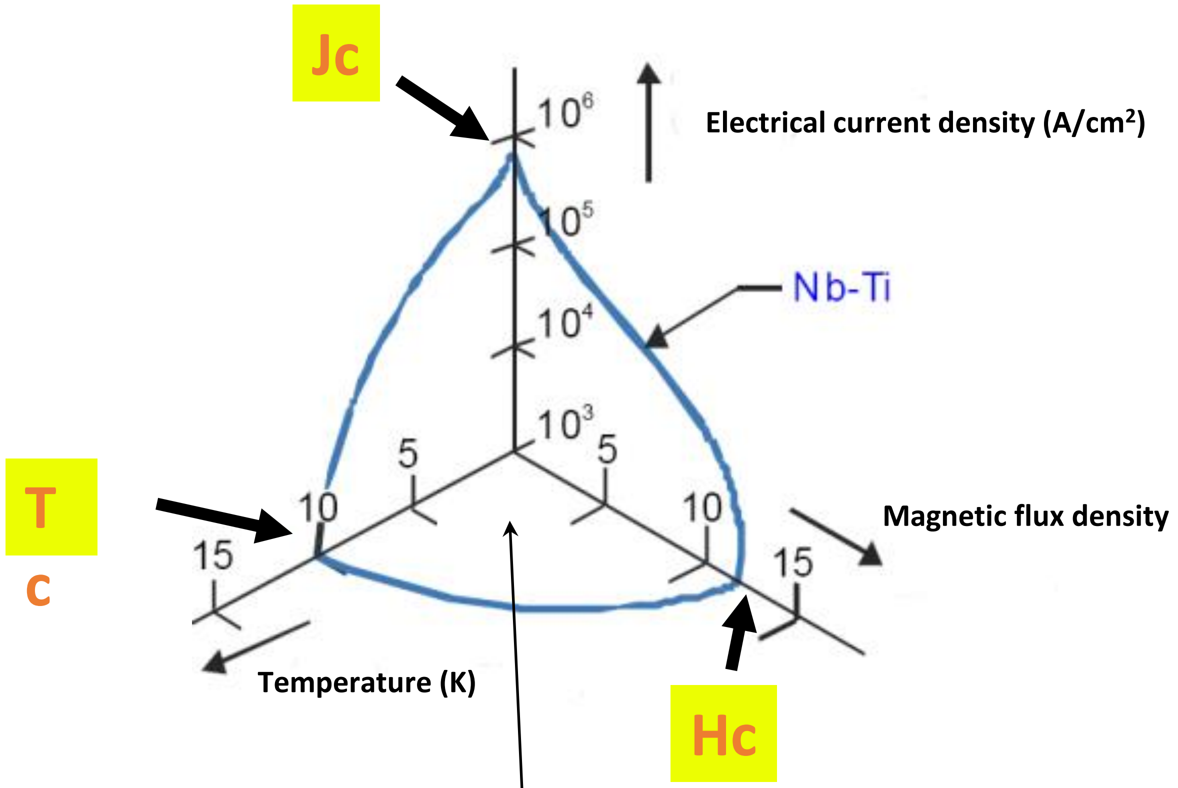
Superconductivity: A state of matter

State Variables

T

J

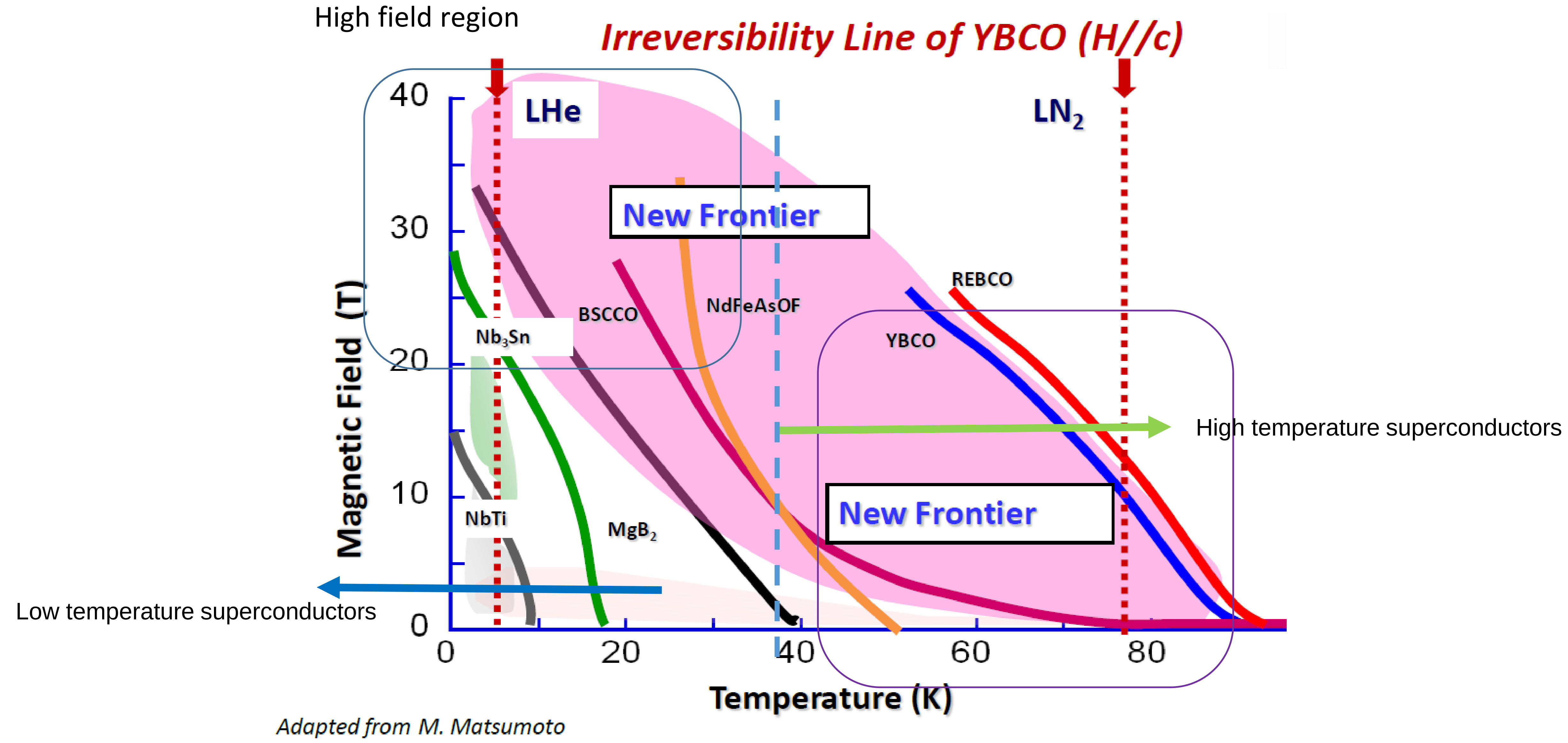
H



Superconducting State

T< Tcritical
H<Hcritical
J<Jcritical

Superconductors: the materials



Commercial High temperature Superconductors

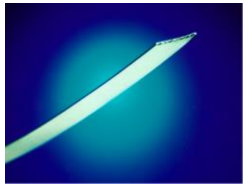
Bulk

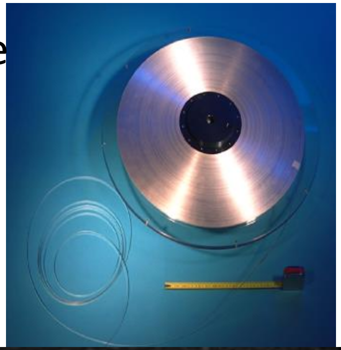
Bi-2212

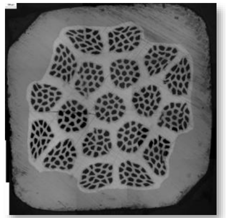
Y-123

Powder in tube

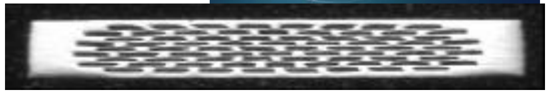
TAPES



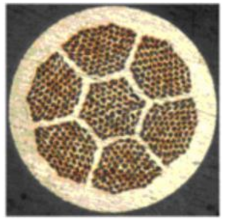




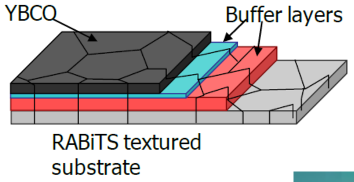
MgB_2



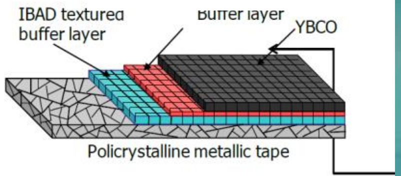
Bi-2223 Tape 1G

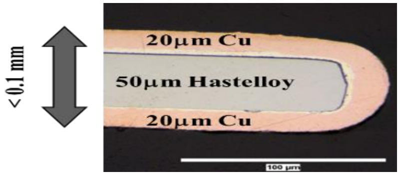


Bi-2212 wire



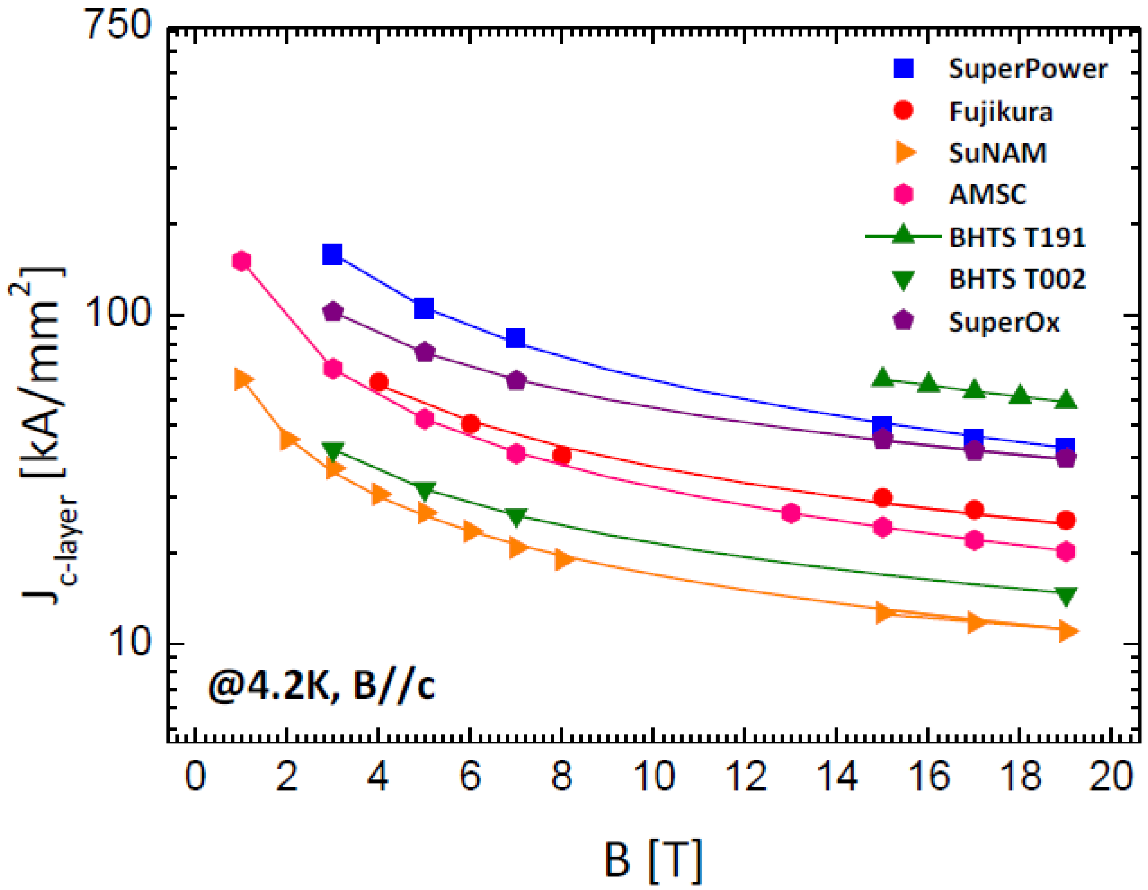
Coated Conductors (YBCO, 123)





Market

Technology Watch for Material Properties



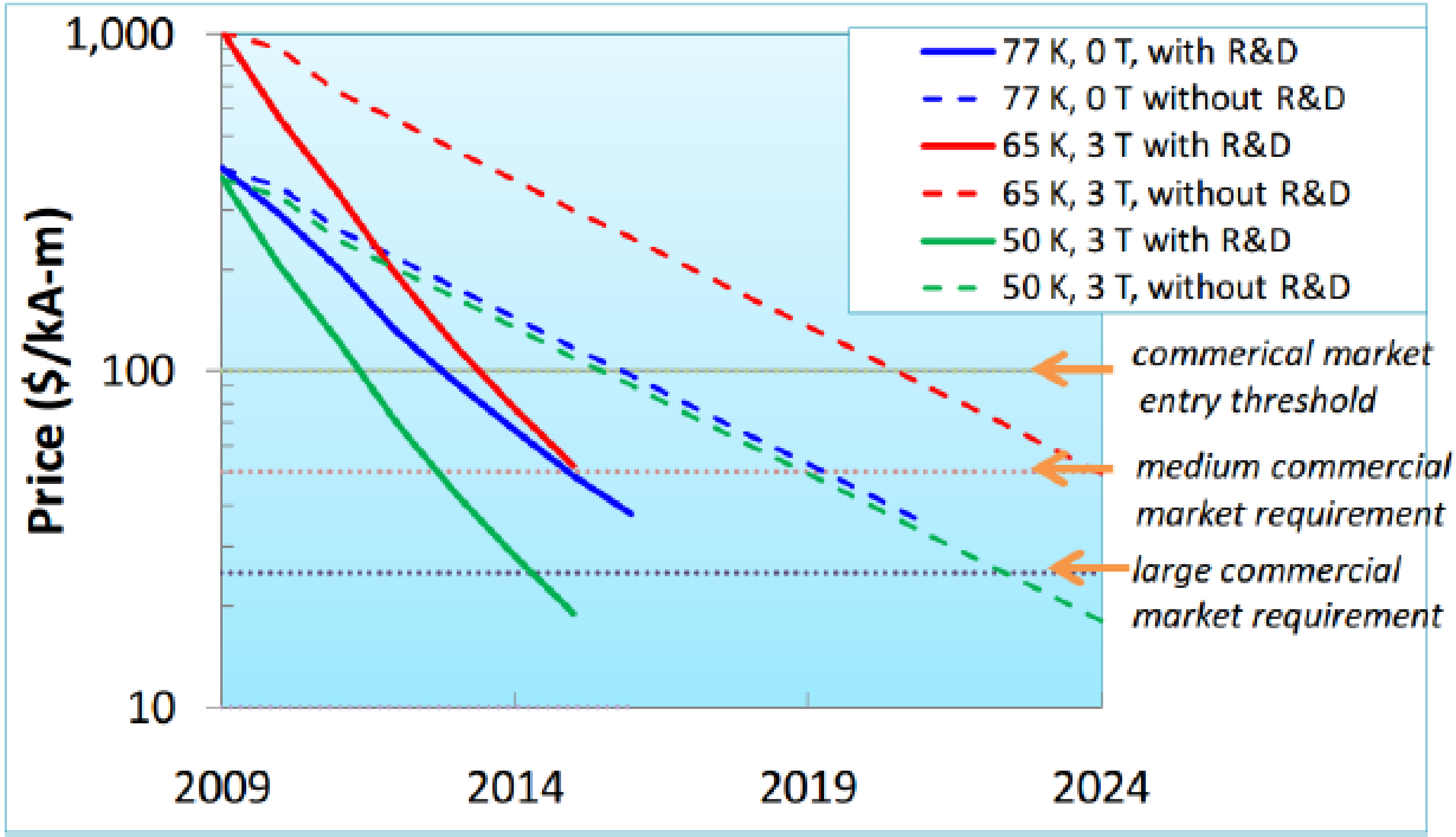
+Theva

Source: C. Senatore, Conductor progress in EuCARD-2 Overview of electrical, mechanical and thermo-physical properties of REBCO CCs
Département de Physique de la Matière Condensée & Département de Physique Appliquée Université de Genève, Switzerland

2 G wire still has a large potential for improvements

Market

Ref. SuperPower



Higher demand lowers de cost

Why Superconductivity can help?

Macroscopic

No resistance
Diamagnetism
Magnetic Flux trapping
Current Driven Transition

Electro-technical Applications

Microscopic

~~Electronic interactions~~
~~Vortex dynamics & other~~
~~Micro-nanoscopic & quantic effects~~

~~Sensors (SQUID)~~

~~Superconducting electronic Devices~~

~~Microwaves~~
~~ETC.~~

NOT NOW

Power Applications and Superconductivity (Terrestrial)

- **Improvement of conventional devices**
- **New functions, new devices**
- **COST Cryogenics+ material+ installation**

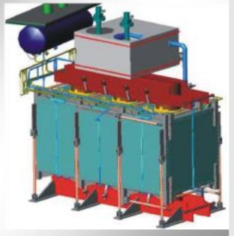
Less weight & volume → Higher power density
Losses reduction → Higher efficiency

Improvement of conventional systems | **New systems**

Cable

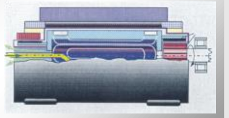
Higher Power Density
Lightweight
Retrofit
Larger efficiency

Trans-former



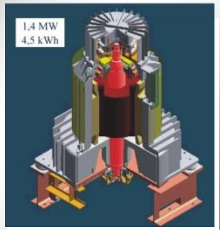
Energy Savings
Environmental Safety
Mobile Transf.!

Motor Generator



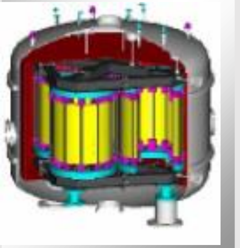
Volume, Weight, Energy savings

Flywheel



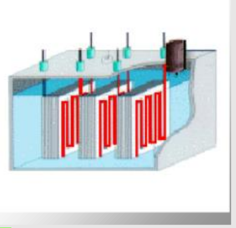
Energy Density
Energy Savings
Safety

SMES



Availability
Savings of Ressources

Fault Current Limiter

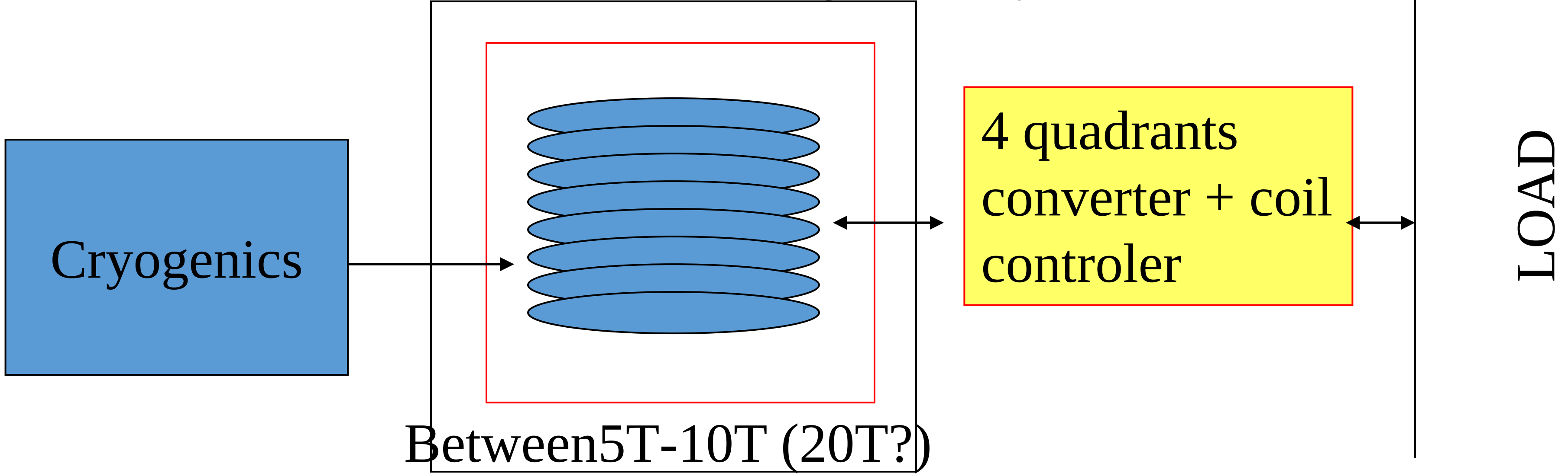


Novel Power Grids
Power Quality
Savings of Ressources

Courtesy of NEXANS

The SMES

No Resistance--------No magnetic decay



$$Q_{max} = \frac{1}{2} L_s I_r^2 = \int_v \frac{B^2(v)}{2\mu_0} dv$$

Between 10 y 40MJ/m^3

Maximum power: limited by V_{max}
(electronics & isolation & losses & quench risk)

Very high efficiency 90-95% (depending on storage time)
More than 30 years operative

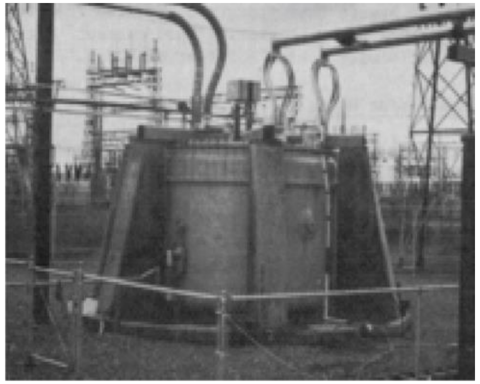
SMES status:
Low temp--------- commercial
High temp------- desenvolupament

Some existing and tested SMES’s

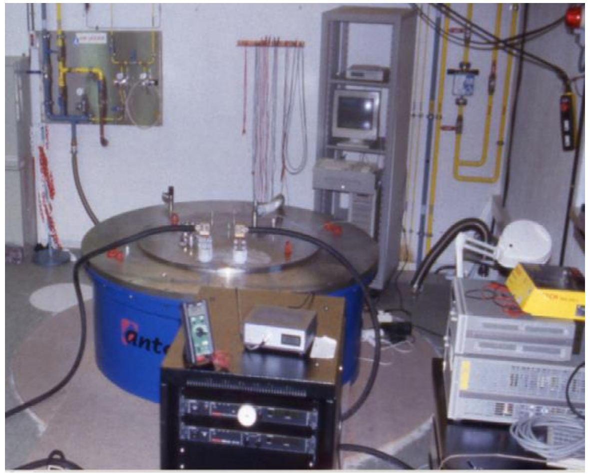
Boneville	US	1980	10MW 30MJ	NbTi	Stability
Asinel	Spain	1996	500 kVA,1MJ	NbTi	Power quality
KIT	Alemania	1997	320 kVA, 203 kJ	NbTi	Flicker compensation
AMSC	US	+	2 MW, 2,6 MJ	NbTi	Power Stability
KIT	Alemania	2004	25 MW, 237 kJ	NbTi	Power levelizer
Chubu	Japón	2004	5 MVA, 5 MJ	NbTi	Voltage stability
Chubu	Japón	2004	1 MVA, 1 MJ	Bi 2212	Voltage stability
KERI	Corea	2005	750 kVA, 3 MJ	NbTi	Power quality
Ansaldo	Italia	2005	1 MVA, 1 MJ	NbTi	Voltage levelizer
Chubu	Japón	2007	10.MVA,19.MJ	NbTi	Load compensation
CAS	China	2007	0.5 MVA, 1 MJ	Bi2223	
KERI	Corea	2007	600 kJ	Bi2223	Power quaity
CNRS	Francia	2008	800kJ	Bi2212	Military
KERI	Corea	2011	2.5MJ	YBCO	Power quality
ABB/SP	US	2013	20 kW 2.5MJ	YBCO	
RDS	Italia	2017	50kW 300kJ	MgB2	Power quality

Mostly to be applied at the grid

Examples

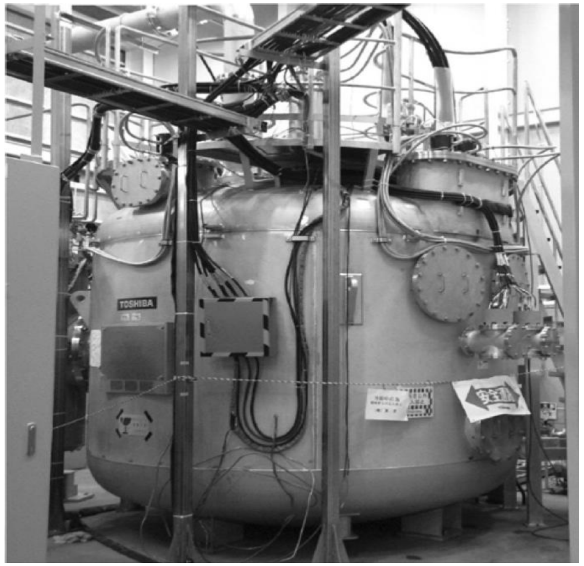


Boneville Authority: 1980
Tested 1 year



AMAS 500, 1994-96 en el laboratorio de CEDEX (asinel)

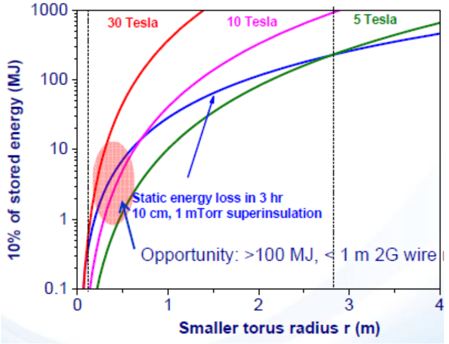
ACCEL, 2003, UPS commercial

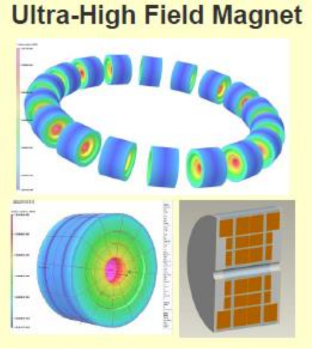


Toshiba, 20MJ-10MW, operating in CHUBU

Research

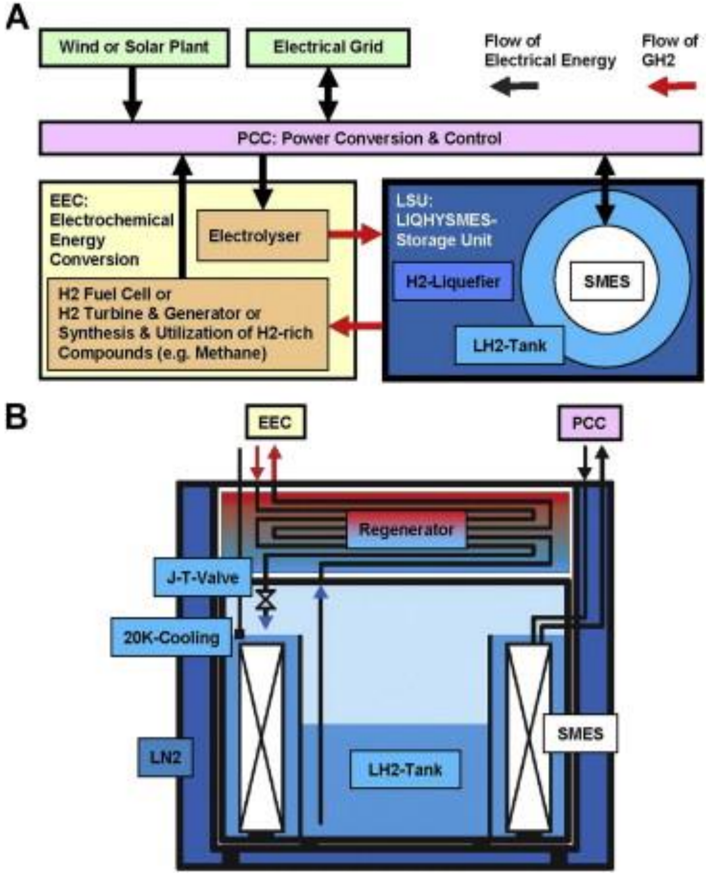
Compact systems





130MJ/m³!!

ABB, Brookhaven NL, la Universidad de Houston y SuperPower inc. 20-25T



M. Sanders (KIT)

Cryogenic improvements

In L-N2 and L-CH4 Storage plants

Regasing enthalpy improves efficiency of cooling systems

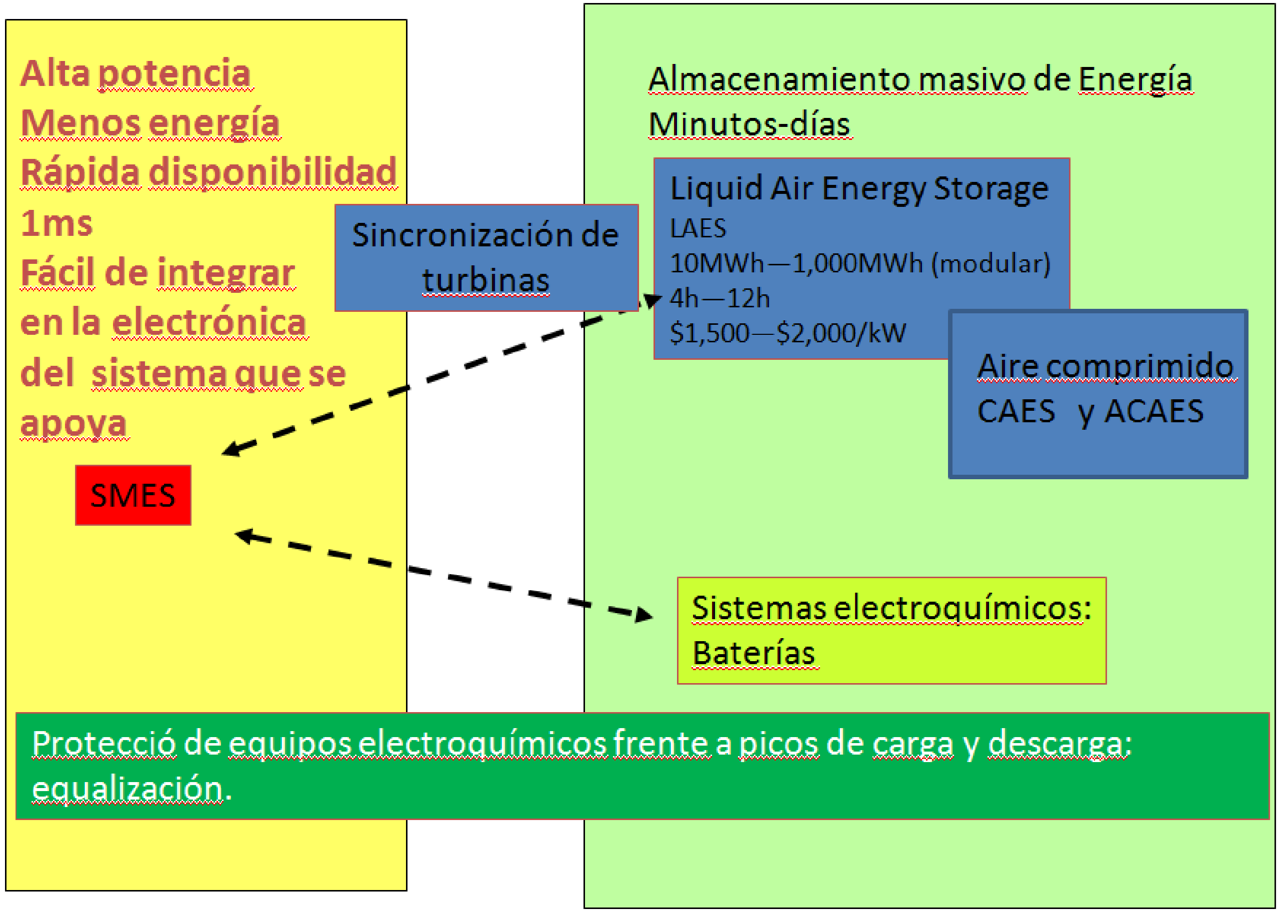
Cryogenic Symbiosis LQHYSMES

Sharing cryogenics with liquid hydrogen ES (20K)

Hybridization: Long term ES with no-latence high power ES

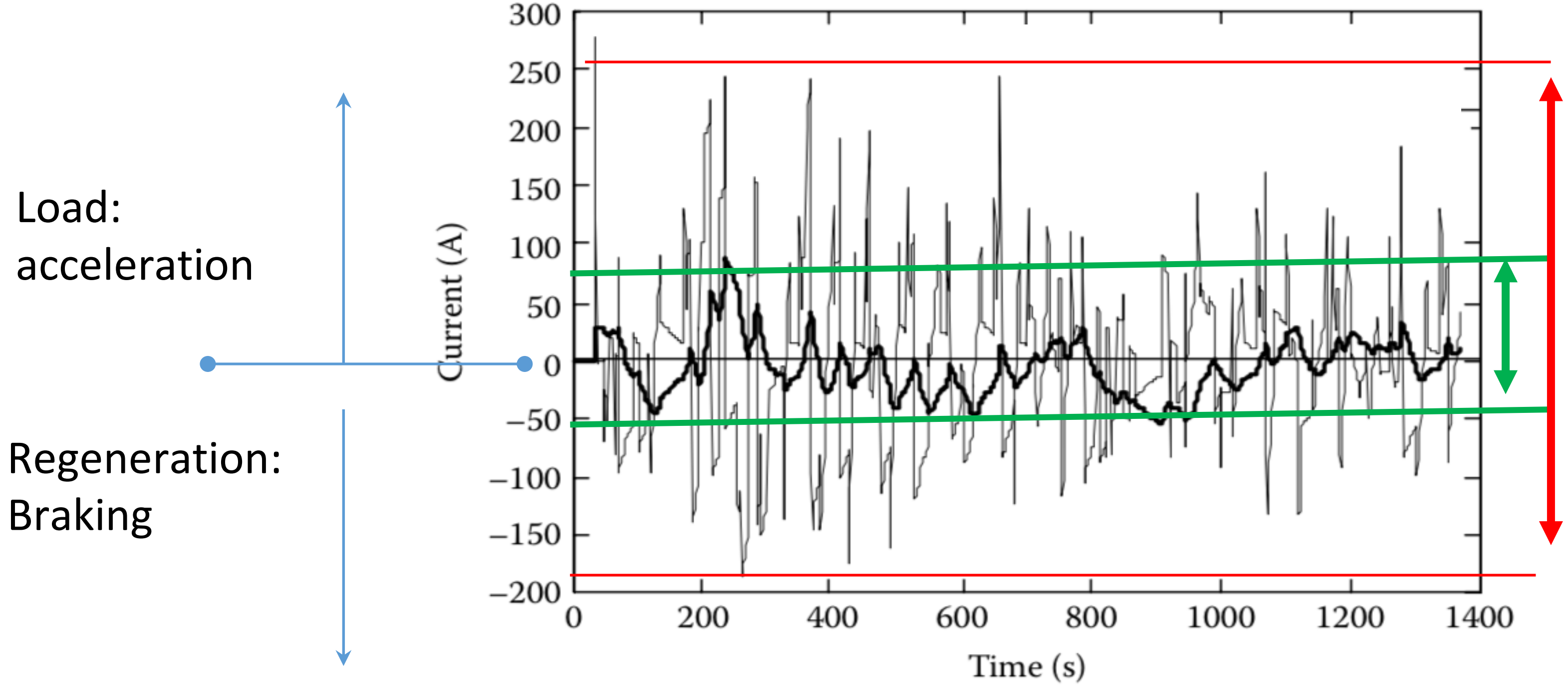
LAES, CAES, ACAES, BATTERIES………
Longer life, fast response, and Sinergies. Combined supply LN2-electric in Dearman motorised trucks

Hybridization



SMES and mobility

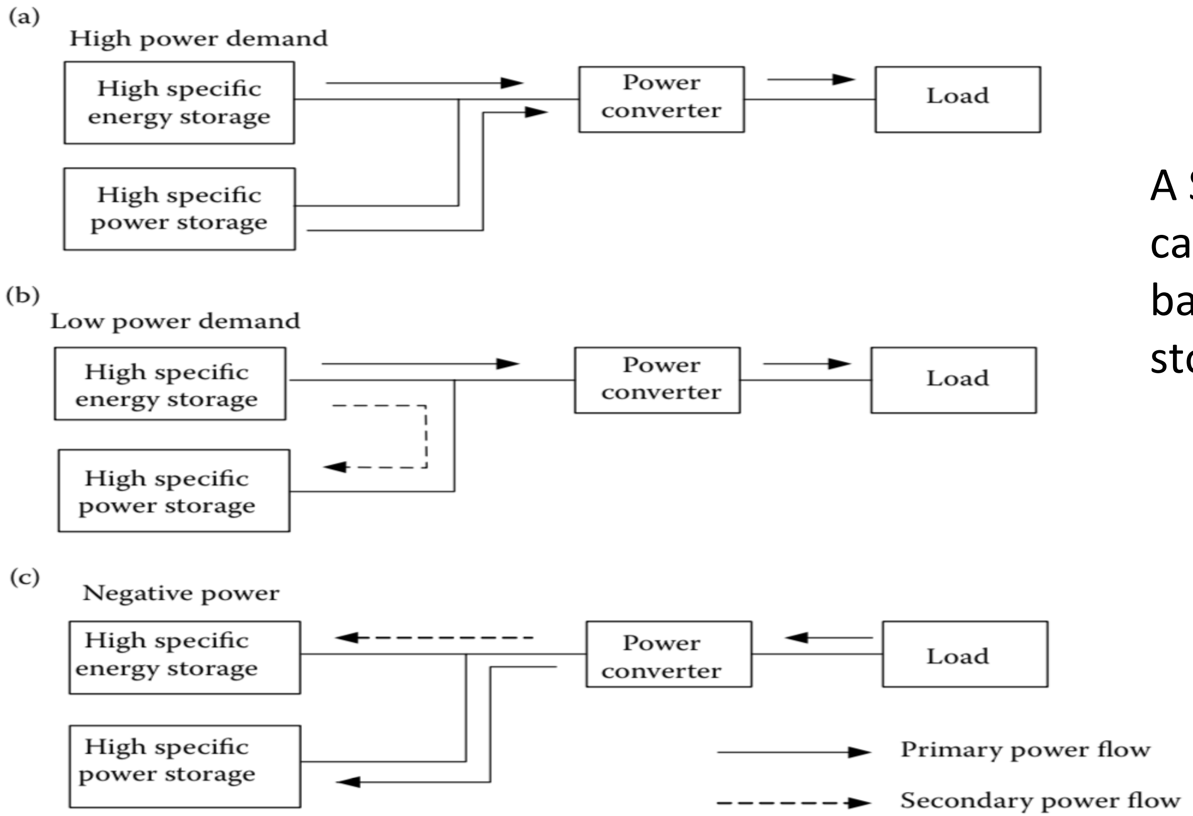
Regenerative braking in cars



Load integrated each 20s is 50A. The peaks achieve 250A

A good managing of the energy requires a good managing of the transients
Batteries should be over-dimensioned to face the transients: they weight more

Load regulation



A SMES of 40kW and 700kJ (0,19kW.h) can reduce the power of the batteries bank to only **10kW** by supplying or storing the difference

Recovering energy

An aircraft (67t) when landing, running along its track, wastes an energy of 0.15 GJ (41,7 kW.h) at an averaged power of 7.4 MW

Is it possible to fit this energy in one of its tires?

Thanks for your attention

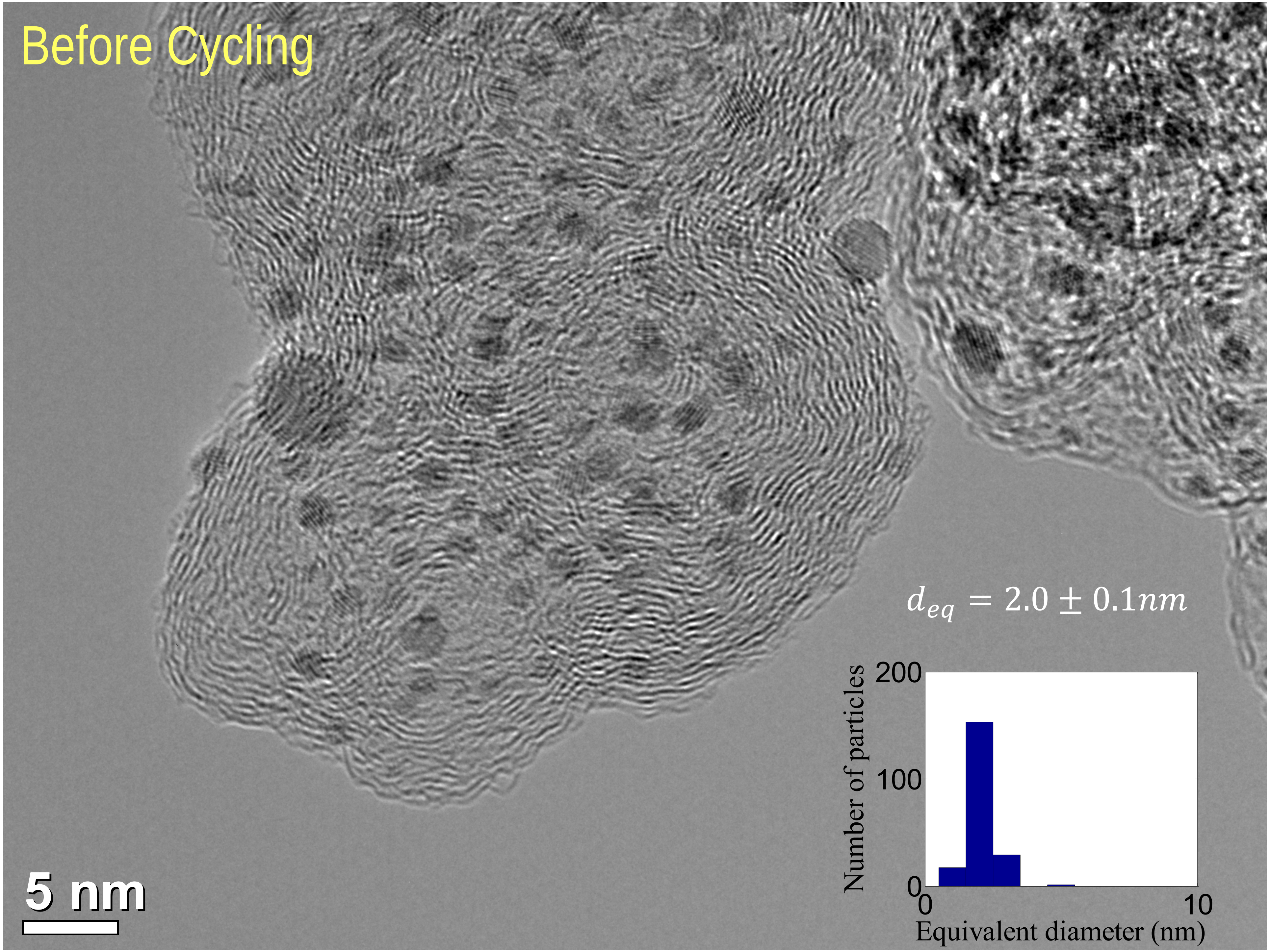
Monitoring Catalyst Degradation using Advanced Electron Microscopy and Spectroscopy

Paulo Ferreira

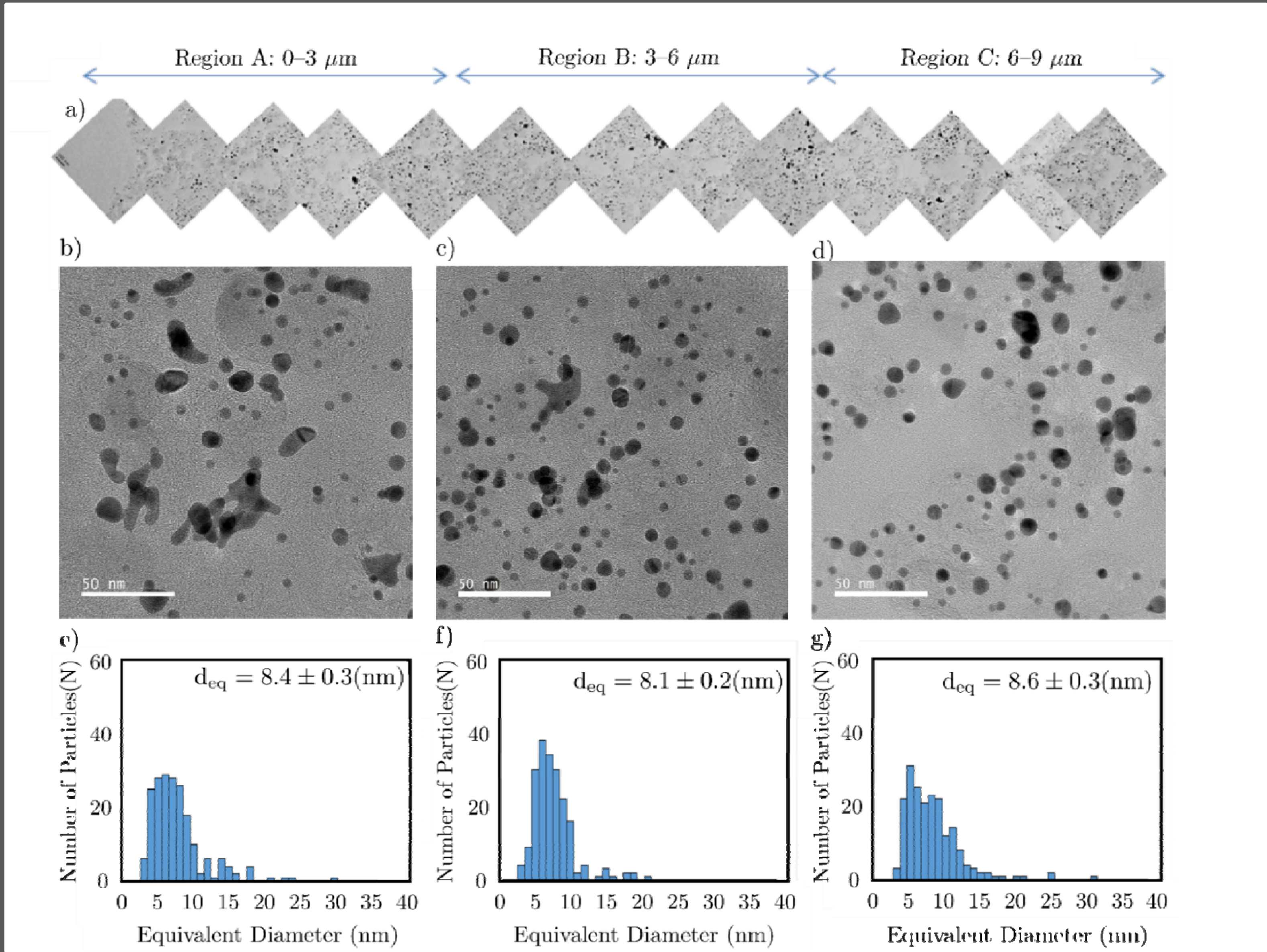
Professor
Department of Mechanical Engineering
IST, University of Lisbon, Portugal

Head of Department of Advanced Electron Microscopy, Imaging and Spectroscopy
INL, Braga, Portugal

Adjunct Professor
Materials Science & Engineering Program
The University of Texas at Austin, USA

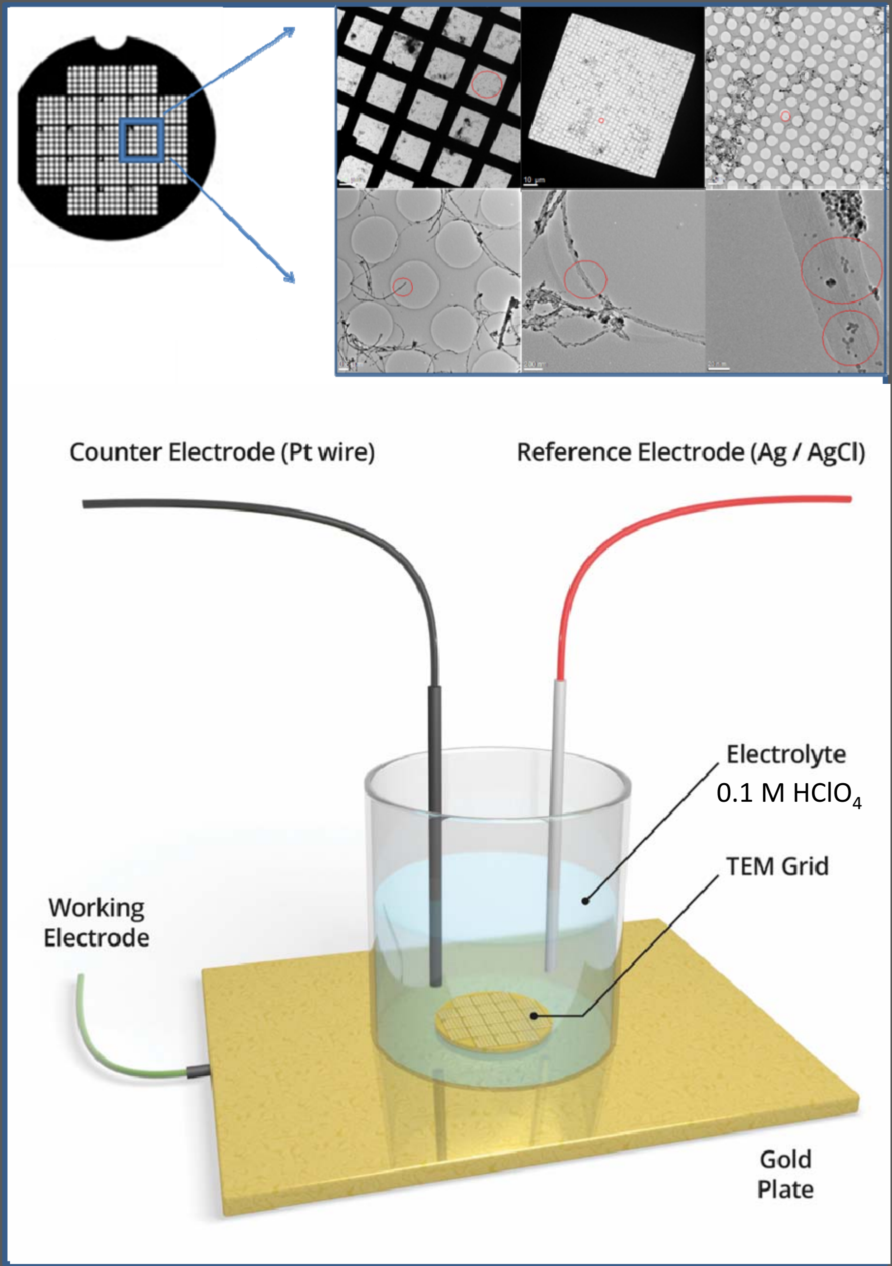

Before Cycling
$d_{eq} = 2.0 \pm 0.1nm$
200
100
0
Number of particles
0
10
Equivalent diameter (nm)
5 nm

After Cycling – 10,000



What is the dominant mechanism for particle growth?

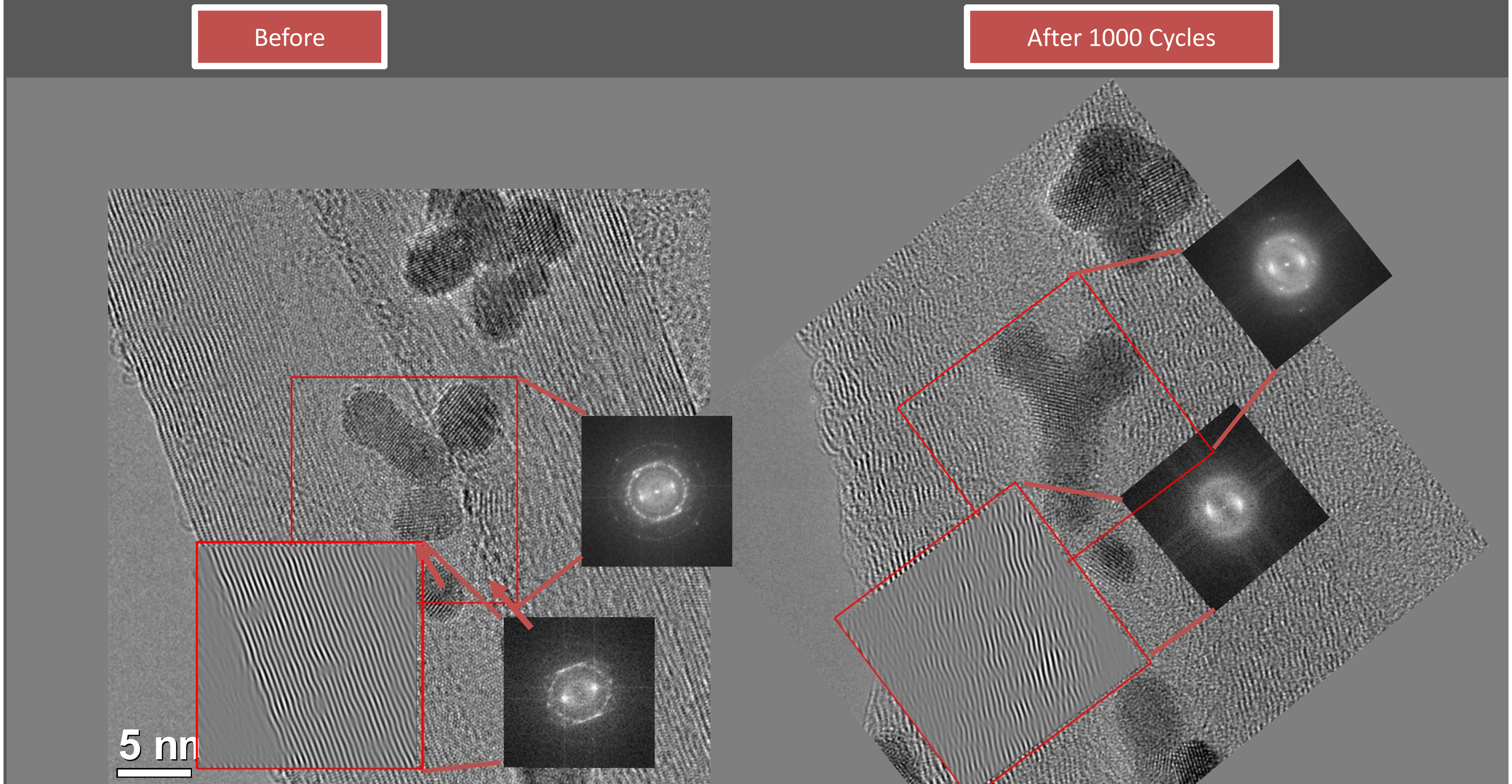
Identical Location TEM

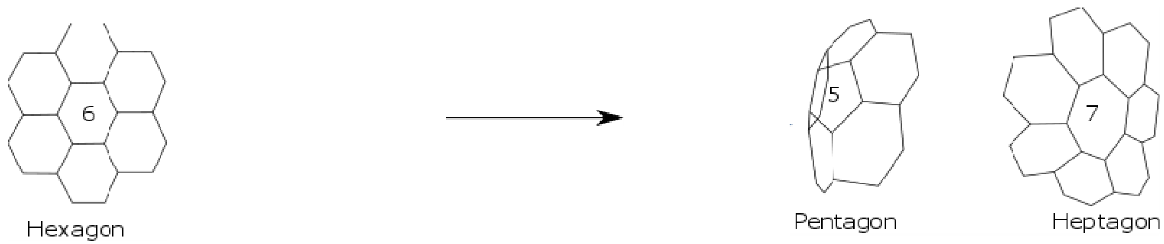


Accelerated Test Protocol

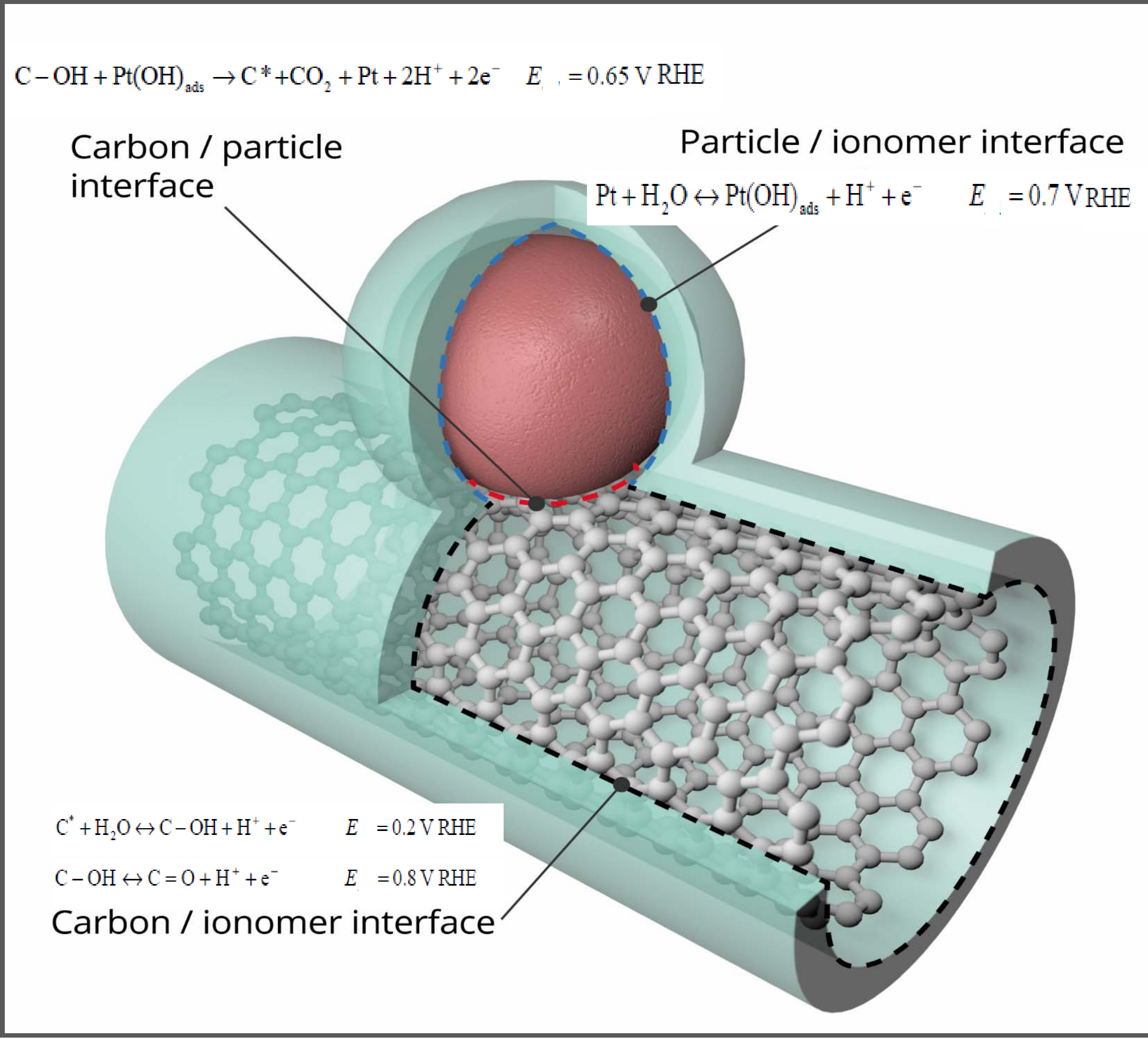
Sample	Testing protocol
Platinum NPs on poly(vinlyphosphonic) acid-doped polybenzimidazole (PVPA-PBI) wrapped on CNTs	TEM grid was cycled between 1V and 1.5 V vs RHE in N_2-saturated 0.1 M $HClO_4$

Particle Movement and Coalescence (Pt/CNT)

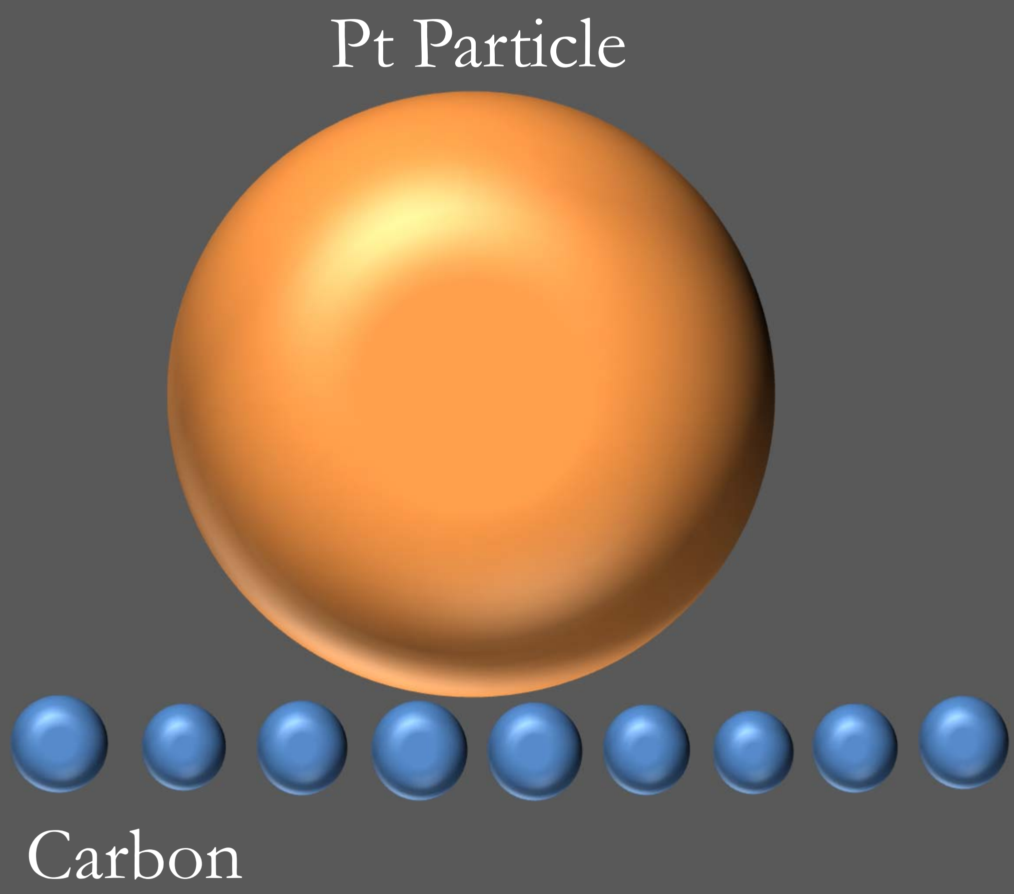


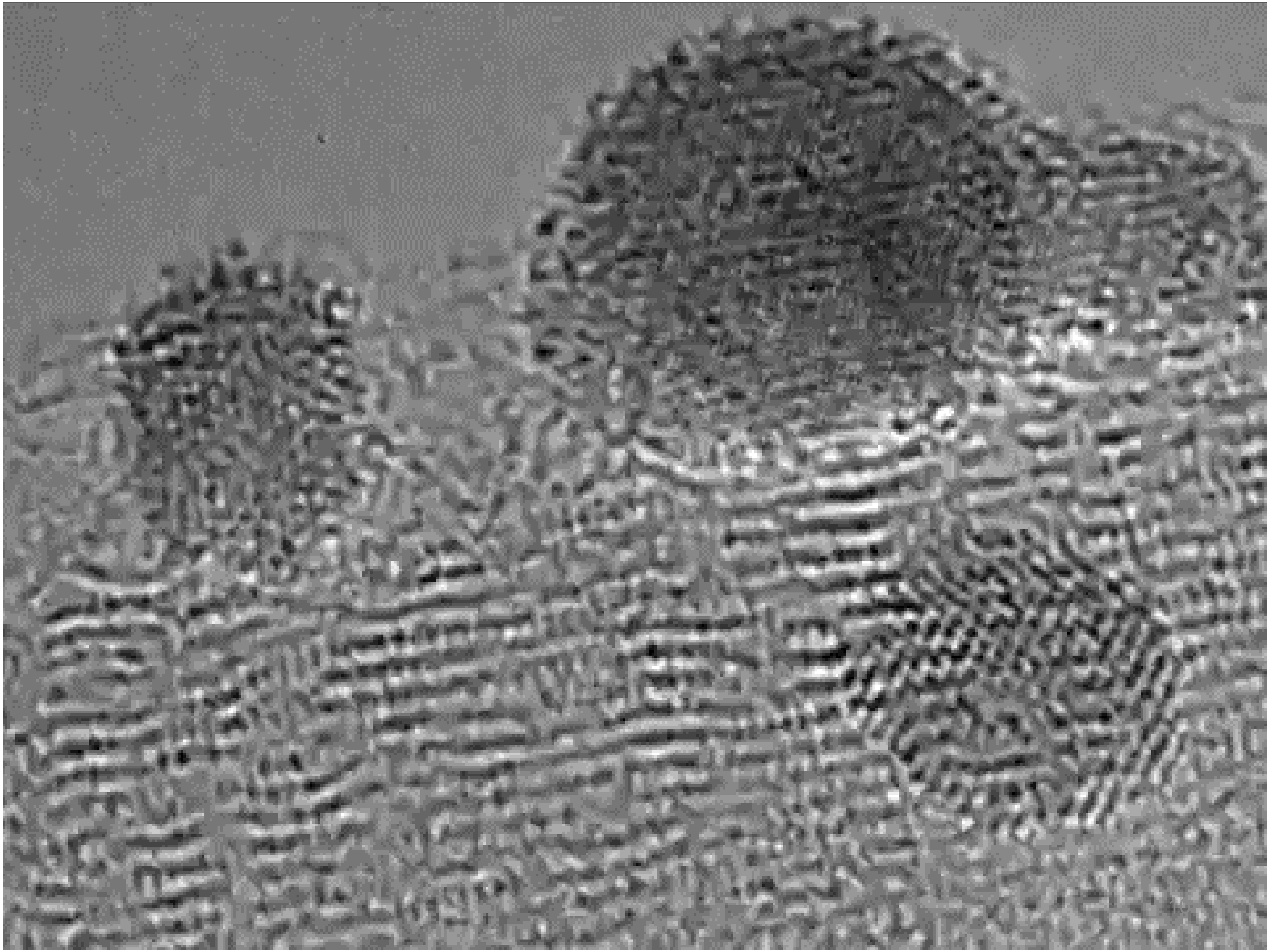


Effect of Voltage on Particle Movement

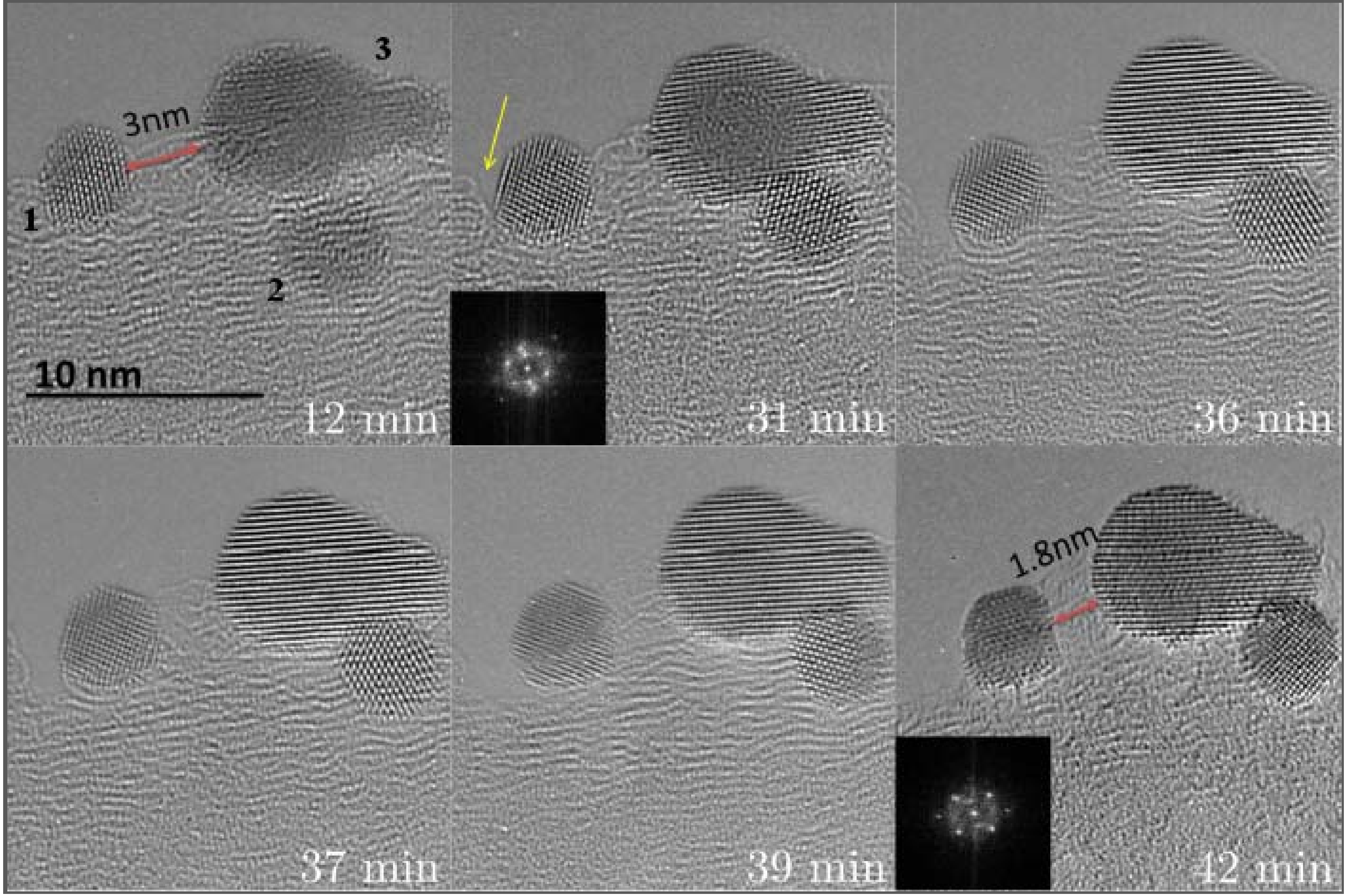


Effect of Voltage on Particle Movement

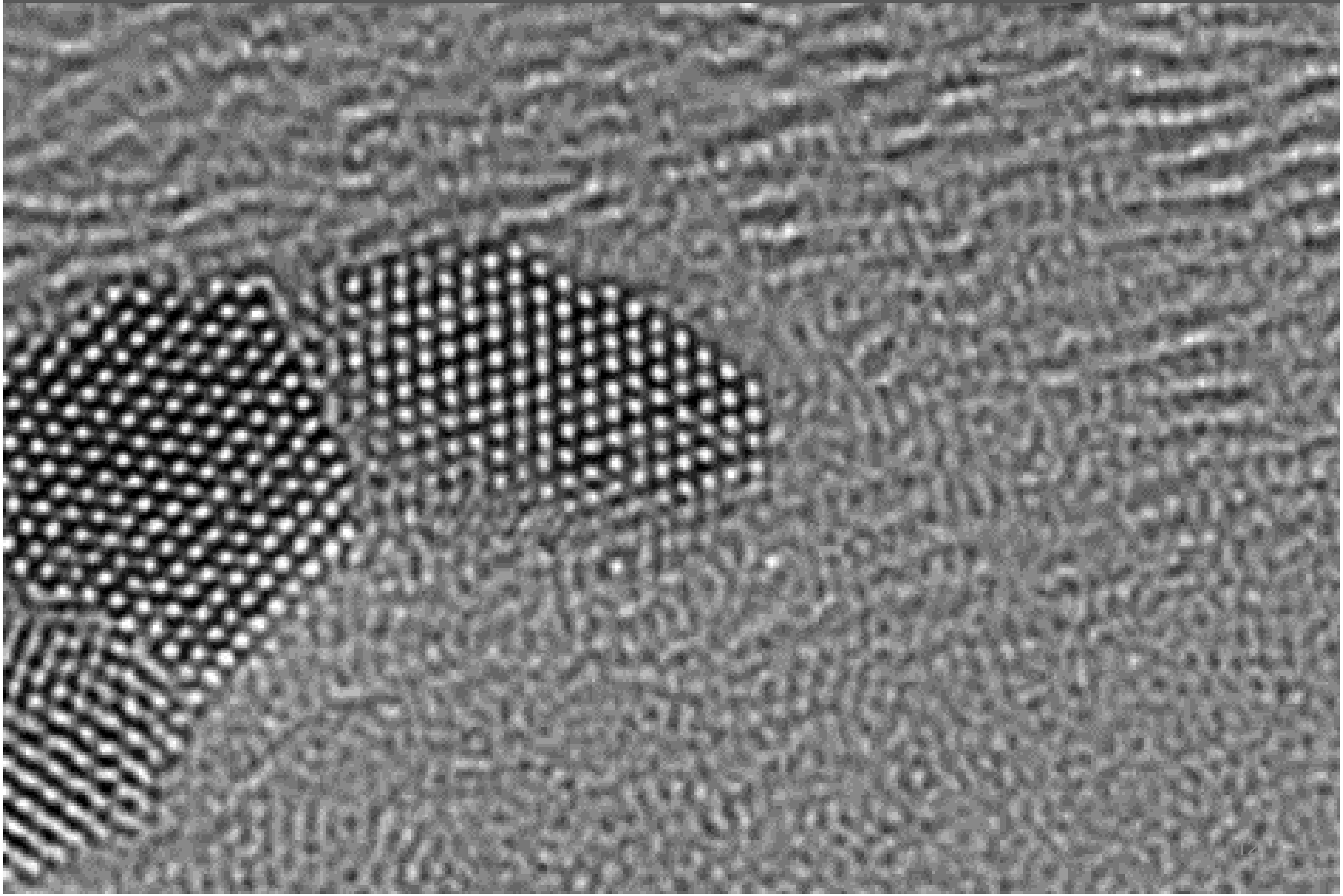




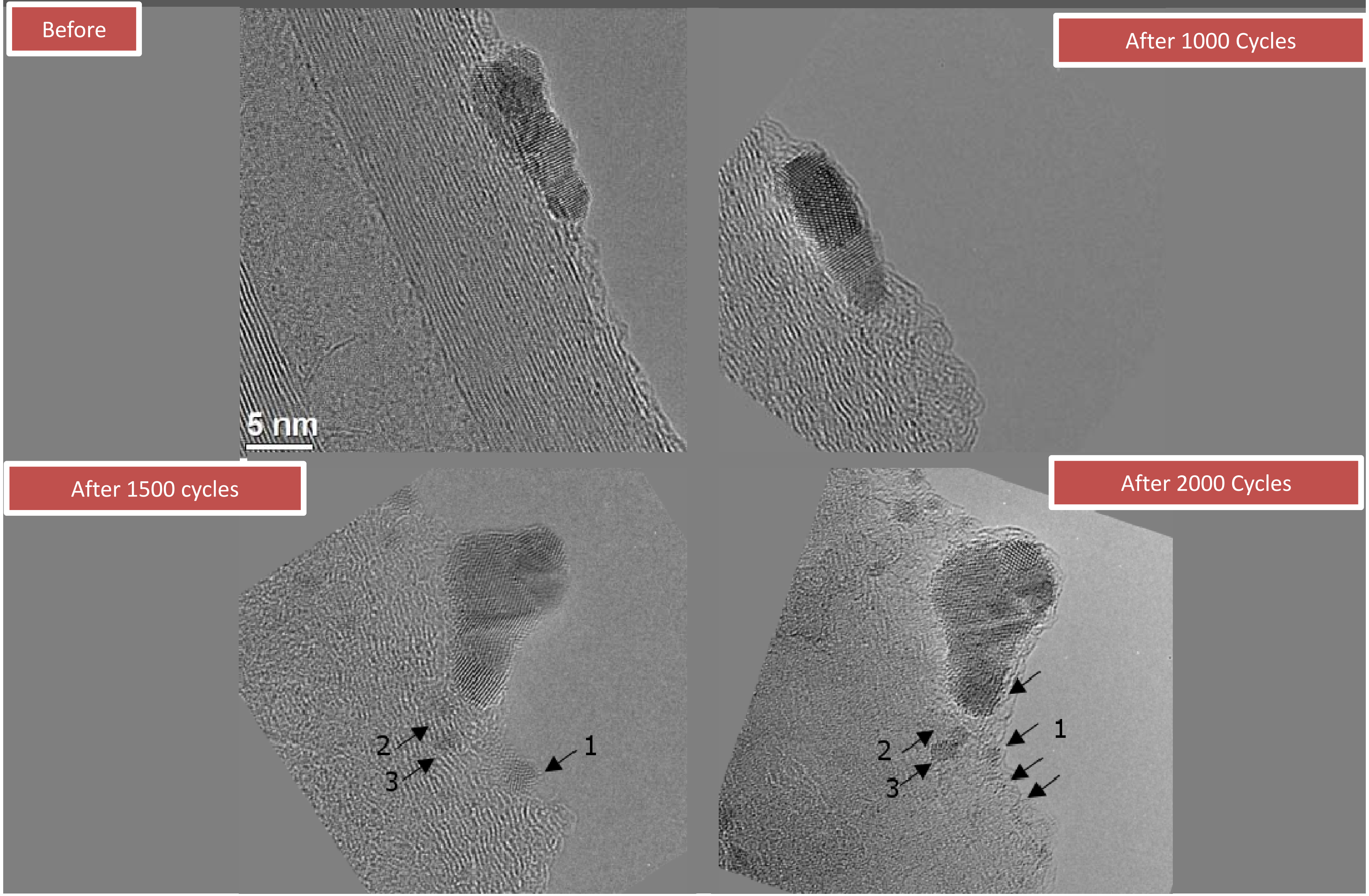
Effect of Carbon Degradation on Particle movement



Particle Coalescence

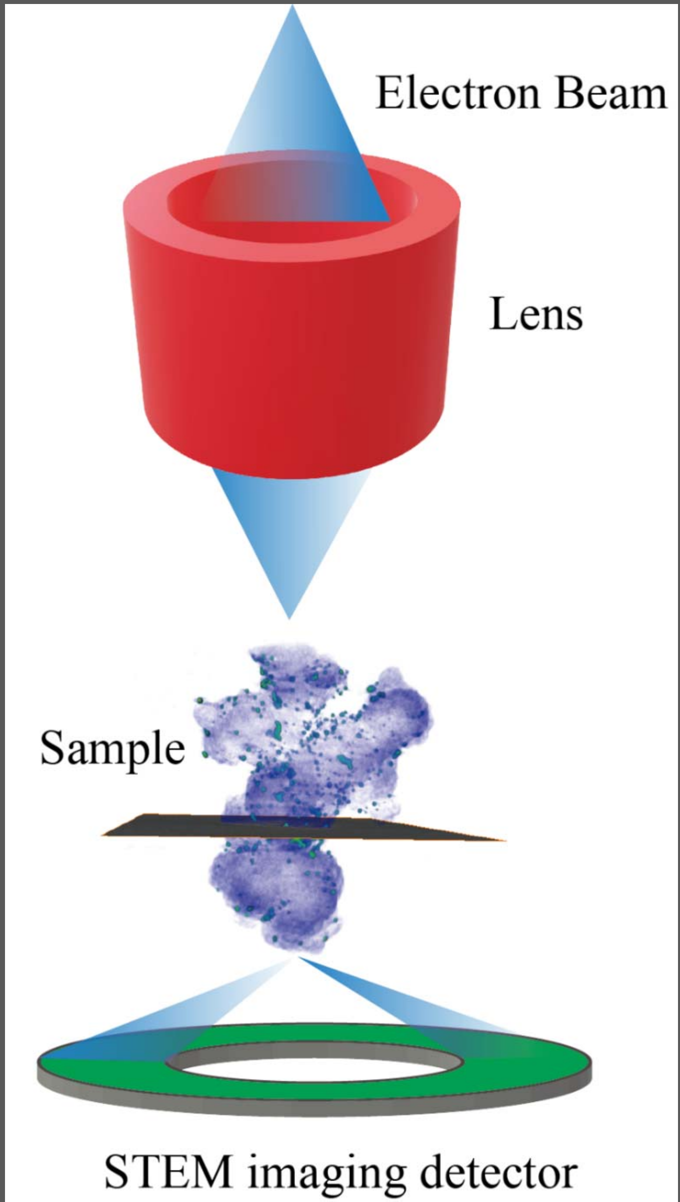


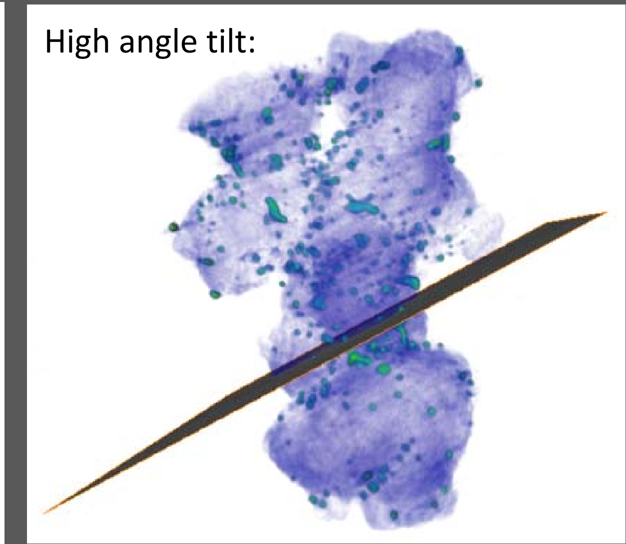
Particle Dissolution and Re-deposition

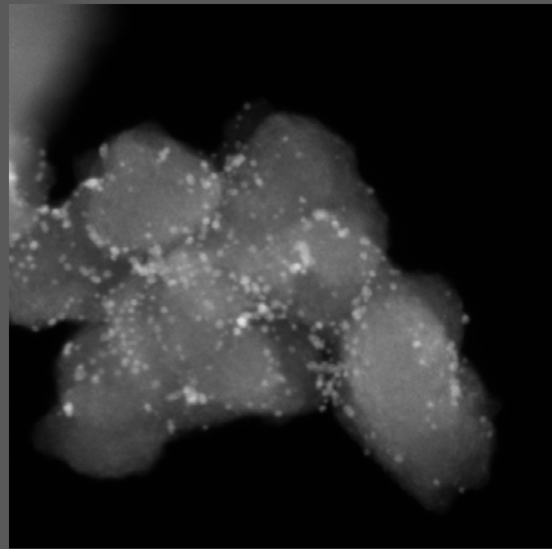


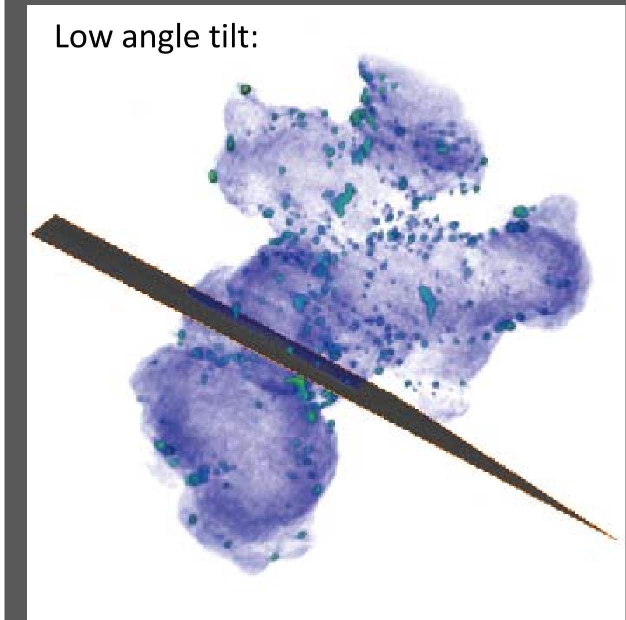
STEM 3D Tomography

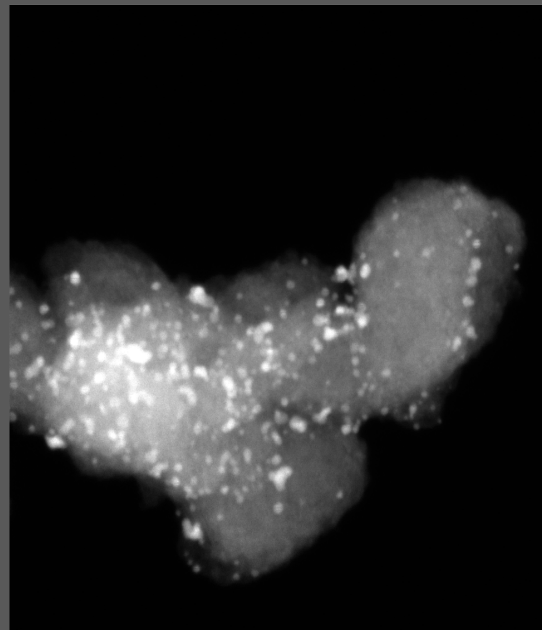
tilt series: -72 to +72° 2° interval





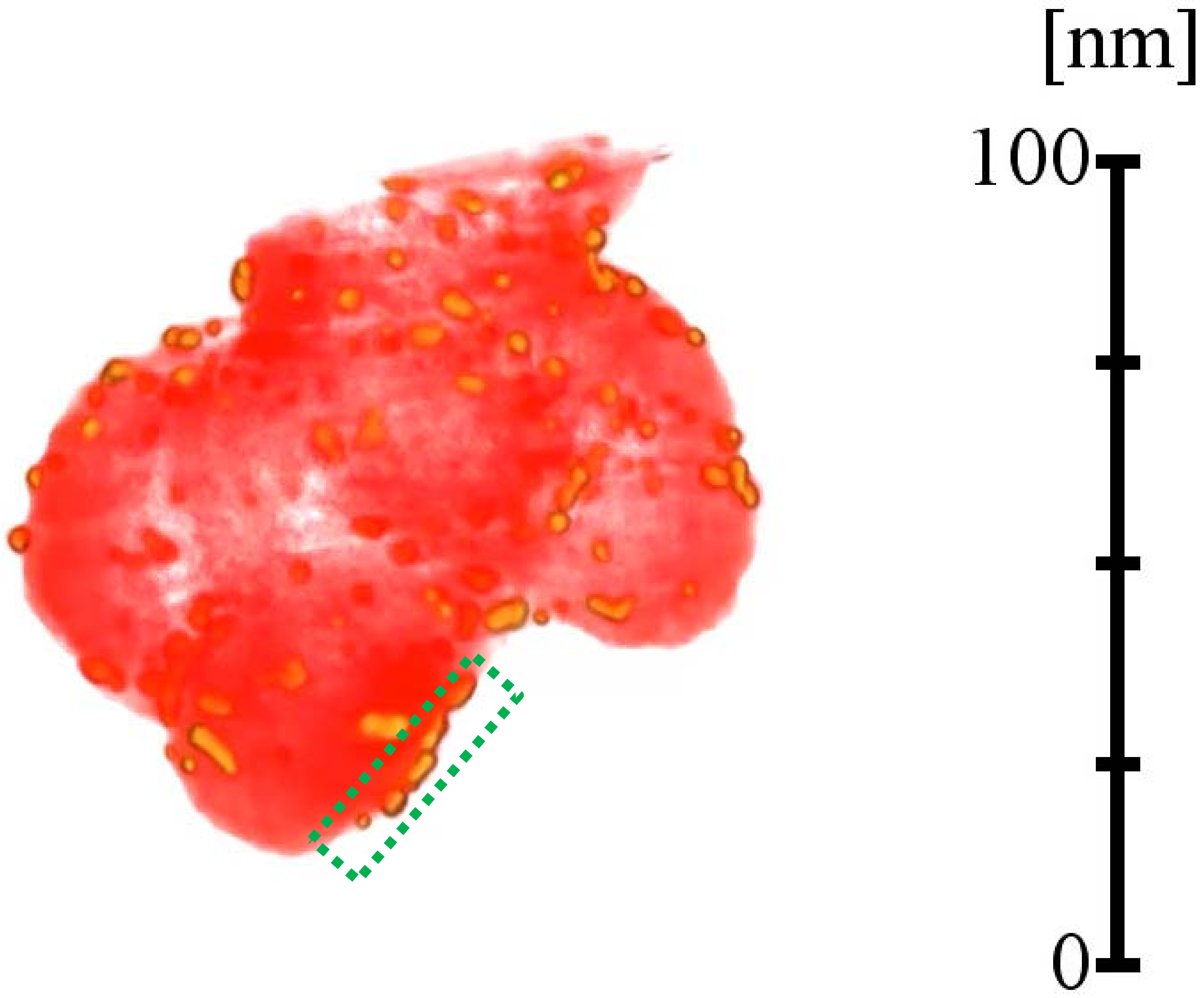




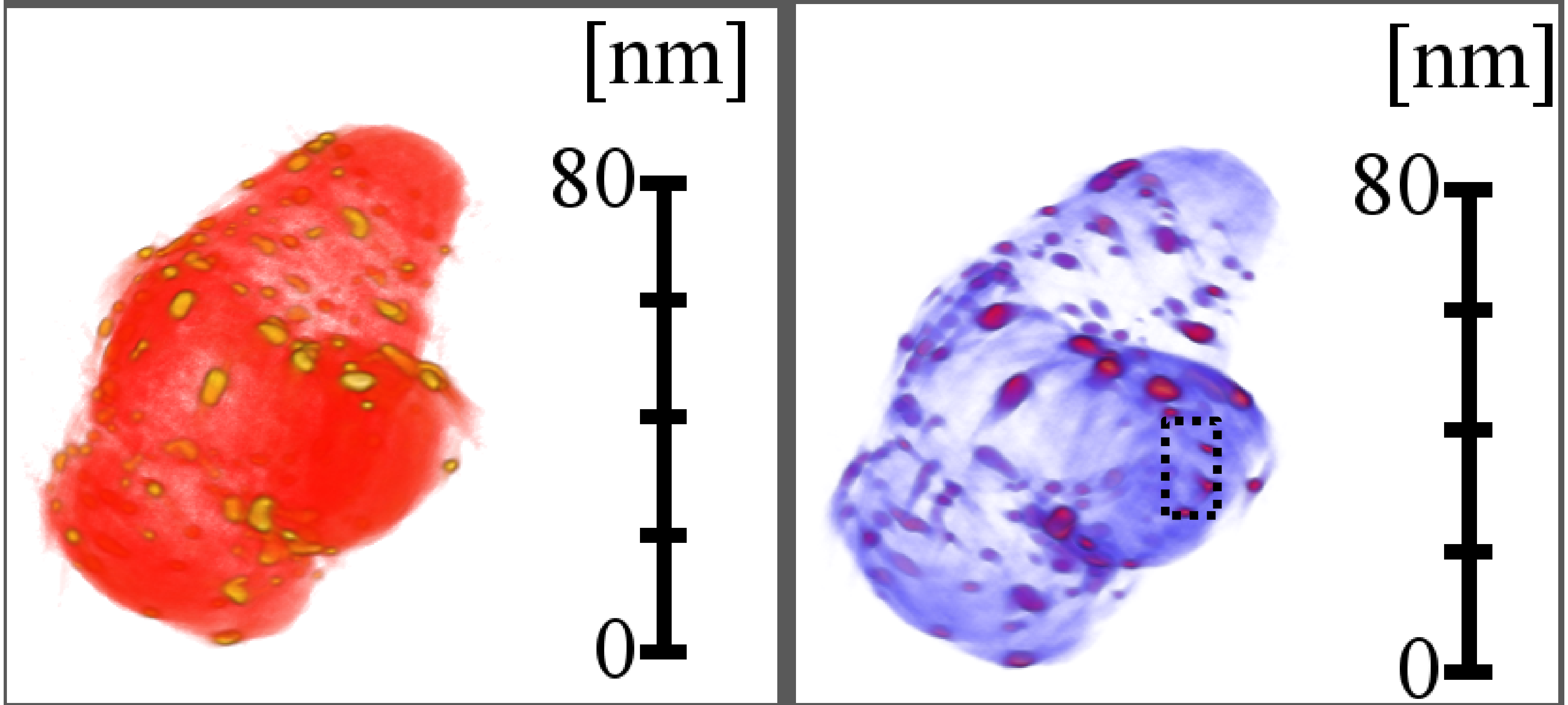



[nm]
100

LAADF STEM

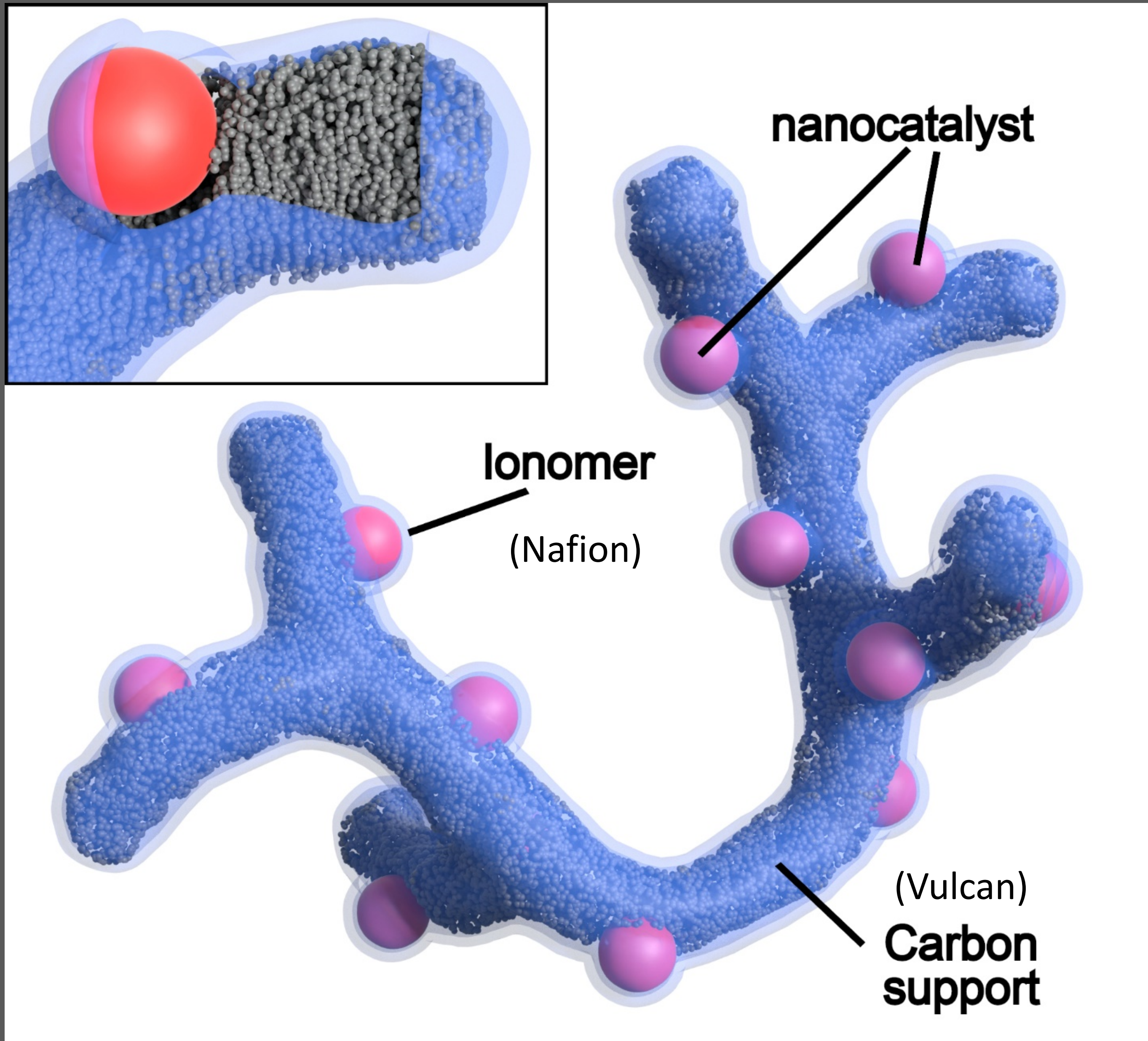


Dissolution & Formation of New Pt NPs/Clusters

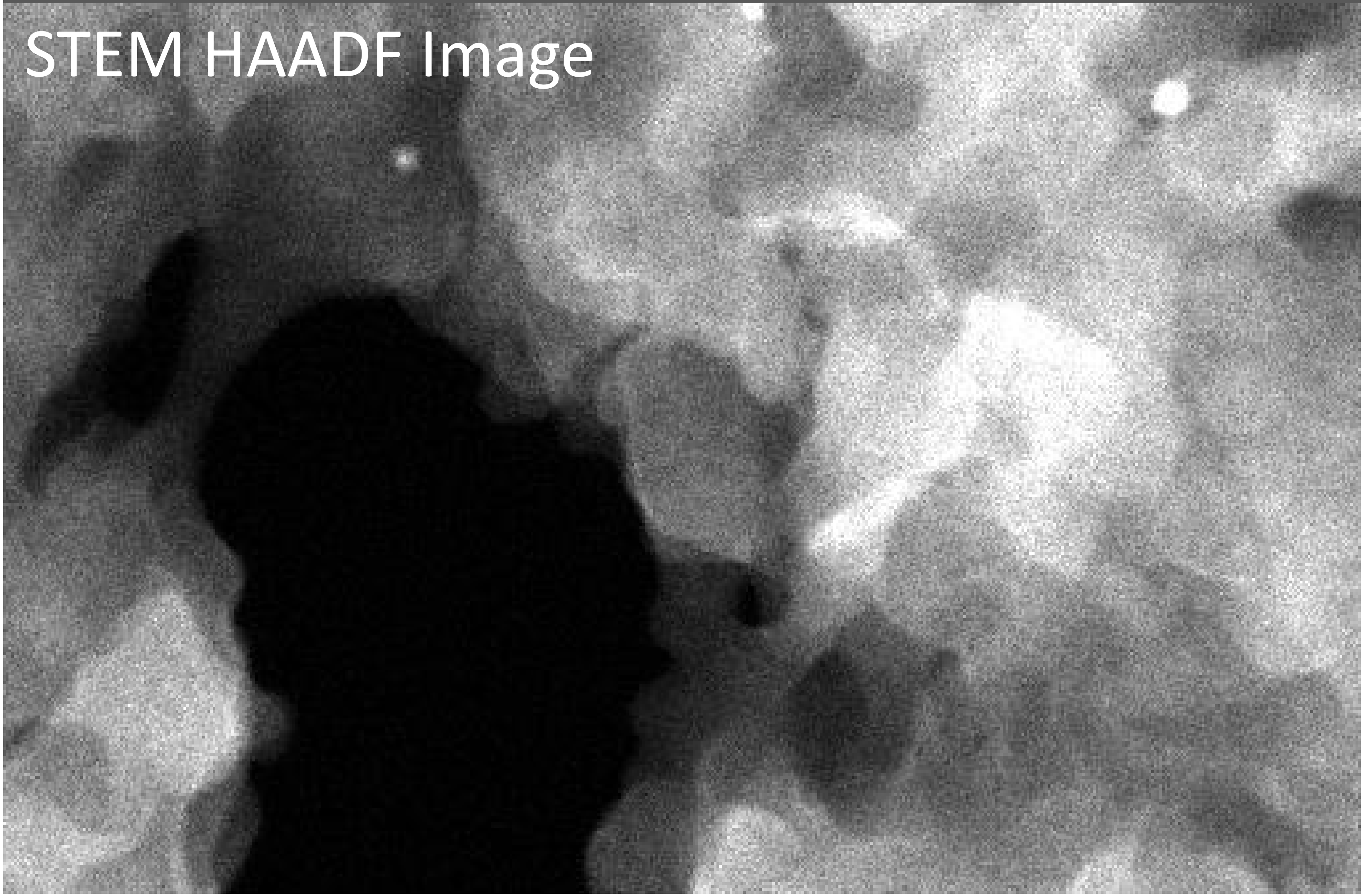


A Novel Approach for Characterization of Ionomer Coverage

Catalytic Layer

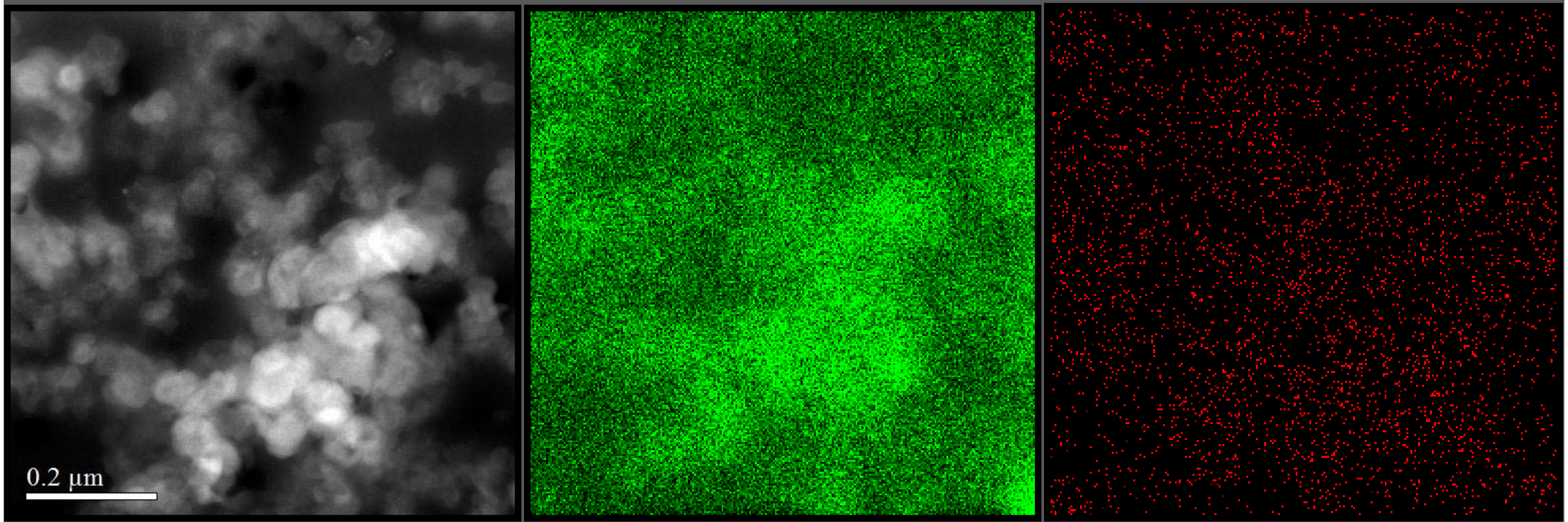


STEM HAADF Image



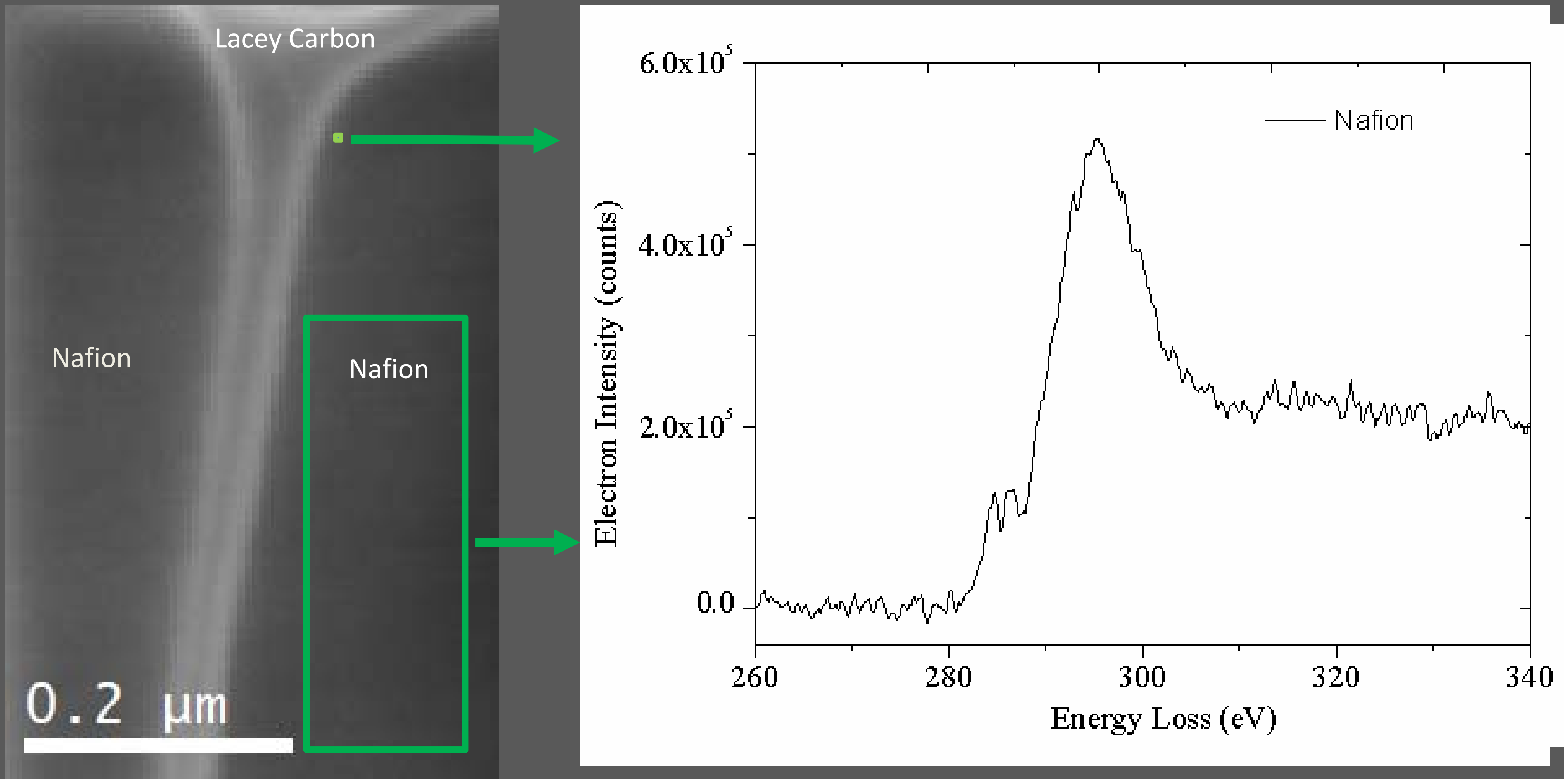
Electron Spectroscopy

Energy dispersive x-ray spectroscopy (EDX) : fluorine signals

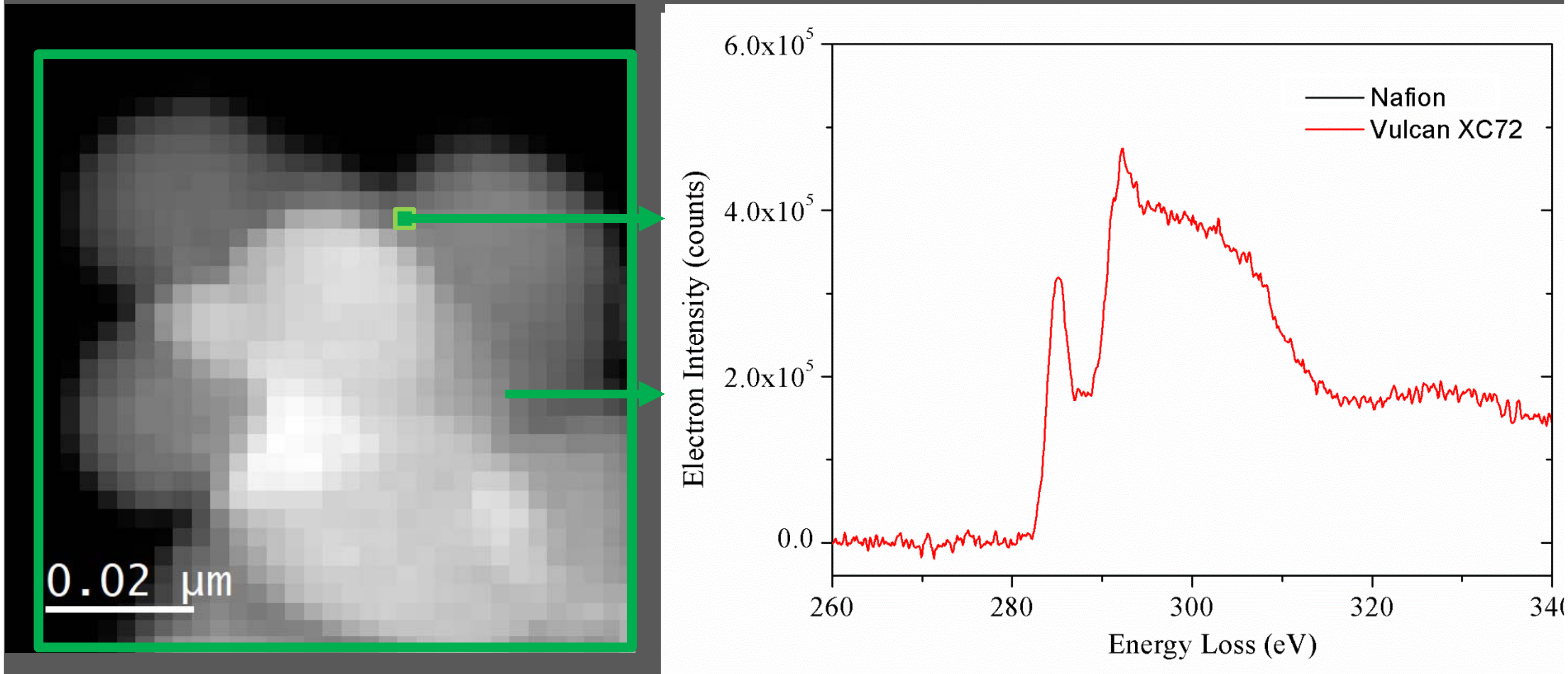


HAADF image　　Carbon　　Fluorine

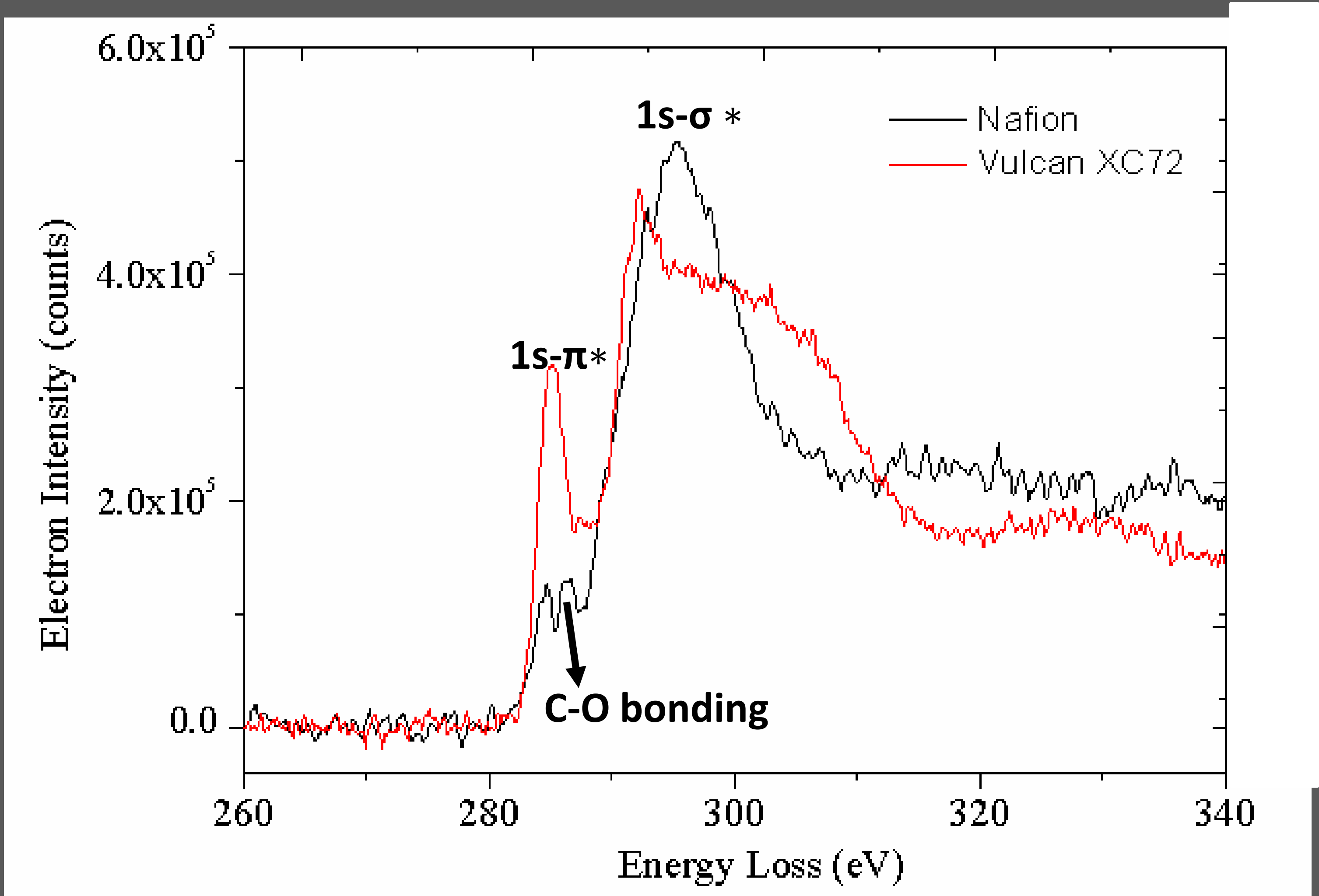
Nafion Fingerprint



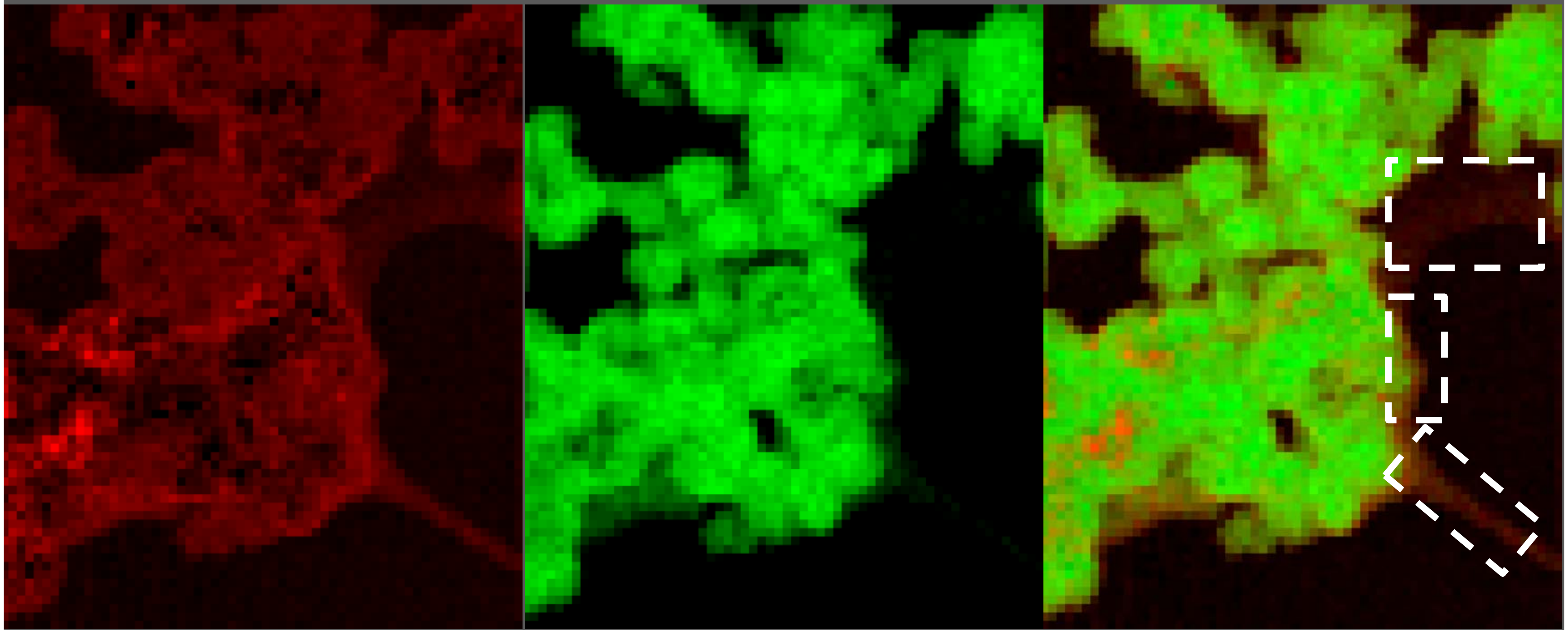
XC72 Carbon Support Fingerprint



Nafion vs Carbon Support (Vulcan XC72) Fingerprints



Higher Signal to Noise Ratio



Nafion | Carbon support | Overlay

What did we learn?

- ✓ Carbon corrosion results in particle movement on the carbon support
- ✓ At early stages of fuel cell cycling, coalescence via particle migration dominates the degradation
- ✓ Single atoms and atomic clusters move subsequently toward particles and deposit on their surfaces through Ostwald ripening and cluster bridging.
- ✓ STEM-EELS (carbon signal)—a powerful technique for the ionomer characterization
- ✓ Distinguish pure ionomer and pure carbon regions
- ✓ High SNR and sensitivity

Madalina Rabung / 10.05.2022

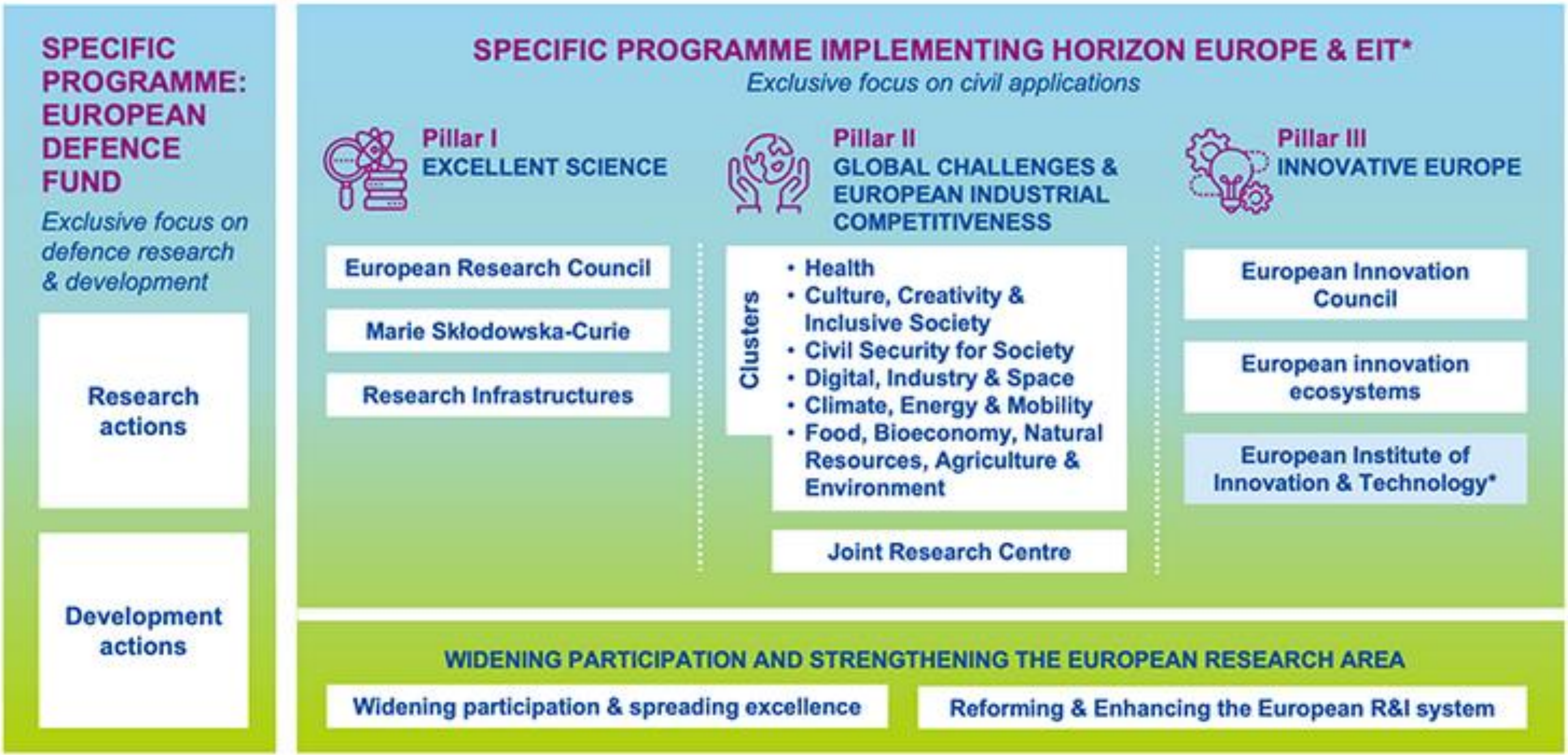
Horizon Europe calls scheduled for 2023-2024 in Cluster 5 “Climate Energy and Mobility” relevant for JP FCH/ES with the aim to defining potential participants

Fraunhofer IZFP


HORIZON EUROPE
The New EU
Framework Programme for
Research and Innovation
2021-2027

intern

HORIZON EUROPE



* The European Institute of Innovation & Technology (EIT) is not part of the Specific Programme

Types of action: specific provisions and funding rates

Innovation actions (IA)

Description: Action primarily consisting of activities directly aiming at producing plans and arrangements or designs for new, altered or improved products, processes or services. For this purpose they may include prototyping, testing, demonstrating, piloting, large-scale product validation and market replication.

A ‘demonstration or pilot’ aims to validate the technical and economic viability of a new or improved technology, product, process, service or solution in an operational (or near to operational) environment, whether industrial or otherwise, involving where appropriate a larger scale prototype or demonstrator.

A ‘market replication’ aims to support the first application/deployment in the market of an innovation that has already been demonstrated but not yet applied/deployed in the market due to market failures/barriers to uptake. 'Market replication' does not cover multiple applications in the market of an innovation that has already been applied successfully once in the market. ‘First’ means new at least to Europe or new at least to the application sector in question. Often such projects involve a validation of technical and economic performance at system level in real life operating conditions provided by the market.

Projects may include limited research and development activities.

Funding rate: 70% (except for non-profit legal entities, where a rate of 100% applies)

Types of action: specific provisions and funding rates

Research and innovation actions (RIA)

Description: Action primarily consisting of activities aiming to establish new knowledge and/or to explore the feasibility of a new or improved technology, product, process, service or solution. For this purpose they may include basic and applied research, technology development and integration, testing and validation on a small-scale prototype in a laboratory or simulated environment.

Projects may contain closely connected but limited demonstration or pilot activities aiming to show technical feasibility in a near to operational environment.

Funding rate: 100%

Coordination and support actions (CSA)

Description: Actions consisting primarily of accompanying measures such as standardisation, dissemination, awareness-raising and communication, networking, coordination or support services, policy dialogues and mutual learning exercises and studies, including design studies for new infrastructure and may also include complementary activities of strategic planning, networking and coordination between programmes in different countries.

Funding rate: 100%

Cluster 5 – Hydrogen

WP 23 - 24

- **D1-3. 2023: Climate impacts of a hydrogen economy**
  - RIA, TRL : tbd
  - Budget: tbd
  - Actions are expected to contribute to all of the following outcomes:
    - A rigorous assessment of the behaviour of hydrogen in the oxidizing cycles of the atmosphere related to methane, water vapour, carbon monoxide and ozone.
    - A rigorous assessment of the ways in which large-scale production, distribution and use of hydrogen can affect anthropogenic radiative forcing.
    - Better monitoring tools for detecting and quantifying hydrogen leakage (in situ or through remote sensing).

Cluster 5 – Hydrogen
WP 23 - 24

- **D5-2-0. Hydrogen-powered aviation (2023)**
  - IA, TRL 6-7
  - Budget: tbd
  - Project results are expected to contribute to all of the following expected outcomes:
    - Innovative ground-based refuelling and supply systems for liquid hydrogen at air transport ground infrastructures, with the potential to be up-scaled at system level by 2027.
    - Transformative aircraft-based hydrogen refuelling technologies, with full safety, standardisation and scalability to various types of aircraft concepts.
    - Zero-emission hydrogen-powered aircraft ground movements, demonstrated and scalable across airports of different sizes, locations and capacities in Europe.
    - Comprehensive and validated liquid hydrogen demand models at air transport ground infrastructures in Europe and globally, in view of entry into service of hydrogen aircraft by 2035.
    - New standards and certification procedures for the roll-out of the new technologies and solutions at large scale, in Europe and on the TEN-T network.
  - The topic aims to exploit synergies with the Horizon Europe Clean Aviation and Clean Hydrogen partnerships, for the roll-out of transformative aircraft liquid hydrogen propulsion technologies, with an eye towards future large-scale demonstrations and real-life airborne plane trials during the later phase of the Clean Aviation partnership

Cluster 5 – Hydrogen

WP 23 - 24

- **D5-2-1. Accelerating climate neutral hydrogen-powered/electrified aviation (2023)**
  - RIA, TRL 2-4
  - Budget: tbd
  - Project results should focus on transformative technologies that address existing technology gaps for an aircraft liquid-hydrogen (LH2) powertrain of a megawatt class. Project results are expected to contribute to at least one of the following expected outcomes:
    - Deliver transformative aircraft energy storage, conversion and distribution technologies for hydrogen and electrified-propulsion that exceed the state-of-the-art.
    - Deliver novel heat dissipation, thermal management and recuperation technologies for megawatt class, that exceed the state-of-the-art.
    - Deliver advanced simulation tools, validation methodologies and control approaches for an aircraft liquid-hydrogen powertrain of megawatt class.

Cluster 5 – Hydrogen
WP 23 - 24

- **D3-1-18. Development of next generation synthetic renewable fuel technologies (2024)**
  - RIA, TRL 3-4
  - Budget: tbd
  - Project results are expected to contribute to all of the following expected outcomes:
    - Increase availability of disruptive emerging synthetic renewable fuel technologies.
    - Accelerate the readiness of cost-effective and highly performing future technologies of synthetic renewable fuels for all economy sectors.
    - Reinforce the European scientific basis and European technology export potential for synthetic renewable fuel technologies.
  - Pathways via production of renewable hydrogen or renewable hydrogen ionic compounds from all forms and origins of renewable energy (e.g., electricity, direct sunlight, heat) are in scope. The new technologies should also address uses in fuel cells for all transport modes for electricity generation from renewable fuels used as renewable energy carriers with high conversion efficiency and low pollution. An assessment of the sustainability and the GHG emissions should be made based on a Life Cycle Analysis.

Cluster 5 – Energy storage
WP 23 - 24

- **D2-1-6. Battery management system (BMS) and battery system design for stationary energy storage systems (ESS) to improve interoperability and facilitate the integration of 2nd life batteries**
  - IA, TRL6-7
  - Budget: tbd
  - Projects are expected to contribute to all of the following outcomes:
    - A European economic base which is stronger, more resilient, competitive and fit for the green and digital transitions, by reducing strategic dependencies for critical raw materials by promoting a circular economy.
    - Battery pack and Battery Management System (BMS) design for single module operation or recombination (reconfiguration) of modules or battery packs for consolidated and new battery technologies.
    - Safe, accessible and reliable operation of batteries and compatible with the battery passport concept.
    - Battery system design to enable disassembly and reconfiguration for 2nd life.
    - Development of fast and efficient qualification strategies and assessment of Electric Vehicle (EV) batteries for 2nd life applications and quantify it with respect to SoA in terms of time and efficiency.
    - Reduction of 30% of repurposing/refurbishment cost for adapting EV batteries to stationary applications in 2nd life.
    - Environmental impact assessment, from both positive and negative aspects, for adapting EV batteries to 2nd life applications.
    - Impact in the European economy by a growth of the market and employment, by facilitating the uptake of stationary ESS Feasibility of operation in the batteries extended life domain (2nd life).

Cluster 5 – Energy storage

WP 23 - 24

- **D2-1-7. Hybrid electric energy storage solutions for grid support and charging infrastructure**
  - IA, TRL7
  - Budget: tbd
  - Projects are expected to contribute to all of the following outcomes:
    - Demonstration of hybrid energy storage technologies for long duration storage (from hours to days) and provision of multiple grid services with improved technical performances, sustainability, as well as increased safety during operation, transport and storage.
    - Enable improved levelized cost of storage supported by design optimisation and optimal service stacking.
    - Creating synergies between producers and strengthening the European Battery Ecosystem, improving the European battery value chain and thus contributing to the EU climate neutrality objectives.
    - Increasing digitalisation of energy storage systems from design to operation phase enabling a faster development and optimal use in grid applications.
    - The establishment of multi-service approaches to energy storage reducing costs and increasing benefits for the European electricity system.
    - Promoting an increased reliability and resilience of the electricity system by demonstrating new multi-purpose energy storage solutions.

Cluster 5 – Energy storage

WP 23 - 24

- **D3-1-3. Novel thermal energy storage for CSP (2023)**
  - RIA, TRL4-5
  - Budget: tbd
  - Projects are expected to contribute to all of the following outcomes:
    - Improved dispatchability of concentrated solar power (CSP) plants.
    - Improved role of CSP plants in the energy system.
    - Reduced greenhouse gas emissions.
    - Achievement of the CSP targets of the Strategic Energy Technology Plan.

Cluster 5 – Energy storage

WP 23 - 24

- **D3-2-17. Development of novel long-term electricity storage technologies**
  - RIA, TRL4-5
  - Budget: tbd
  - Projects are expected to contribute to all of the following outcomes:
    - Increased availability, robustness and safety of sustainable and efficient energy storage solutions to reduce energy losses, increase cost effectiveness and improve the environmental footprint of the energy system.
    - Availability and functionality of innovative energy storage systems developed for specific system designs and applications.
    - Increase technology leadership, competitiveness and technology export potential of European storage technology industry.
    - Enhanced sustainability of storage technologies, taking fully into account circular economy, social, economic and environmental aspects in line with the European Green Deal priorities.

Cluster 5 – Energy storage

WP 23 - 24

- **D3-2-18. Demonstration of innovative, large-scale, seasonal heat and/or cooling storage technologies for decarbonisation and security of supply**
  - IA, TRL7-8
  - Budget: tbd
  - Projects are expected to contribute to all of the following outcomes:
    - Increased availability, robustness and safety of sustainable and efficient choices for energy storage to reduce energy losses, cost effectiveness and improve the environmental footprint of the energy system.
    - Availability and functionality of innovative large-scale energy storage systems developed for specific system designs and applications.
    - …

Many thanks for your attention

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- www.izfp.fraunhofer.de