Bringing research and industry closer

Accelerating innovation and uptake of new technologies

Energy storage & Concentrated Solar Thermal Energy

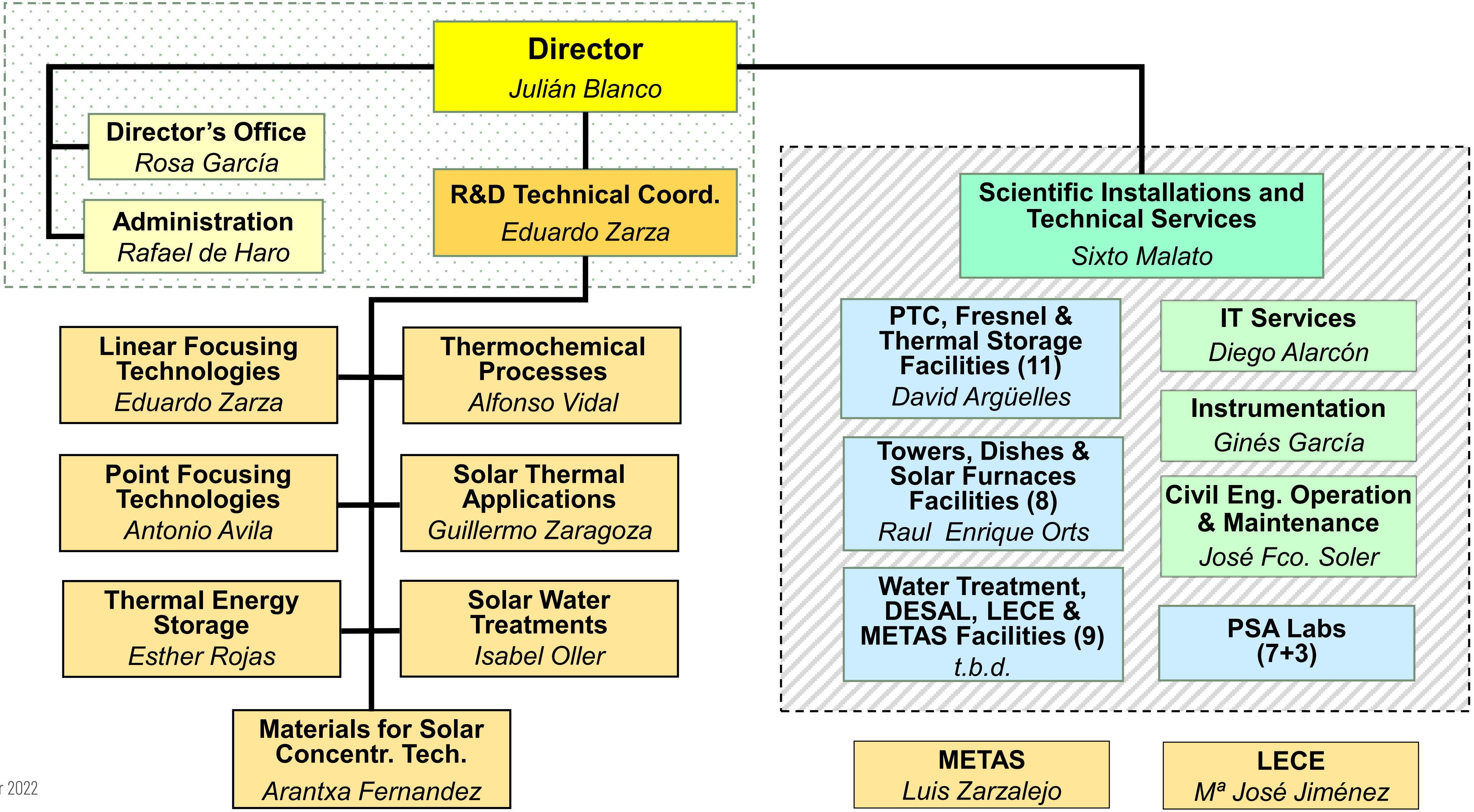
15 November 2022

Plataforma Solar de Almería
www.psa.es
GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA E INNOVACIÓN
Ciemat
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas
PSA

Main worldwide CSP research facility

- PSA is a research center belonging to the CIEMAT focused on research, testing and development of Concentrating Solar Technologies and its applications
- CIEMAT is a large and public Spanish scientific institution devoted to energy and environment.
- PSA started its activities in 1981 (IEA initiative), always around solar concentrating technologies and with strong profile on international collaboration

PSA: Organization & Structure



PSA: Research Facilities & Labs

A) Parabolic Troughs
- A1.- DISS
- A2.- HTF
- A3.- PROMETEO
- A4.- PTTL
- A5.- NEP
- A6.- IFL
- A7.- TCP100

B) Linear Fresnel
- B1.- FRESDEMO

C) Other Parabolic Troughs related facilities
- C1.- KONTAS
- C2.- REPA

D) Thermal Energy Storage
- D1.- MOSA

E) Central Receiver Systems
- E1.- CESA
- E2.- SSPS-CRS
- E3.- AORA SOLAR

F) Solar Furnaces
- F1.- SF-60
- F2.- SF-40
- F3.- SF-5

G) Parabolic Dishes
- G1.- EURO-DISH
- G2.- AGING TEST BED

H) Solar Desalination
- H1.- MED
- H2.- CSP+D
- H3.- MDTF

I) Water Treatment
- I1.- SOLWATER
- I2.- HYWATOX
- I3.- WETOX

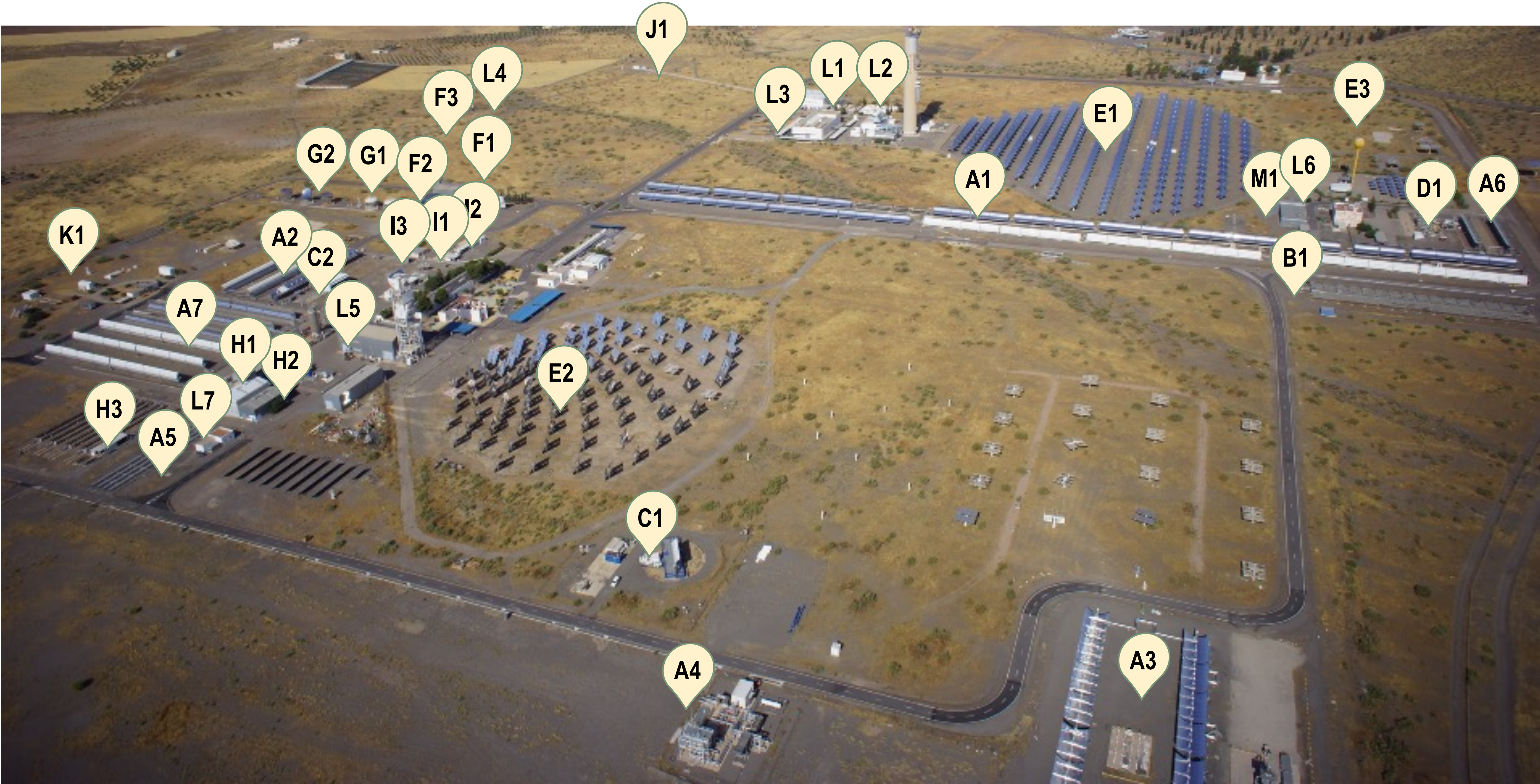
J) Meteo
- J1.- METAS

K) Energy Efficiency
- K1.- LECE

<u>L) Laboratories</u>
- L1.- OPAC (Lab. de Caracterización óptica y envejecimiento acelerado de reflectores)
- L2.- GeoLab (Lab. de Caraterizacion geométrica de concentradores solares)
- L3.- RadLab (Lab. De Radiometría)
- L4.- SRTLab (Lab. de Caracterización óptica y térmica de tubos receptores)
- L5.- MaterLab (Lab. de Análisis, tratamiento y durabilidad de materiales para concentr. solar)
- L6.- WATLAB (Lab. de Tecnologías del Agua)
- L7.- BES (Bancos de Ensayos de Sales)
- *L8.- OCTLAB (Optical coatings technology laboratory), located in Madrid*
- *L9.- POMELAB (Porous media lab for solar concentrating Systems), located in Madrid*
- *L10.- ATYCOS (Lab. de Almacenamiento Térmico y Combustibles Solares), located in Madrid*

PSA is formed by 27 Research Facilites and 10 Laboratoires

PSA: Research Facilities & Labs



SUPEERA
Support the coordination of national research and Innovation programmes in areas of activity of the EERA.
PSA-CIEMAT. Almería, 15th November 2022

Keynote speech

Cristina Trueba
Deputy Directorate for Innovation Coordination
Ministry of Science and Innovation
Spain

Published on 25 February 2015, as a key priority of the Juncker Commission (2014-2019), aims at building an energy union that gives EU consumers - households and businesses - secure, sustainable, competitive and affordable energy.

http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2015:80:FIN

Builds five closely related and mutually reinforcing dimensions:

- Energy **security**, solidarity and trust - diversifying Europe's sources of energy
- A fully **integrated** internal energy market
- **Energy efficiency** first
- Transition to a **low-carbon** society
- **An Energy Union for Research, Innovation and Competiveness**

European Strategic Energy Technology Plan

https://setis.ec.europa.eu/system/files/Communication_SET-Plan_15_Sept_2015.pdf

Strategic Energy Technology Plan: SET Plan

- Aims to accelerate the deployment of green technologies, by improving new technologies and bringing down costs through coordinated national research efforts,
- Helps promote cooperation among EU countries, companies and research institutions,
- Consists of the:
  - ✓ SET Plan Steering Group,
  - ✓ the European Technology and Innovation Platforms (ETIPs),
  - ✓ the European Energy Research Alliance (EERA),
  - ✓ and the SET Plan Information System (SETIS),
- Identifies 10 actions for research and innovation, that address the whole innovation chain, from research to market uptake.
- Current REVAMPING Process of SET Plan to align with Green Deal Priorities

Key actions and IWG

SET Plan 10 Key Actions

Nº 1 in Renewables
1. Performant renewable technologies integrated in the system
2. Reduce cost of technologies

Energy systems
3. New technologies & services for consumers
4. Resilience & security of energy system

Energy efficiency
5. New materials & technologies for buildings
6. Energy efficiency for industry

Sustainable transport
7. Competitive in global battery sector (e-mobility)
8. Renewable fuels and bioenergy

CCS-CCU
9. Carbon capture storage use

Nuclear Energy
10. Nuclear safety

13 Implementation Working Groups

- Global leadership in **Photovoltaics**
- Global leadership in **Concentrated Solar Power**
- Global leadership in **Off-shore Wind**
- Global leadership in **Deep Geothermal**
- Global leadership in **Ocean**

- **Positive Energy Districts**
- **Smart Energy Systems**
- **High Voltage Direct Current**

- **New materials and tech**nologies For EE solutions for **BUILDINGS , AND Heating and Cooling technologies for Buildings**
- Energy Efficiency in **Industry**

- **Become competitive in the global battery sector**
- **Bioenergy** and **Renewable fuels** for Sustainable Transport

- Carbon Capture Storage and Use of CO2

- **Maintaining a high level of safety of nuclear reactors**

SET Plan

The IWGs benefit from the support of other EU R&I initiatives such as:

- **European Technology and Innovation Platforms (ETIPs):** in which industry, research centers and academia work together to implement the priorities of the SET Plan throughout the innovation chain.
- **European Energy Research Alliance (EERA):** which represents the European research community and seeks to catalyze energy research aligned with the objectives defined by the SET Plan.
- Coordination and Support Actions (CSA), funded by Horizon 2020/Horizon Europe, to support IWGs in communication, outreach and mutual learning activities: **HORIZON-STE and CST4ALL.**
- Co-Funded Partnerships under Horizon Europe (CET and DUT) (former ERA-NETs).

Set up in April-May 2016 and brought together stakeholders, the EC and SET Plan countries to discuss the ambitious initiative of the European CSP industry becoming a global leader in its field. Its implementation plan **(IP)** include the strategic targets to be achieved and the R&I activities to be carried out.


Integrated SET-Plan

Initiative for Global Leadership in Concentrated Solar Power

—

Implementation Plan

November 2017

Participating SET Plan Countries:
Belgium, Cyprus, France, Germany, Greece, Italy, Portugal, Turkey, Spain

Currently finishing the Update of the Implementation: **Plan-Concentrated Solar Thermal**:

- ✓ to adapt initial targets to a new timeframe (for 2030), and to redefine R&I activities taking into account the progress of technologies made from 2017
- ✓ to align targets and related R&I Activities with the new energy policy context, **EU Green Deal**, and other relevant policies
- ✓ to include two new CSP-related targets not considered appropriately in other IWGs, i.e. solar heat for industrial processes and solar fuels.

CSP/PV full hybrid integration of electrical renewable energy sources, flexibility and storage:

- ✓ Both are mature as separate technologies,
- ✓ Their integration as a single unit CSP/PV fully hybridized will provide 24/7 dispatchable and flexible power,
- ✓ Power generation fully independent from meteorological variations,
- ✓ System more stable with high rates of intermittent renewable generation connected to the grid.

Design/implementation of solar heat for industrial process application (temp. 125-350 °C):

- ✓ Concentrating solar thermal field with parabolic trough or linear Fresnel collectors,
- ✓ Thermal energy storage system in sensible or latent heat (cheaper than PV + batteries),
- ✓ Solar system interface with the industrial process.

Thank you for your attention!

cristina.trueba@ciencia.org.es

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***

Almeria, Spain, 15.11.2022

AGENDA 1/5

09:30 - 10:10

Introduction

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

Keynote speech
Cristina Trueba, Chair of the Implementation Working Group on CSP/STE

Workshop background: the SUPEERA project

Ivan Matejak, SUPEERA coordinator, EERA

Presentation of two pathways: Energy Storage, Concentrated Solar Power

Maria Oksa, Senior Scientist - Project Manager, VTT

AGENDA 2/5

10:10 - 11:30

Panel session 1

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

The SET Plan as a tool for EU-wide collaboration on R&I priorities of low-carbon technologies
Ivan Matejak, SUPEERA coordinator, EERA

EERA Joint Programme Concentrated Solar Power
Ricardo Sanchez, EERA JP CSP Coordinator, PSA

EERA Joint Programme Energy Storage
Myriam Gil Bardaji, JP Energy Storage Manager, KIT

Current challenges of CSP: the vision from the industry
David Trebolle, Secretary General, Protermosolar

Synchronous pumped heat electricity storage for the energy transition from fossil to renewables
Escarlata Munoz Granero, Senior Industrial Engineer, Malta Inc.

R&D and CSP: How close are they?
Sergio Relloso, New Technologies Business Unit, SENER [online]

AGENDA 3/5

11:50 - 13:00

Panel session 2

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

Systemic and cross-sectorial issues pertaining to the Clean Energy Transition
Spyridon Pantelis, Project Manager, EERA

Integrating concentrated solar heat in industrial processes
Miguel Frasquet, CEO, SOLATOM (topic: energy system integration) [online]

Thermal storage integration into STE plants - A success story from Spain
Eduardo Zarza, Technical coordinator, PSA (topic: energy system integration)

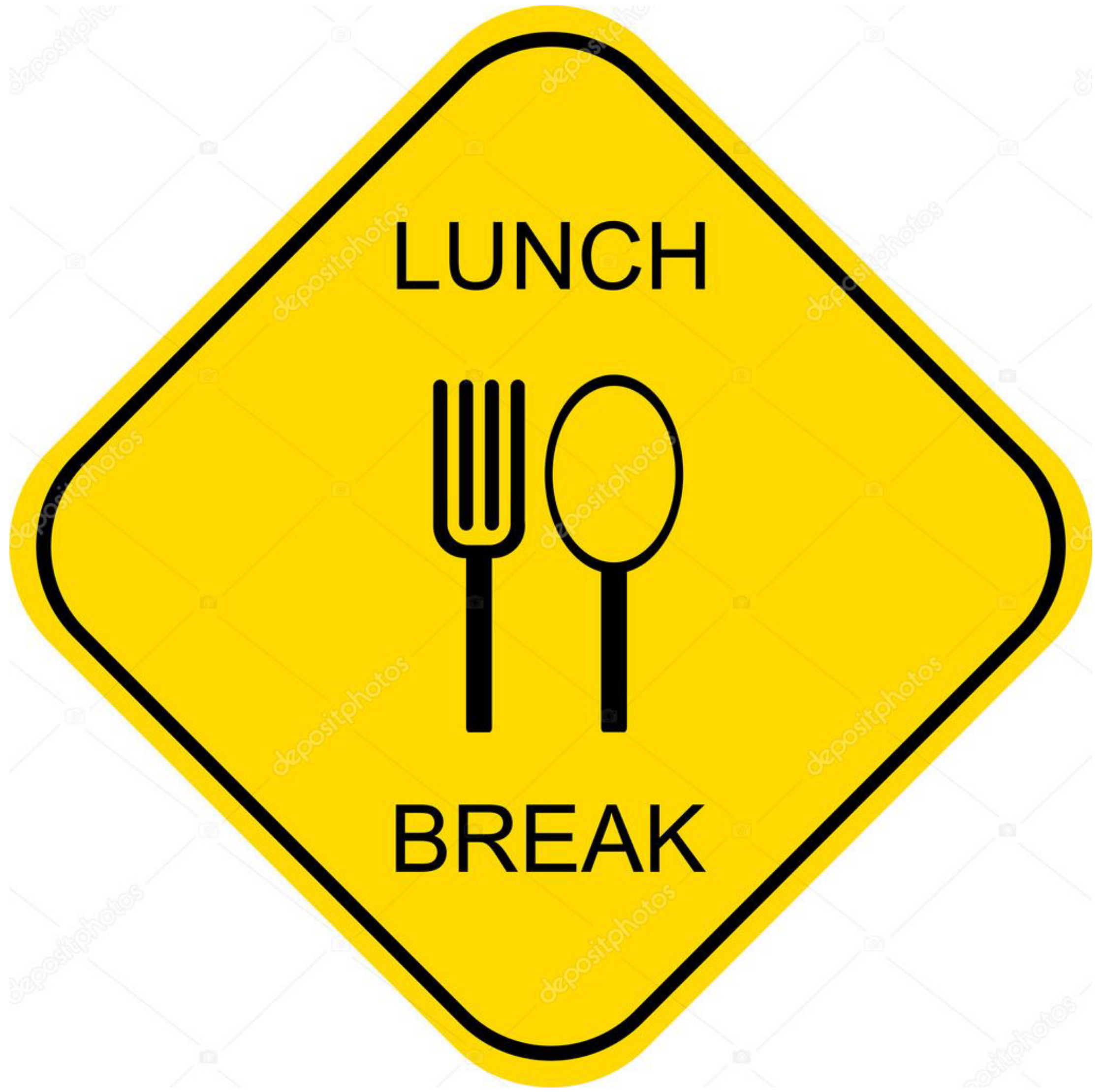
Thermal storage for electricity production
Rocío Bayón, Senior Scientist, CIEMAT/PSA (topic: energy storage)

Digitisation to accelerate CSP development & considerations for an open discussion
Cristóbal Villasante, Renewable Energy Coordinator, Tekniker & Tekniker representative at the JP-CSP of EERA (topic: digitalisation)

AGENDA 4/5

13:00 - 14:00

Lunch break



14:00 - 15:30

Visit to PSA facilities

AGENDA 5/5

15:30 - 17:45

Panel session 3

The role of energy storage in future power grids

Energy Storage and Energy Transition, Challenges and Concerns
Javier García-Barberena, Strategy and Business Development Manager, CENER

The thermal energy storage systems at support of new renewable power networks
Walter Gaggioli, Head of Solar Thermal and Smart Network Division, Department of Energy Technologies and Renewable Energy Source, ENEA

Investigation of the potentialities of CLOSED CYCLE sorption TES for industrial applications
Salvatore Vasta, Research Engineer & Coordinator of the EERA JP-ES - Sub-Programme on Thermal Energy Storage, Italian National Research Council (CNR) [online]

Hybrid energy storage systems integration into power grid
Linda Barelli, Associate Professor, University of Perugia [online]

Energy storage in future power grids - potential sustainability challenges
Manuel Baumann, Researcher at KIT, Institute for Technology Assessment and System Analysis (ITAS)

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 & CSP;**
- 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**

Overview of key factors and trends

EUROPEAN CLEAN ENERGY TRANSITION
KEY FACTORS

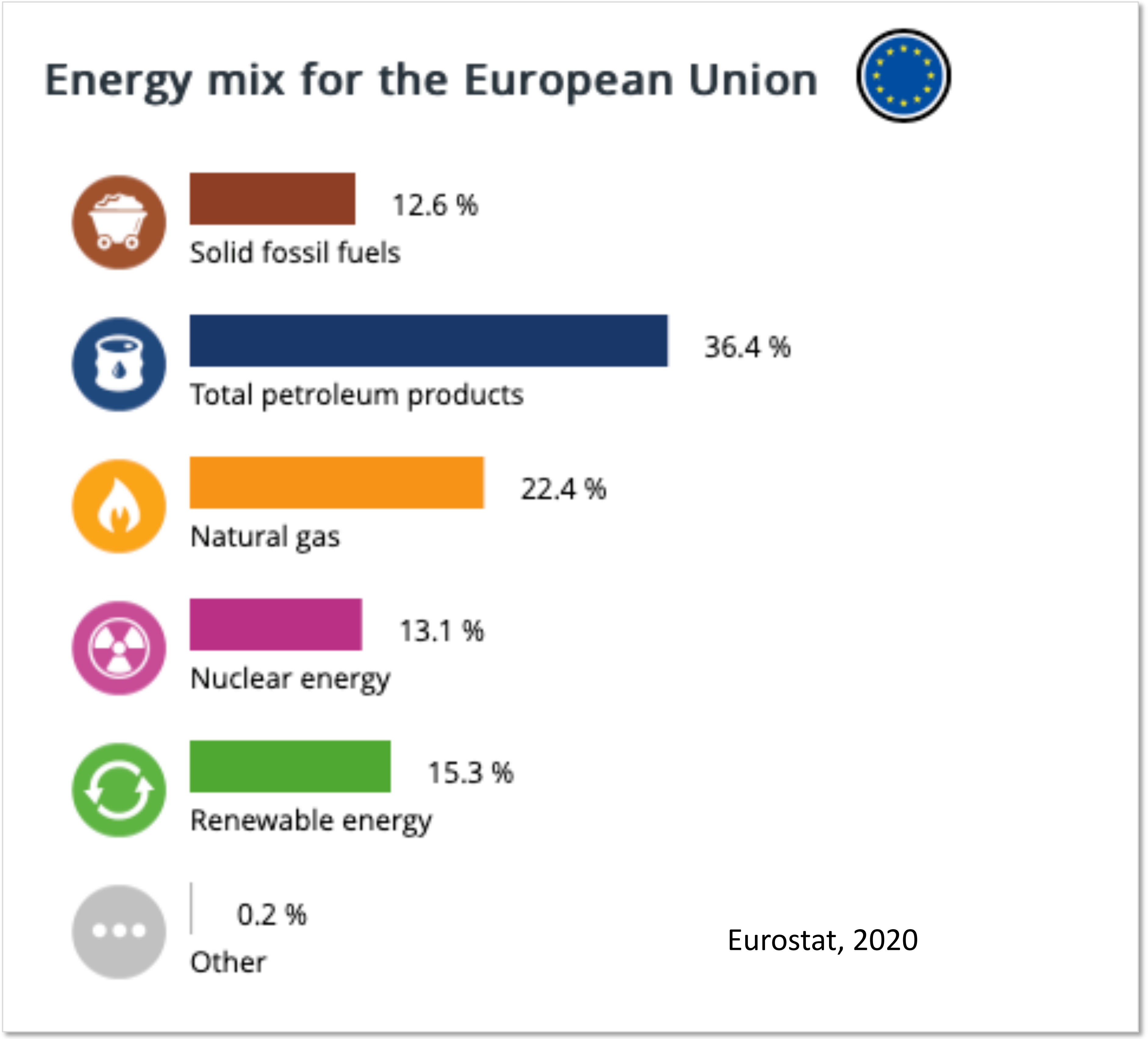
1

Nearly all **new capacity** additions in the EU now being renewable technologies

STILL

EU is heavily depended on fossil fuels...

Fossil Fuels < 70%

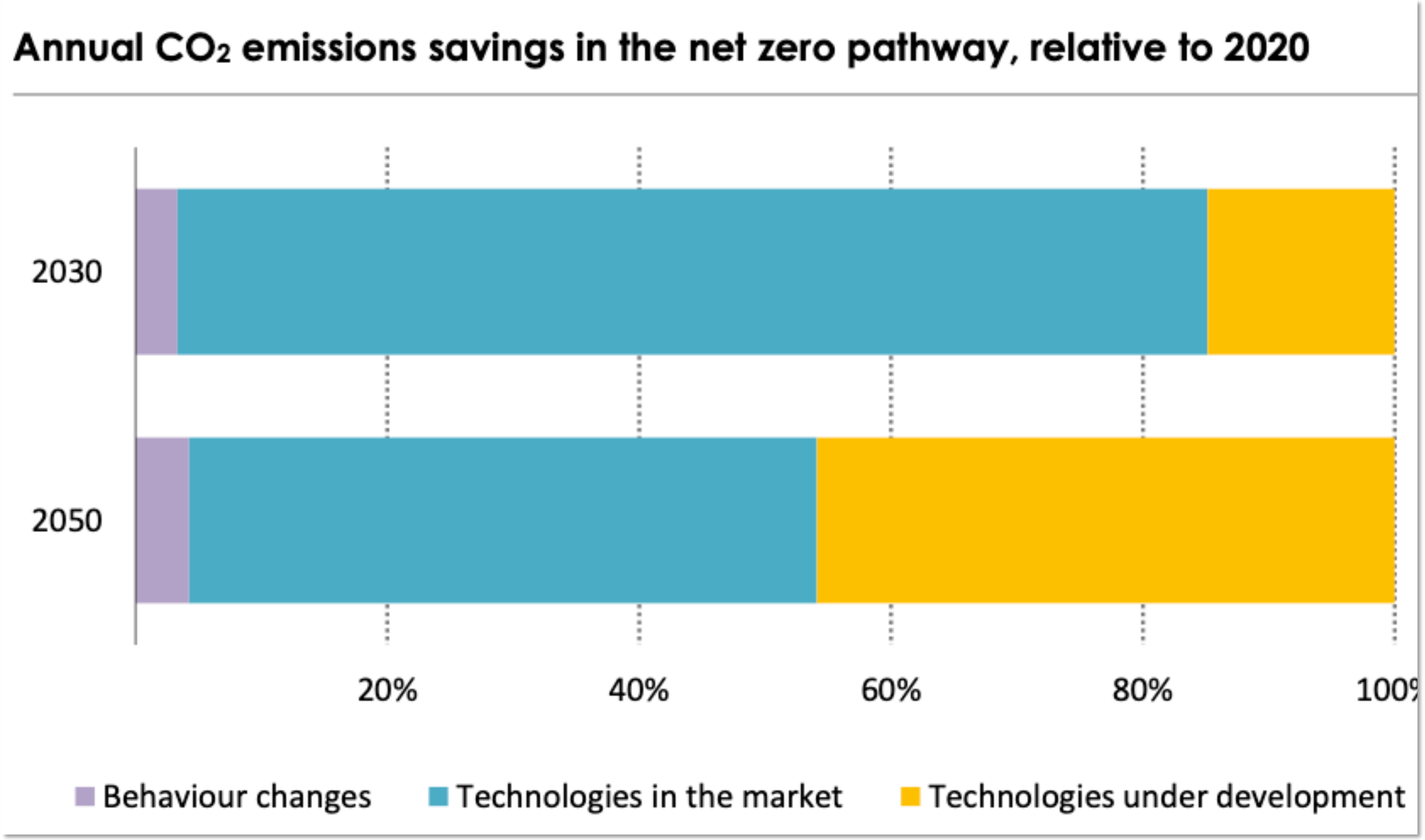


2

The growth of EU primary production from **renewable energy sources exceeded** that of all the other energy types (approx. 39.2 % from 2011-2021)

STILL

A large part of the solutions needed for net zero pathway are still under development...



Source: IEA

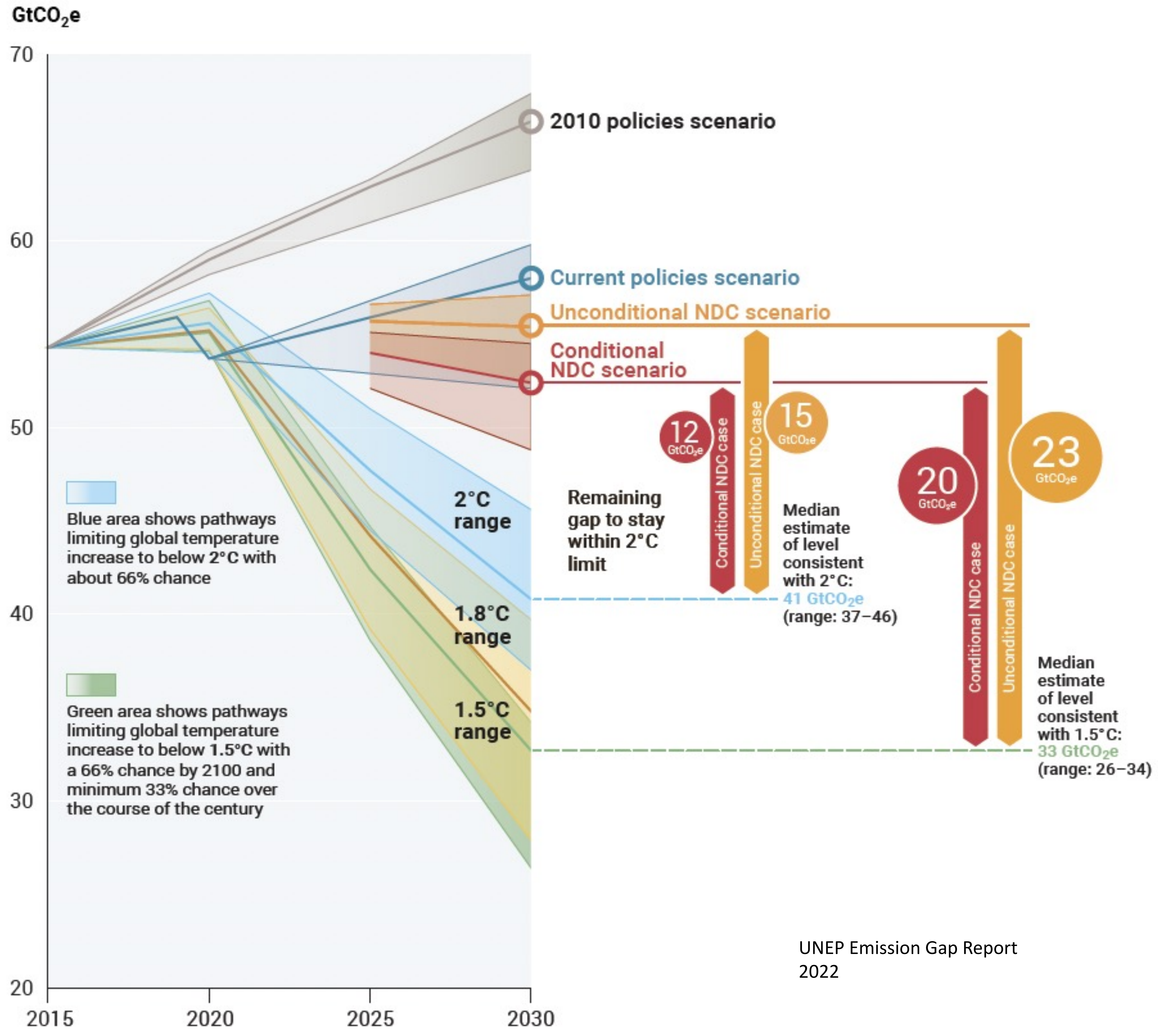
SUPEERA

3

Full **achievement of all climate pledges** (1,5 C°) would move the world towards safer ground

STILL

it is easier to make pledges than to implement them...



Without additional action, current policies lead to global warming of 2.8˚C over this century. Implementation of unconditional and conditional NDC scenarios reduce this to 2.6˚C and 2.4˚C respectively

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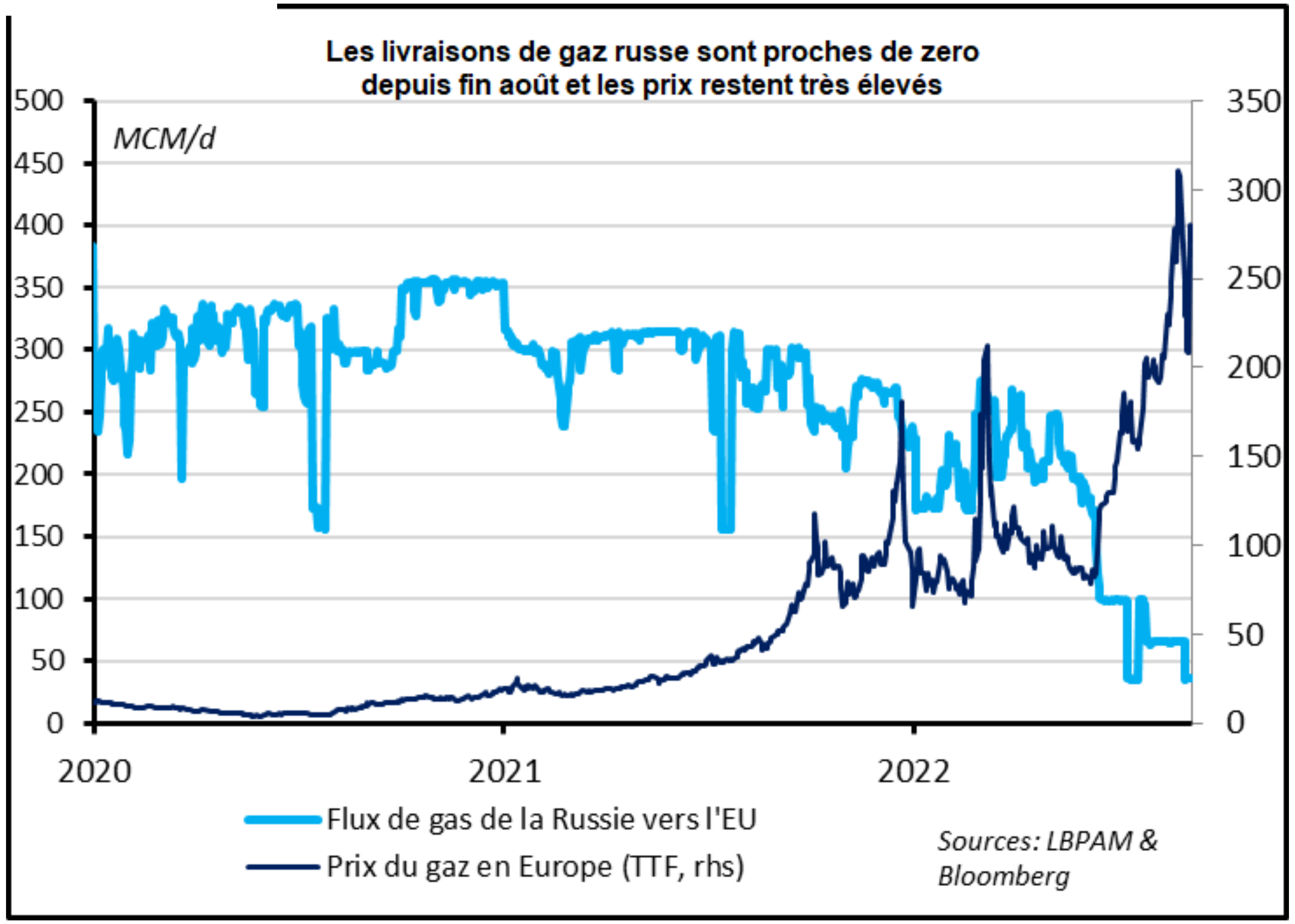
War in Ukraine: Evolution of gas price: A Factor 10 - 20

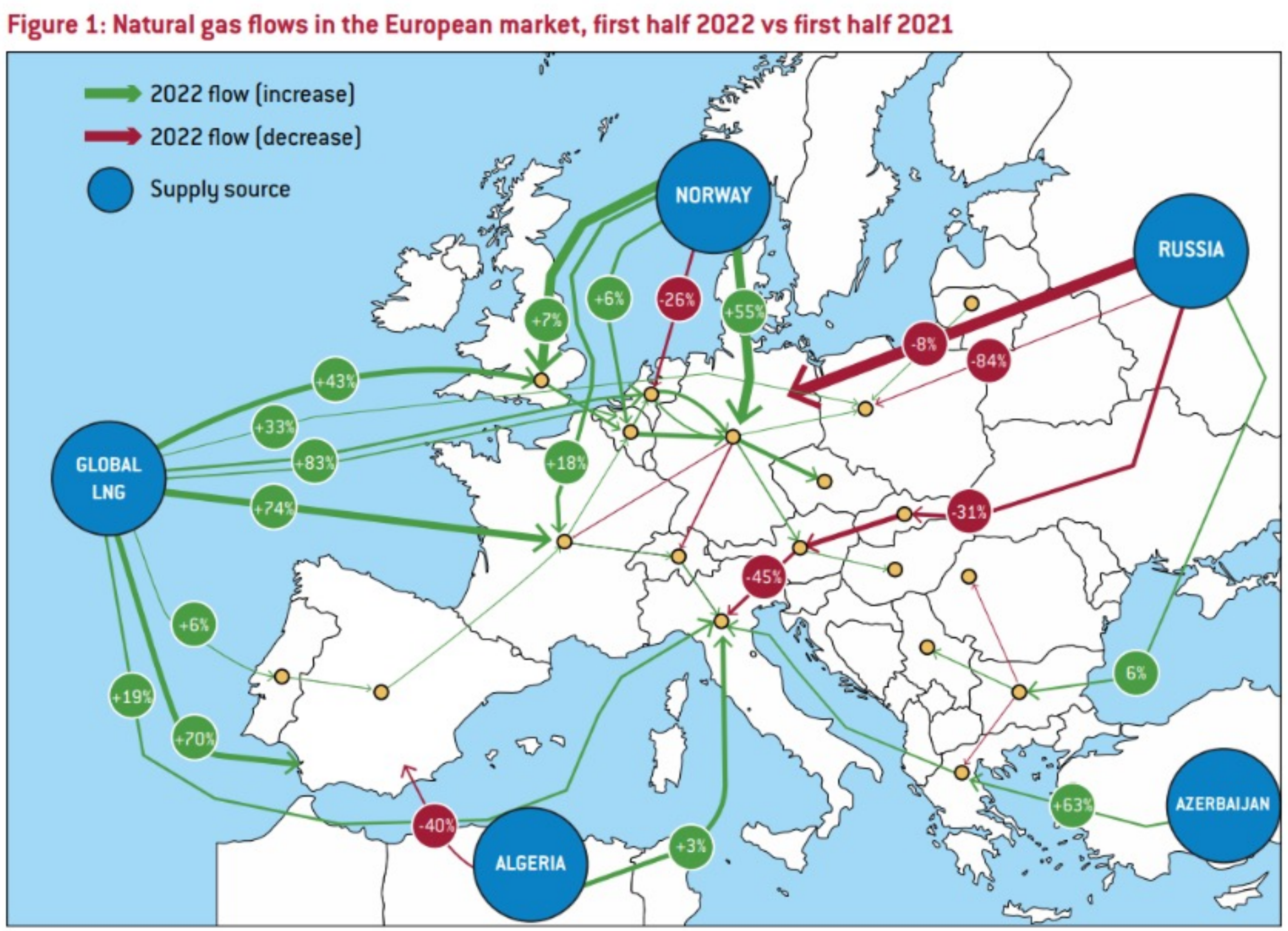
Dutch TTF - Futures

CONTRACT	LAST	TIME(GMT)	% CHANGE	VOLUME
DEC22	133.500	11/3/2022 10:32 AM	6.068	7115

INTRADAY 3 MONTHS 1 YEAR 2 YEARS LAST UPDATE TIME: 11-03-2022 10:44 AM GMT

Gas : War Market consideration





- In 2019, EU imported 155 bcm of gas from Russia, representing 45% of its imports
- **155 bcm represented 40% of current LNG market and will still represent about 30% of it by 2023**
- Currently Russian imports to EU represent about 30 bcm → shortfall of > 120 Bcm
- **New LNG capacities will arrive from 2024/2025 onwards**

SUPEERA

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

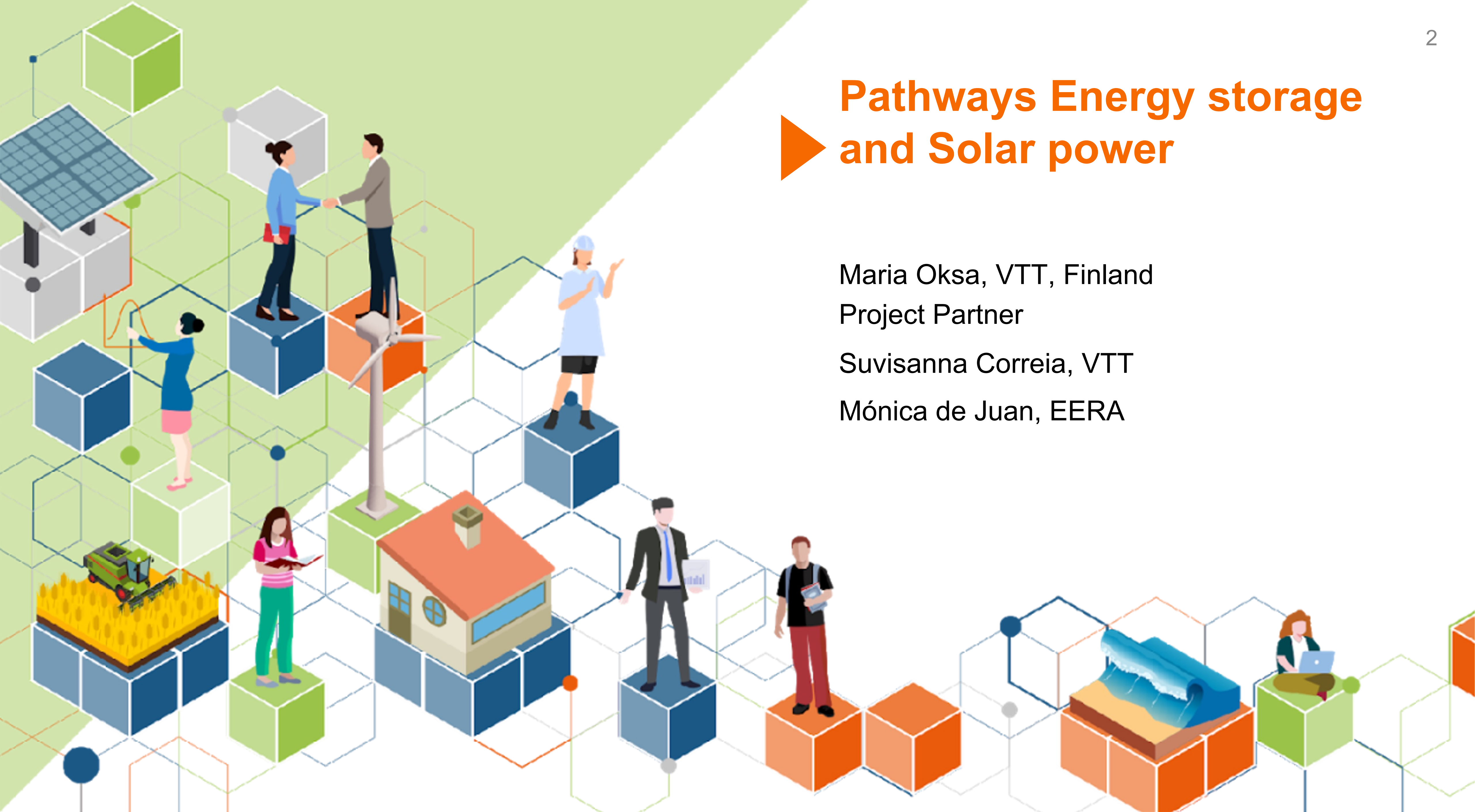
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 949125.

Workshop – Energy storage & Concentrated Solar Thermal Energy

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

Almeria, Spain, 15.11.2022

Pathways Energy storage and Solar power

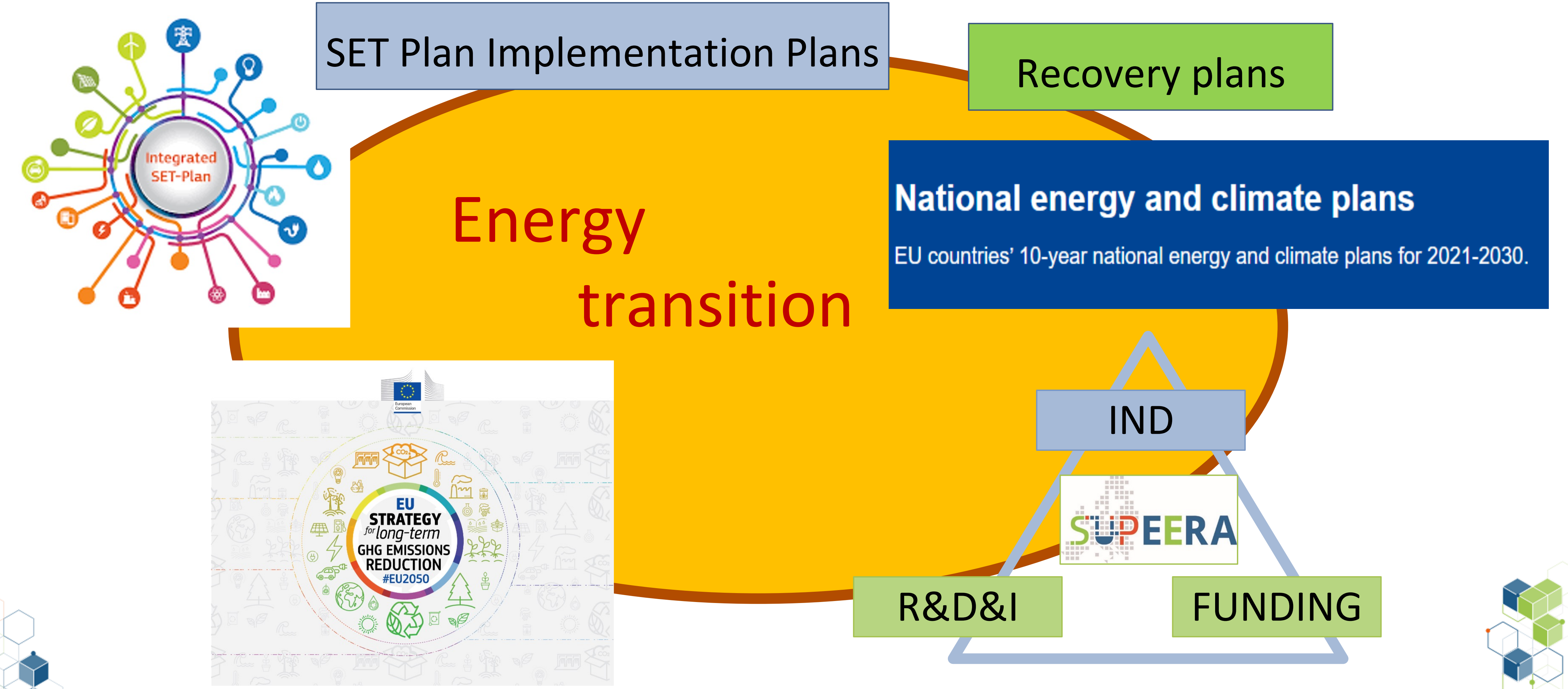


Maria Oksa, VTT, Finland
Project Partner

Suvisanna Correia, VTT

Mónica de Juan, EERA

SUPEERA supporting the energy transition



National Energy and Climate Plans (NECPs)

- EU countries released 2019-2020 their **National Energy & Climate Plans (NECPs),** with strategy, objectives and activities to meet the EU´s energy and climate targets for 2030

- The plans include national targets, objectives, policies and measures for different **dimensions** and they address an array of **technologies**

- **Dimensions**
  - *Decarbonisation*
  - *Energy efficiency*
  - *Energy security*
  - *Internal energy market*
  - *Research, innovation & competitiveness*

- The NECPs are being updated (original deadline June 2024)

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

→ Selection of pathways

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

Dialogue between R&D&I and IND

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

→ Focus on NECP chapter 2.5 Research, innovation and competitiveness

→ **Best practices, barriers and gaps**

Framework for transnational cooperation

Recommendations

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
Reaserch 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.

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

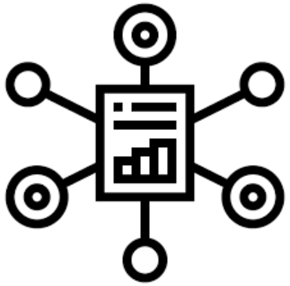
- **Greece** plans to promote solar powered desalination plants with battery storage to produce water for drinking or irrigation on islands and in remote areas.
- RE and energy storage systems will supply stable power for these desalination plants.

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

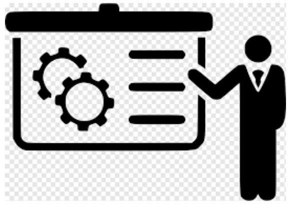
Background for Solar Energy

Renewable Energy Directive



- Sets rules for the EU to achieve its 32% renewables target by 2030.
- Regulatory framework related to support and tendering schemes for solar installations.
- Treatment of solar prosumers and communities.
- Removal of administrative barriers to unlock the development of all solar projects across Europe.

National Energy and Climate Plans



- Key instruments for the EU to deliver on 2030 climate and energy targets.
- Outline their climate and energy targets, policies and measures to reach the 32% renewable energy target by 2030.
- Each member state will set specific targets for solar deployment and define how they plan to achieve it.

NECP Key highlights

Predict a visible growth for the solar energy production in the next 10 years

The NECPs can ease a cost-effective solar energy deployment by suggesting clear funding mechanisms, enabling regulatory frameworks, and simplifications in the permitting processes.

Decentralization of the renewable energy production as a vital aspect in order to achieve the Clean Energy Production targets.

Most of the countries consider future developments both at the small scale (community level) and large scale (solar plants or farms).

Best practices

BUILDINGS

- Roof photovoltaic in residential and non-residential buildings
  - AT: 100 000 rooftops solar panel and small-scale storage programme
  - FI: decarbonising the current building stock by 2050
  - FR: up to 200 km² of roof panels by 2028
  - HU: 200 000 households with roof PV panels

- R&I prefabricated active roof and facade elements combining photovoltaic and thermal solar systems (HE)

PROSUMERS/SELF-CONSUMPTION

- LU: tariffs for small installations, special categories for cooperatives for citizen participation and calls for tender for larger installations.
  - Preconditions, development and production permits no longer required
  - cost of connecting prosumers to the networks has been reduced
  - enterprises are allowed to become prosumers
  - the capacity limitation requirements have been revised
- LT: a sustainable ecosystem for prosumers and ensure its sustainable development.
- IE: supports customers' participation in the energy system
- PL: 'My Electricity Bill' with a pool of funds of PLN 1 billion

Factors that lead to the expansion of solar technology

Funding mechanisms, enabling regulatory frameworks, and simplifications in the permitting processes

- Tenders to speed up the expansion of photovoltaics (AT, DE, LU, FR)
- Administrative measures: Simplified processes for development of solar energy projects (IT, PT, SE, LT)
- Purchase Agreements (DK, LU, IT, ES)
- Subsidy grants (AT, NL, DK, DE, LU, SK)

Collaboration

- INSHIP and CySTEM projects
- Denmark has entered a cooperation agreement with Germany for statistical transfers for the electricity production from 50 MW solar PV
- International initiatives: Clean Energy Ministerial, IRENA, International Solar Alliance.

www.supeera.eu

SUPEERA

EERA
European Energy Research Alliance

cea DTU KIT Karlsruhe Institute of Technology SINTEF VTT

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…)

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**

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

→“Traffic lights”

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

Analysis of the pathways

→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**

State of the Energy Union 2022

Published on 18.10.22 → link to full report here

The EU has already **surpassed 91% of gas in storage**

% Russian pipeline gas in EU imports → **from 41% in 2021 to 9% in Sept 2022**

LNG → key source of supply, accounting **for 32% of the EU's total net gas imports**

Record **12% of EU electricity from solar from May to Aug 2022**, **13% from wind**

General Takeaways

2022 will be a record year for the European solar PV market, (peaks of annual deployment growth of 17-26%)

% of renewables in electricity mix expected to **grow from 37% in 2021 to 69% in 2030**

Electrolyser manufacturers in Europe have committed to **increase their capacity** to manufacture electrolysers **tenfold**, to **17.5 GW by 2025**

In 2020:

- Emissions reduction: **32%**
- Energy efficiency: **5 to 6%** lower than the **20%** target
- Renewables deployment: **22.1%**

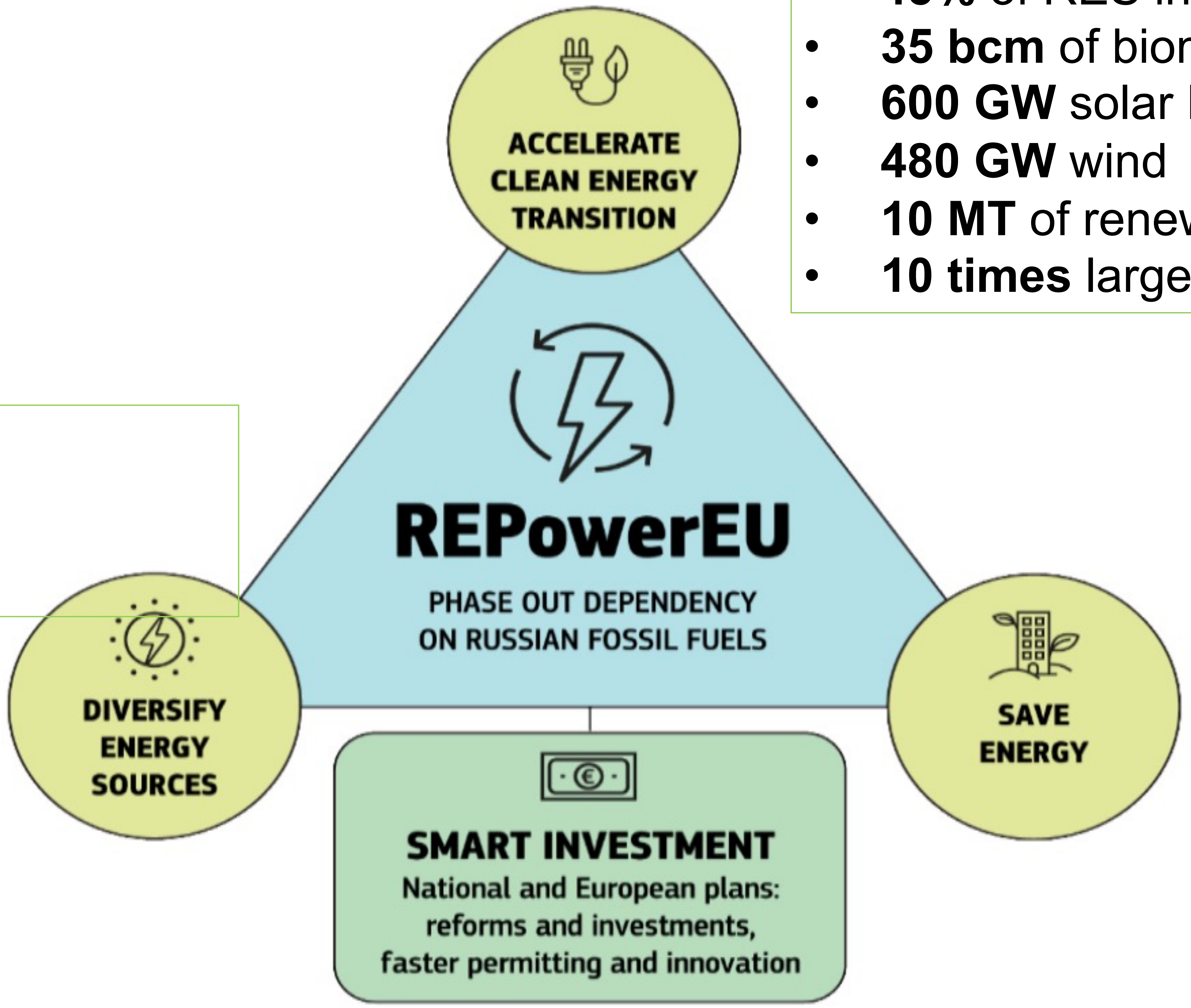
*Compared to 1990 levels

After falling by more than 5% in 2020 due to COVID restrictions, **fossil fuel subsidies in the EU remained fairly stable in 2021**

REPowerEU

- **45%** of RES in the mix
- **35 bcm** of biomethane
- **600 GW** solar PV
- **480 GW** wind
- **10 MT** of renewable H2 produced in the EU
- **10 times** larger electrolyser manufacturing

- Joint **gas** and **H2** purchases
- **LNG** investment



- **15%** reduction in gas demand
- **35 bcm** gas saving in industry

- **200 bln €** in diverse CET infrastructure
- **200 bln €** in green H2
- **10 bln €** in LNG

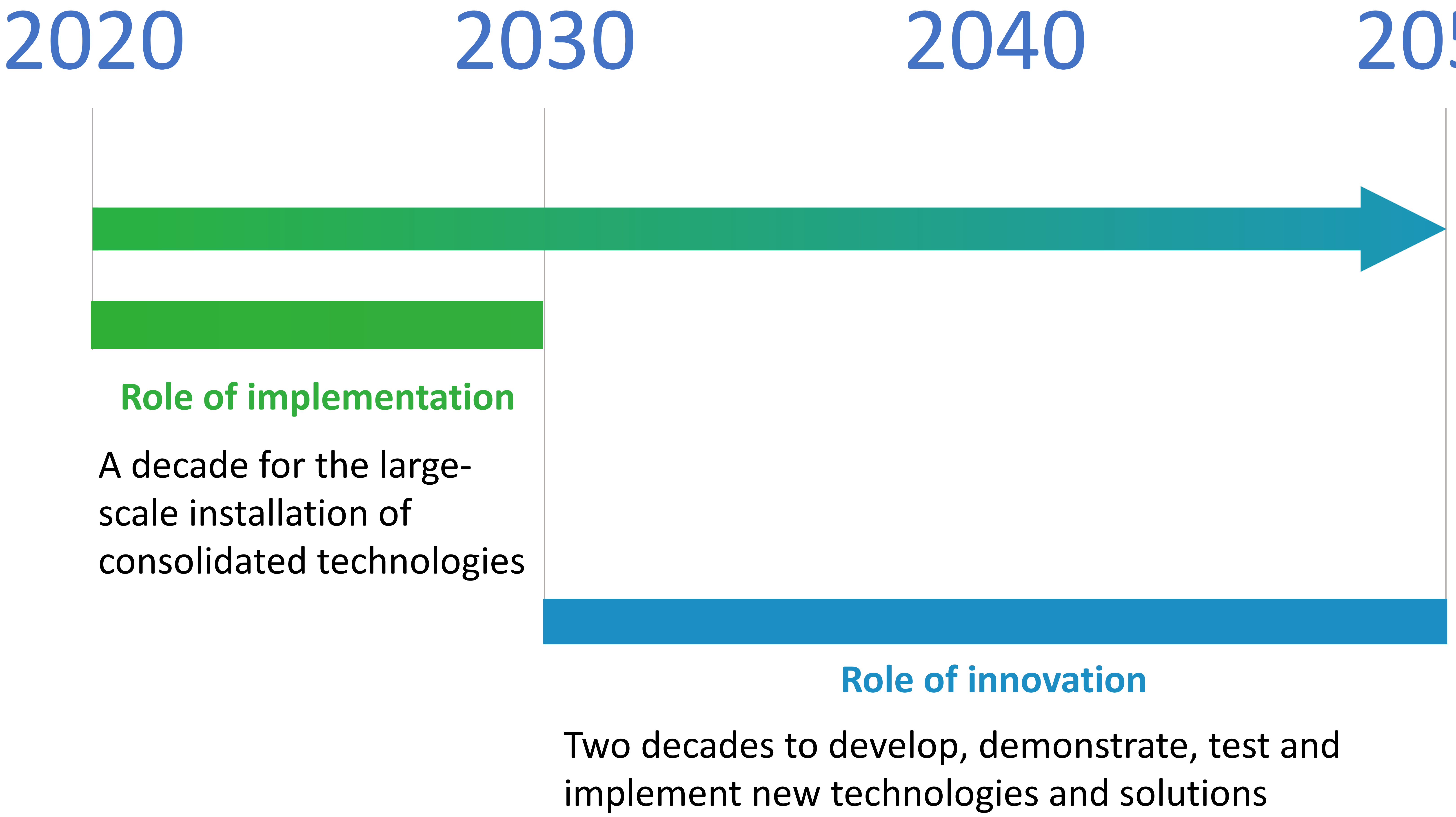
EERA Manifesto on REPower EU

1. **A holistic approach of the repowering challenge**
2. **A new role For Research:**

   Facilitating REPowerEU implementation
3. **Detailed technology-related recommendations**
4. **12 high-level policy recommendations**

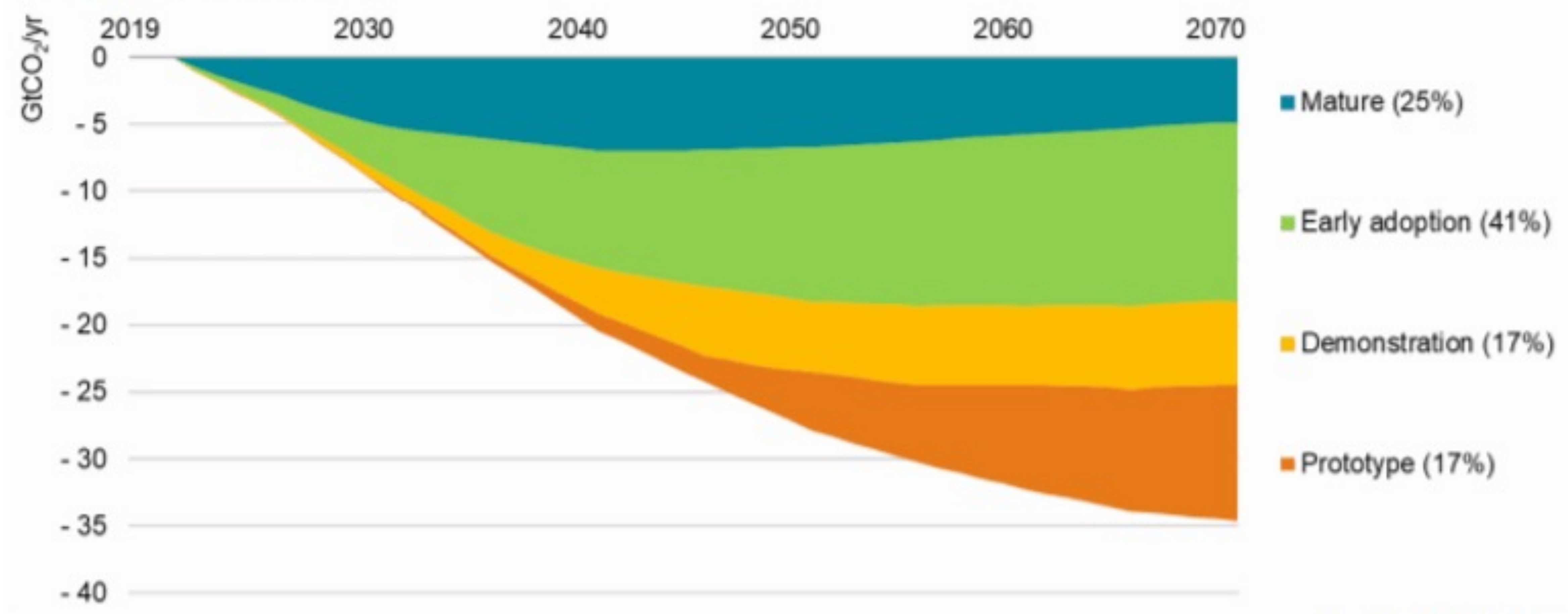
Link : EERA REPowerEU Manifesto

A new role for research: facilitating REPowerEU implementation



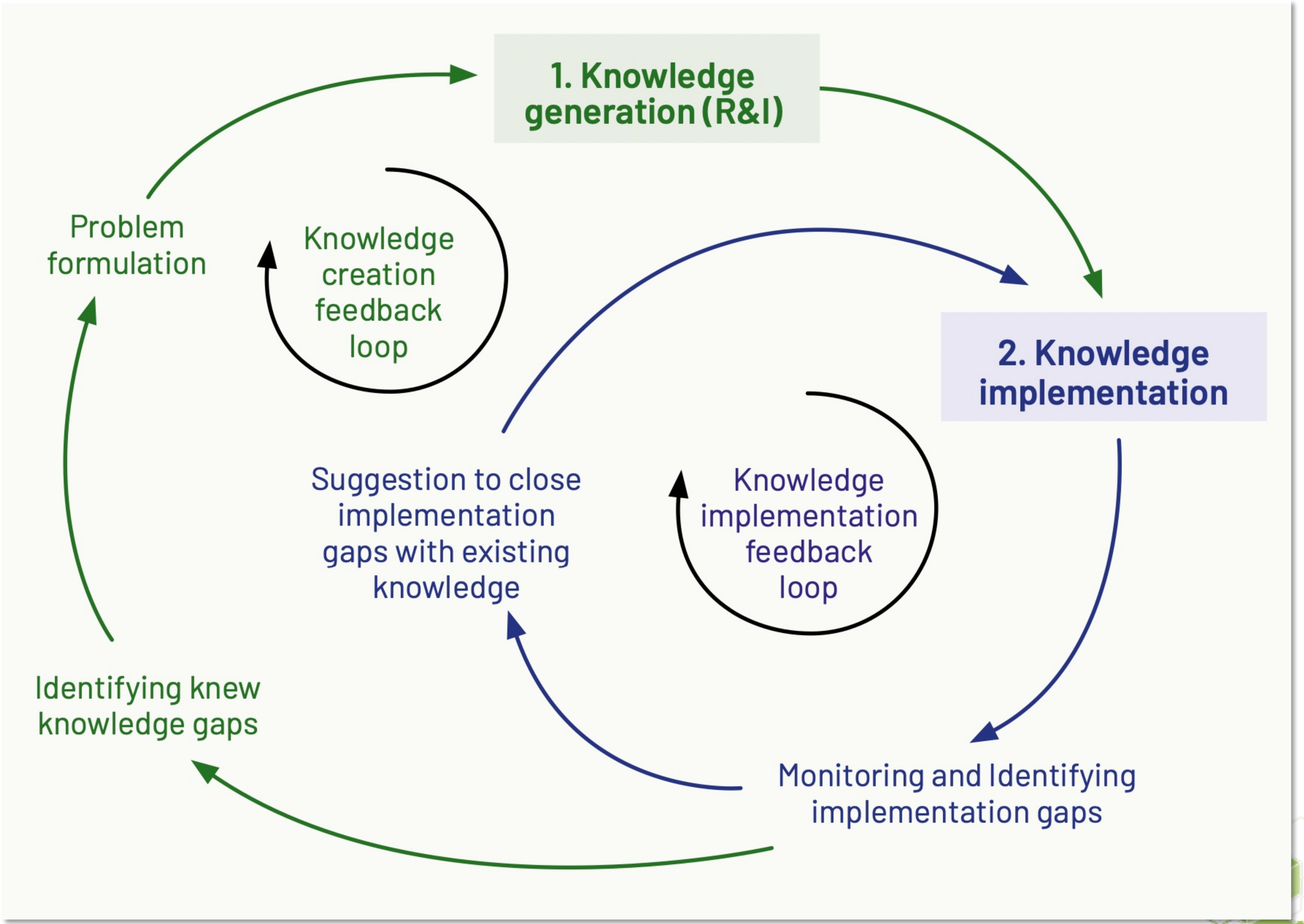
Need to accelerate the existing knowledge implementation

CO_2 emissions reductions by technology readiness category in the Sustainable Development Scenario



Notes: Percentages refer to cumulative emissions reductions by 2070 between the Sustainable Development Scenario and baseline trends enabled by technologies at a given level of maturity today.

Technologies that are at the prototype or demonstration stage today contribute more than one-third of the cumulative emissions reductions in the IEA Sustainable Development Scenario.



Detailed technology-related recommendations

- **Reduction of Energy Demand** (explicitly differentiates between energy-efficiency measures and structural demand-reduction measures)
- **Heating & Cooling** (REPowerEU focuses on electricity which currently represents only about 23% of the final energy consumption in EU-27)
- **Electricity** (higher penetration of renewables reuqires increased system flexibility → smart grids and more dispatchable renewables)
- **Storage** (crucial to include energy storage priorities in both electricity and heating technological pathways)
- **Natural gas, Hydrogen & other chemicals** (their use in the EU, in the medium- and long-term, should be designed taking into account expected energy demand scenarios)

www.supeera.eu

SUPEERA

EERA
European Energy Research Alliance

cea DTU KIT Karlsruhe Institute of Technology SINTEF VTT

European Energy Research Alliance

Concentrated Solar Power

EERA Joint Programme on CSP

Bringing research and industry closer: Energy storage and CSP/CST- 15 November 2022

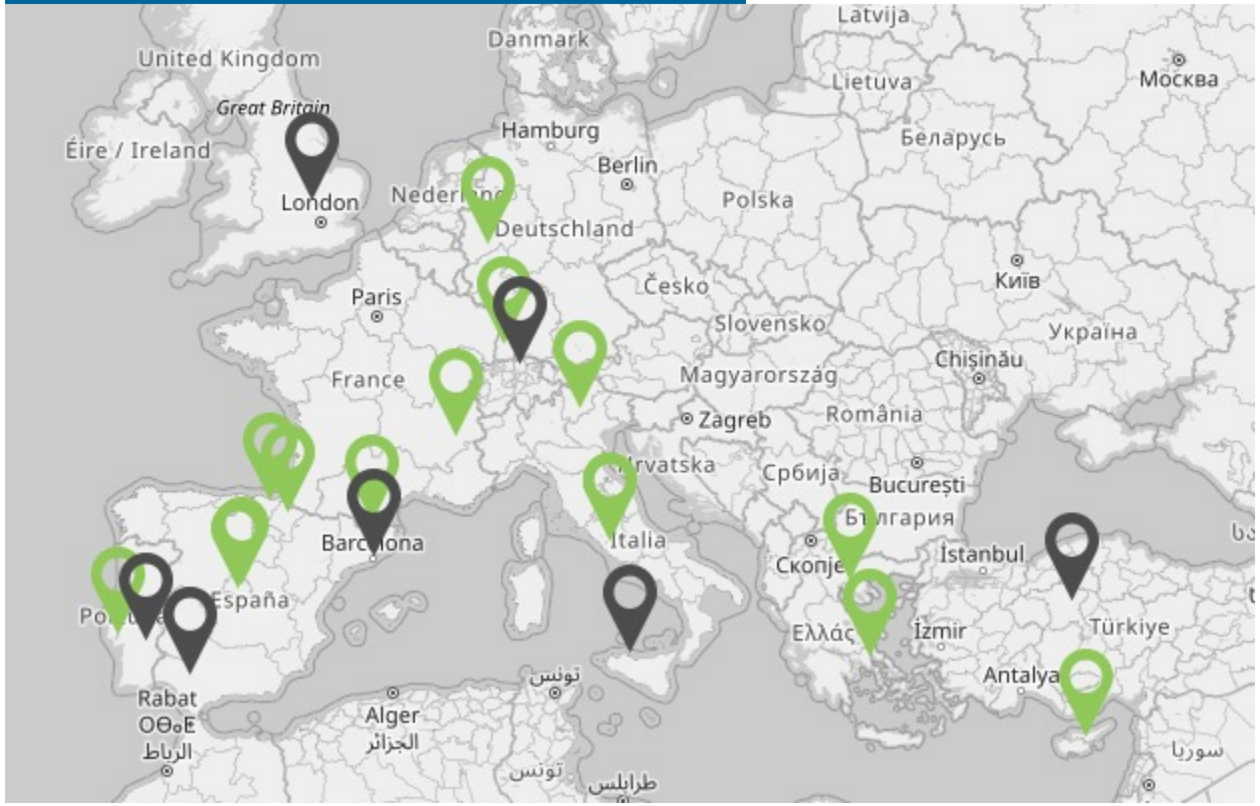
Joint Programme on CSP

Established in **2011**

27 ROs and Universities dedicated to support a climate-neutral society by 2050

10 Member States /Associated countries collaborating through this JP CSP

EERA
European Energy Research Alliance
Concentrated Solar Power



Joint Programme on CSP

The Joint Programme is structured into six sub-programmes:

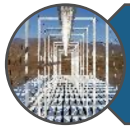

Sub-Programme 1: Line-Focusing CSP systems


Sub-Programme 2: Point-Focusing CSP systems


Sub-Programme 3: Thermal Energy Storage


Sub-Programme 4: Materials for CSP


Sub-Programme 5: Solar Driven Thermochemical Processes


Sub-Programme 6: Solar Heat for Industrial Processes and Applications

Joint Programme on CSP

EERA JP-CSP Team

Ricardo Sánchez, CIEMAT
JP Coordinator

Mónica de Juan, EERA
EERA Sec Link

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Univ. of Derby – SP1

Marcelino Sánchez
CENER- SP2

Walter Gaggioli
ENEA – SP3

Peter Heller
DLR – SP4

Martin Roeb
DLR – SP5

Peter Nitz
Fraunhofer ISE –SP6

Sub-Programme 1: Line-Focusing CSP systems

Objectives

- **Consolidate the technology of line-focusing solar collectors for electricity generation**
- **Increase its competitiveness in the market of electric power generating facilities**
- **Further promote the innovation in line-focus solar collector technology and components to favour their use at small scale for**
    - industrial process heat applications
    - solar cooling/refrigeration applications
    - decentralized electricity generation
    - water desalination and purification applications

Sub-Programme 2: Point-Focusing CSP systems

Objectives

- **Increase the robustness of current commercial technology available** → Increasing reliability, quality control, on-site inspection, monitoring, and control; to increase durability and long-term plant performance while reducing O&M costs
- **Facilitate the development of innovative concepts, paving the way to the necessary technological breakthroughs** → Increase plant efficiencies and reduce LCOE
- **Reduce the time to market of the successful R&D projects and ideas developed within EERA** → Enhancing knowledge exchange between the scientific community and the industry
- **Promote the utilization of CSP in the electrical system** → Enhancing knowledge of the benefits of the CSP for the wide public and, especially, the politicians and energy planners

Sub-Programme 3: Thermal Energy Storage

Objectives

- **Reduction of the capital and operating costs of the CSP plants (of both large and small size) → to make them more competitive with respect to plants utilizing fossil fuels and other renewable energy sources**
  - improving the efficiency of the main components and systems (e.g. by extended operation temperature window)
  - simplifying the systems and maintenance operations and procedures

Sub-Programme 4: Materials for CSP

Objectives

- **Improve the main materials used in CSP/CST**
  - Investigating the occurrence of abrasion and soiling under desert conditions corrosion under marine and industrial environments and simulate the effects under laboratory conditions
  - Developing methods of accelerated ageing for reflectors and absorbers that provide more precise estimations of degradation over a lifetime
  - Designing test benches and facilities to allow for accelerated ageing of materials
  - Improve mirrors and enhance the durability
  - Analysing the suitability of enhanced materials (including new manufacturing processes) for high temperature processes
  - Qualifying materials in contact with new HTFs for increased plant performance, durability and environmental benefit

Sub-Programme 5: Solar Driven Thermochemical Processes

Objectives

- Improve the solar chemical production processes and get them closer to their theoretical efficiency limits
- Reduction of hydrocarbons consumption as natural gas to ensure a reduction of greenhouse gases emissions such as CO_2

Sub-Programme 6: Solar Driven Thermochemical Processes

Objectives

- Addressing the specificities of the use of CST technologies in the Industrial framework
- Promoting a higher penetration of CST technologies in heat supply to industry

European Energy Research Alliance

Thank you

www.eera-csp.eu

Ricardo Sánchez, ricardo.sanchez@psa.es

EERA Joint Programme Energy Storage

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

European Energy Research Alliance

Joint Programme on Energy Storage

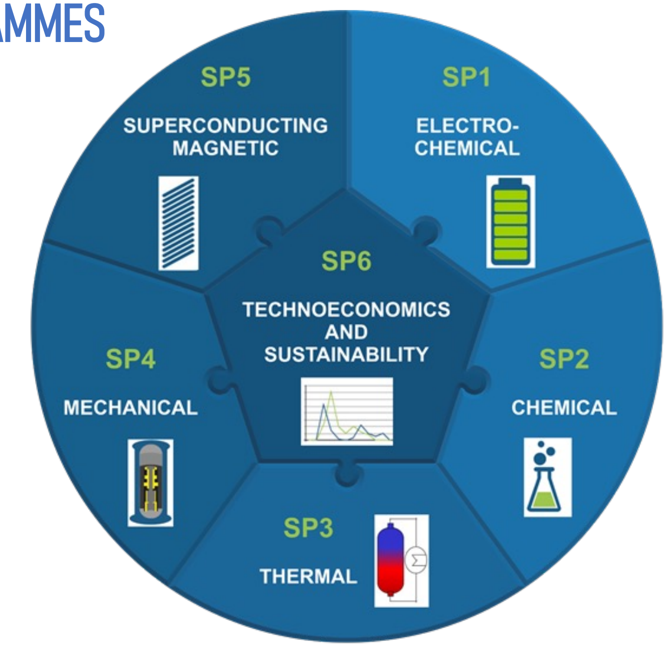
MISSION & VISION

- Develop common research in the field of energy storage at EU level
- Facilitate knowledge transfer
- Advise policy makers

NUMBERS and FIGURES

- Launch: 2011
- Members: 39 research centres & universities
- Countries involved: 15
- Energy Storage Areas: 5

SUB-PROGRAMMES



www.eera-energystorage.eu

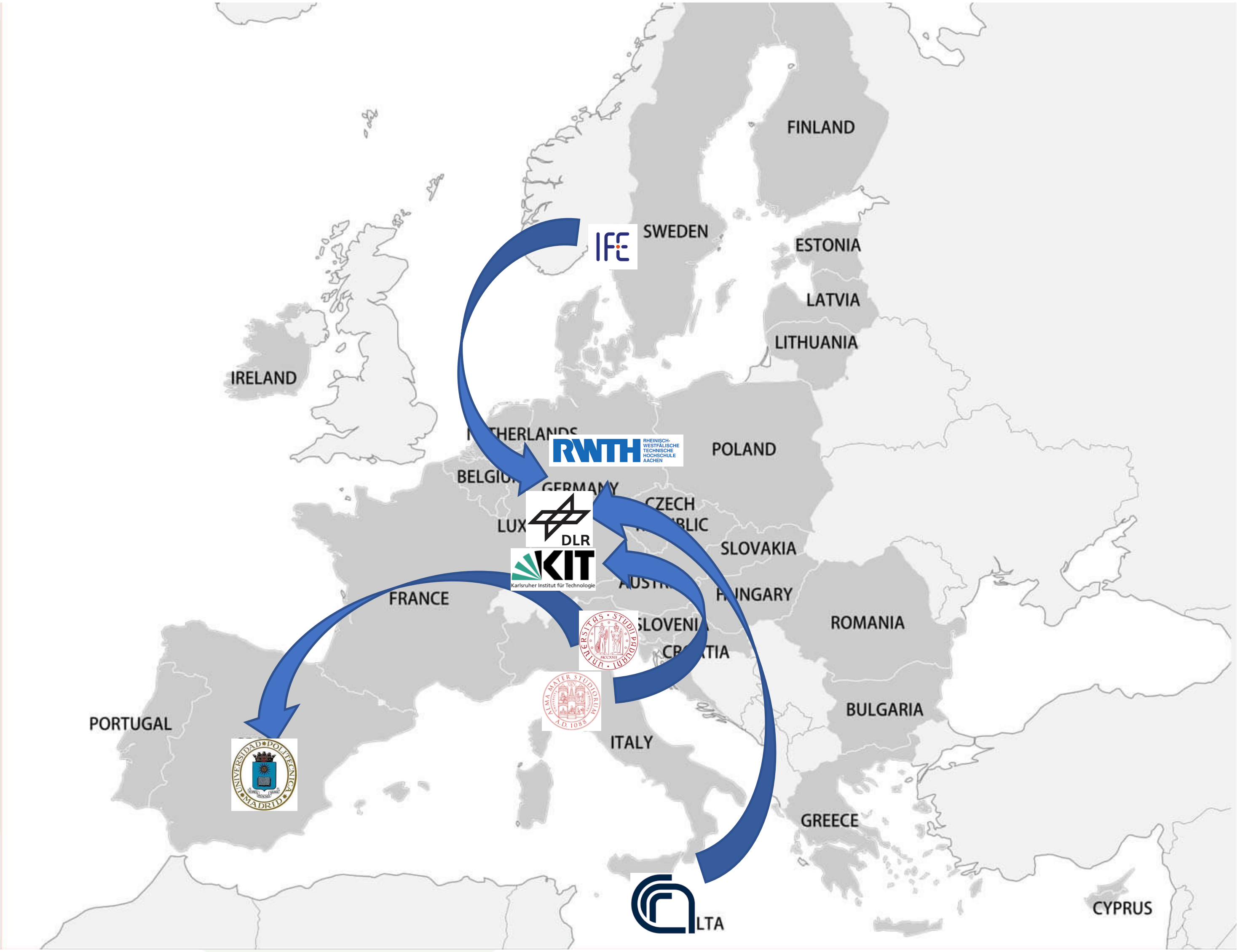
Mission and Vision

- 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
- Policy and Stakeholder Workshops: facilitating knowledge transfer
- Online PhD Days: stimulate exchange and discussion on the topic with young scientist
- JPES Award: support activities in the field of energy storage
- JPES @EUSEW: networking with other initiatives and establish a dialogue with EC
- Industry Advisory Board: take into account current industry needs
- Interaction with other EERA JPs: use synergies and avoid duplication of work
- Joint applications for EU projects: SmiLES (2016 – 2019), StoRIES (2021 – 2025)

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)

5- KIT (DE) → EMPA (CH)

6- CNR (IT) → KIT (DE)

EERA European Energy Research Alliance Energy Storage

STAKEHOLDER WORKSHOPS 2021

Policy/industry oriented

EERA EVENT

14 April 2021 - online

Materials for Hybrid Energy Storage - Creating an Ecosystem for Innovation

READ MORE

EERA EVENT

24 November 2021 - Hybrid Event

JP ES Joint Workshop on EU Clean Energy Transition: Perspectives and Challenges for Energy Storage

READ MORE

Technology oriented

EERA EVENT

14 May 2021

New flexibility resources: the role of hybrid pumped hydropower

READ MORE

EERA EVENT

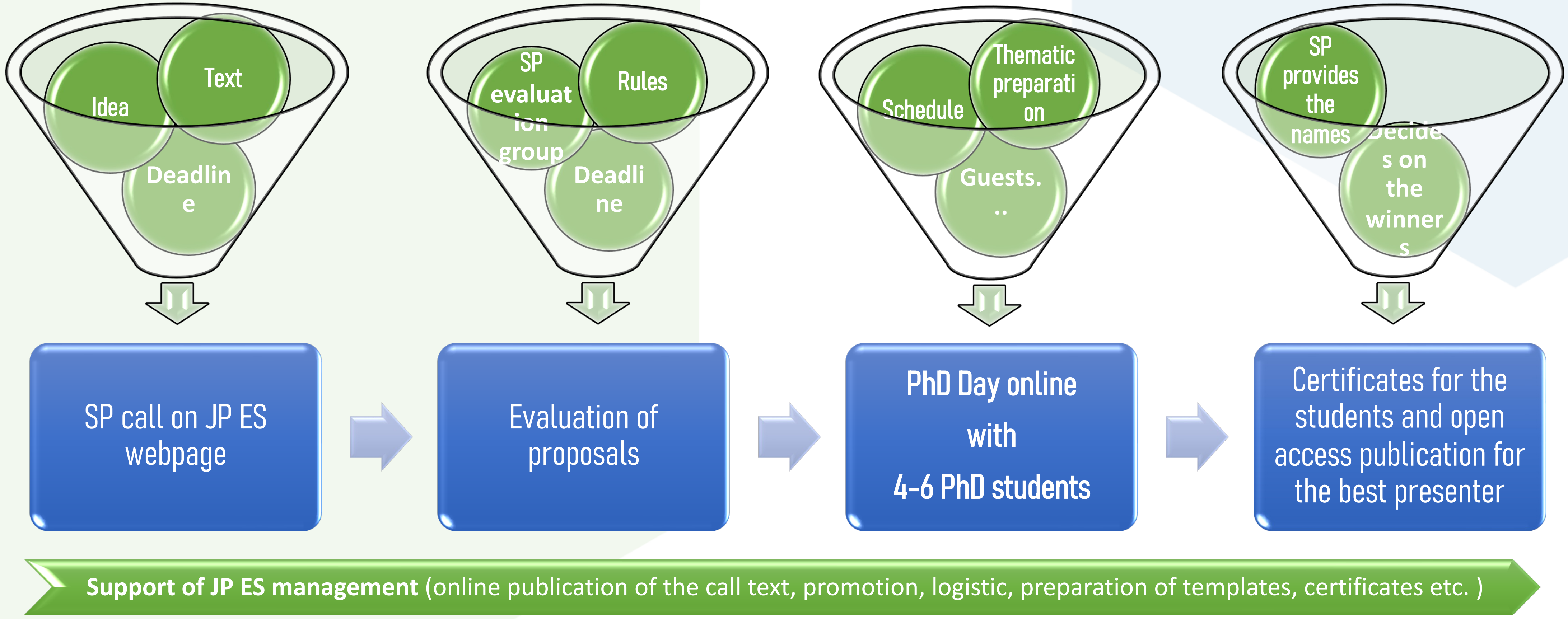
13-14 September 2021 - Lappeenranta, Finland

Future Energy Solutions

READ MORE

Recording and reports at www.eera-energystorage.eu

PhD Days


Idea
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SP
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Decide
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winner
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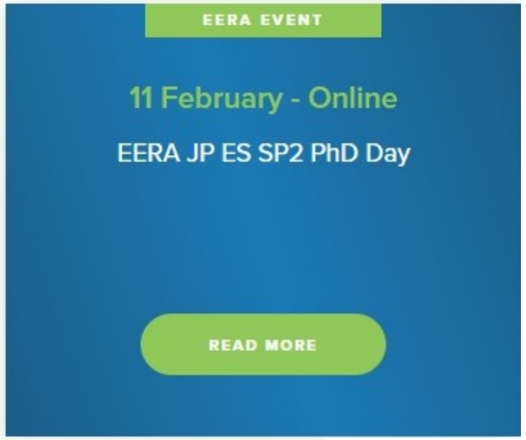
SP call on JP ES webpage
Evaluation of proposals
PhD Day online
with
4-6 PhD students
Certificates for the students and open access publication for the best presenter
Support of JP ES management (online publication of the call text, promotion, logistic, preparation of templates, certificates etc.)

PhD Days and JP ES Award 2021-2022



PhD days
Open Access publication
(scientific journal is chosen by the winner)

JPES Award
Best oral presentation: €300
Best poster presentation: €200

GERMAN-CANADIAN
MATERIALS ACCELARATION CENTRE

ABAF
BRNO
Advanced Batteries, Accumulators and Fuel Cells


EERA
European Energy Research Alliance
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

Industry Advisory board

Up to **10 members** from a variety of categories within the energy storage sector:

- Energy storage industry
- Power companies
- Manufacturers/suppliers
- Consultancy/advisory
- TSO/DSO regulators
- NGOs
- Policy makers
- National Authorities
- Consumers organisations

The EERA Joint Programme on Energy Storage (JP ES) will include an Advisory Board, which will serve as a *forum for the energy storage sector* to advise and give feedback to the JP ES Management Board and Steering Committee. This will ensure that the JP ES is aligned with the research and innovation needs from stakeholders in the energy storage domain.

Scope of work

The Advisory Board shall:

- Discuss the progress of the Joint Programme and provide strategic advice from industry, policy and civil society perspectives
- Identify R&D and innovation needs
- Bridge relevant networks and stakeholders
- Ensure JP ES's relevance to the energy storage sector
- Increase the awareness and knowledge about energy storage and hybrid energy storage research for the sector, and promote its role to enable the green energy transition

Joint EU Projects: StoRIES

Storage Research Infrastructure Eco-System

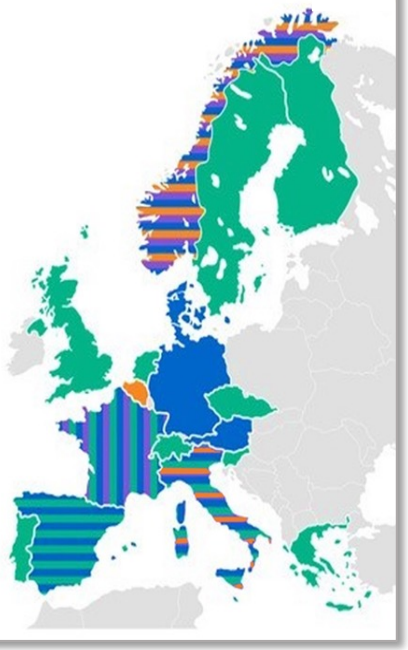
BENEFICIARIES

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

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

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

Linked Third parties:
IFE (NO), RTE (FR), HVL (NO)



StoRIES

NUMBERS and FIGURES

- Duration: 2021-2025
- Budget: 7 Mio €
- Beneficiaries: 47
- Infrastructures: 64
- Countries involved: 17
- Stakeholders > 100

MAIN OBJECTIVES

- Foster a European eco-system of **industry and research** organisations on hybrid energy storage technologies
- Provide **access** to world-class materials and energy storage related research infrastructures

ECO-SYSTEM

PROJECT CORE

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

~50

EXTERNAL LAYER

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

>100

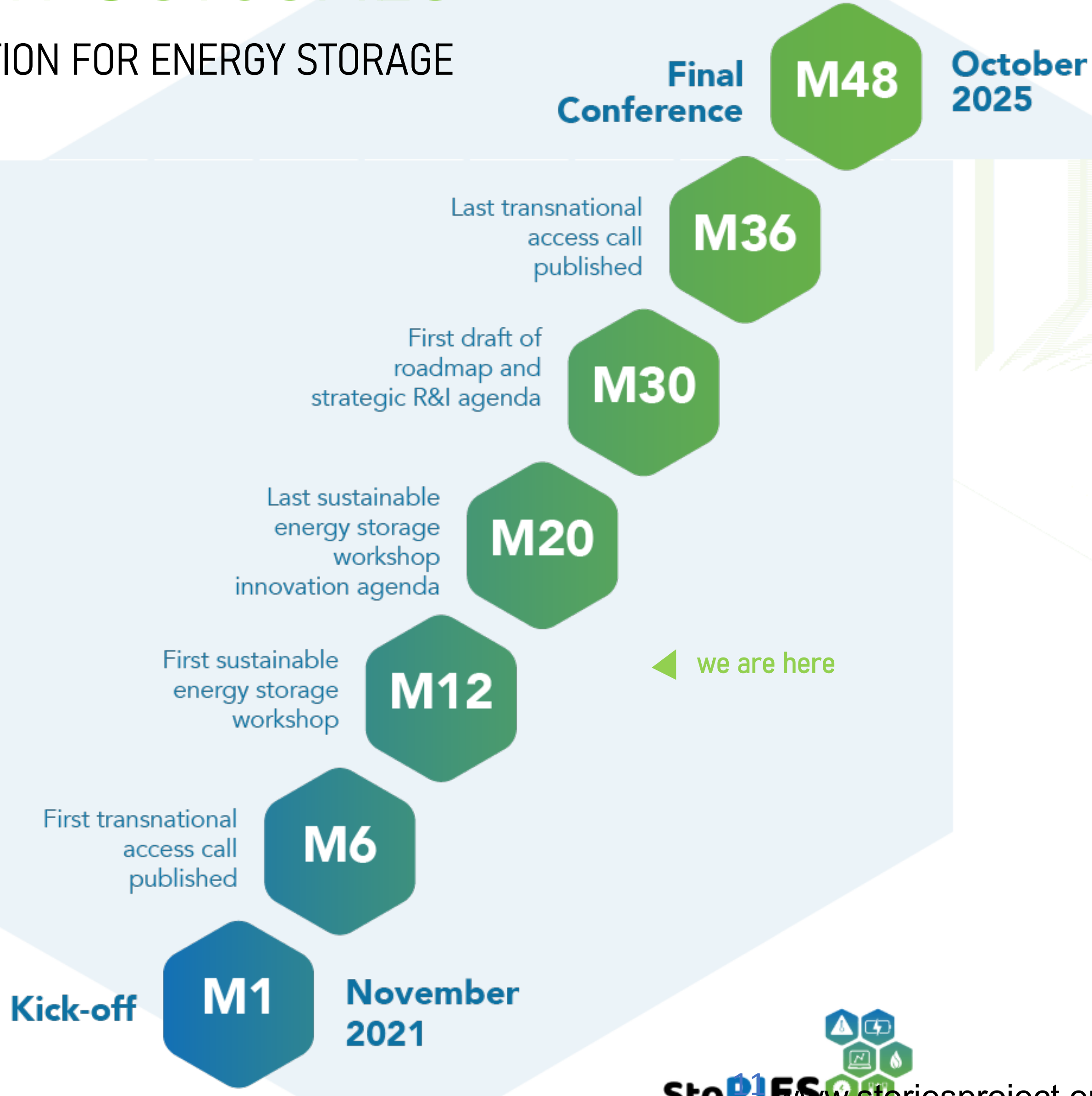
This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No 101036910

www.storiesproject.eu

StoRIES Main Outcomes

Key Research Priority: HYBRIDIZATION FOR ENERGY STORAGE

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



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StoRIES www.storiesproject.eu

Thank You Very Much For Your Attention

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This project has received funding from the European Union's Horizon 2020
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PROTERMO SOLAR
Asociación Española para la Promoción de la Industria Termosolar

Current challenges of CSP: the vision from the industry

David Trebolle – Secretary General
davidtrebolle@protermosolar.com
15th November, SUPEERA

About Protermosolar

Protermosolar is the Spanish Association of the Solar Thermal Electricity Industry, which brings together most of the main companies in the sector in Spain. It was established in 2004 by Abengoa, Cobra and Sener.

Protermosolar represents all the CSP owners in Spain, most of the O&M Contractors, the main EPC companies, as well as the most representative business developers, key suppliers and advisors.

Protermosolar's main objective is to promote the expansion and development of solar thermal technology both in Spain and in the rest of the world.

Protermosolar's head office is in Madrid.

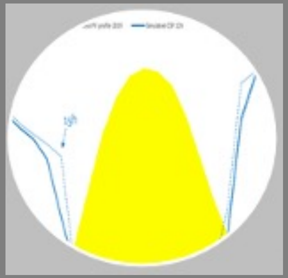
CSP Challenges and Key aspects

There is still a lot work to be done…

Grid Connection & Access

Spanish CSP tender vs grid access are decoupled

More participation will be expected with coupled processes.



Generation Profile

Night generation must be incentivized

PV at day times and CSP at night times

Spanish CSP costs

International references may be not applicable to the Spanish case

Key aspects: tender scheme duration, inflation, DNI, hybridization, capacity factor and market exposure…

LCOE ≉ Cost of the system

The contribution to security of supply, adequacy and quality of service. A target of RES must be considered.

LCOE mainly considers inherent parameters to the technology such as capex and opex.

Less curtailments --> More Storage

Fossil fuels must be replaced by alternative firm and synchronous generation

All RES and Storage technologies will play an essential role.

Regulatory Framework

PROTERMO SOLAR
Asociación Española para la Promoción de la Industria Termosolar

Two schemes

RECORE (2014 - CSP power plants connected between 2007-2013). Based on Royal Decree "RD" 413/2014 + revenues / year

Market revenues + R_o + R_{inv} = $R_{evenues}$

Operational revenues: Power plants sell electricity to the pool market. Deviations vs reference provided by the regulator (every 3y) are compensated (upward/downward) through the regulatory life of the asset . R_o parameter (based on unit reference values) to cover the gap between the standard OPEx and the pool price.

CAPEx revenues: a 7,4% allowed pretax rate of return guaranteed to be achieved during the Regulatory Life of the asset. Based on a Unit reference value where type of technology, storage and COD[1] year are considered.

25 years CSP scheme

REER (2020 – present day). Pay as bid Tender Scheme. Based on RD Law 23/2020 + RD960/2020 + Order 1161/2020 + 3rd Tender on October 25th

P_{tender} + 15 % X P_{market} - P_{tender} = $R_{evenues}$

Price of the tender: Pay as bid regime. Tender product is capacity based with the right of receive an energy price €/MWh for 20 years (3rd tender scheme).

Market exposure: 15%.
With the aim of the production in order to capture highest hourly marginal prices.
If market prices are above tender prices -> tender price may be incremented.

20 years CSP scheme

(1) COD: Commercial Operation Date

Key aspects of CSP tender design in Spain

The scheme for CSP (25th October 2022)

Allocation based only on price [€/MWh]. **Pay as bid** regime.

Guarantee of 60€/kW to participate → 3-6 M€ (50-100 MW CSP)

The revenues scheme duration of the tariff will be **20 years**

Hybridization: 10% PV or biomass (thermal boiler capacity < CSP capacity)

4,5 years to commercial operation date

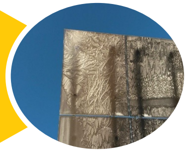
There are penalties if the plant does not meet a minimum energy every 3 years

No CSP technology restriction (Parabolic Trough Collector, Tower, Fresnel, etc.)

2,600 – 4,500 h annual equivalent hours (implies 7-9h of storage)

380MW shared quota with biomass.

Dedicated **220MW CSP quota**



15% Exposure to the market

(P_{market} - P_{tender})

Applicable to *new installations* but also to *expansion* or *modification** of existing ones

50% limit per company

(applicable over the total quota)

*modification applicable to installations older than 15 years.

At least 600 MW of CSP until 2025

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Expected tenders according to order TED1161/2020 (legally binding)

		2020	2021	2022	2023	2024	2025
Wind	Increase	1000	1500	1500	1500	1500	1500
	accumulated	1000	2500	4000	5000	7000	8500
FV	Increase	1000	1800	1800	1800	1800	1800
	accumulated	1000	2800	4600	6400	8200	10000
CSP	**Increase**		**200**		**200**		**200**
	accumulated		**200**	**200**	**400**	**400**	**600**
Biomass	Increase		140		120		120
	accumulated		140	140	260	260	380
Others (biogas, hydro..)	Increase		20		20		20
	accumulated		20	20	40	40	60

CSP Tender 25th October 2022

Bringing research and industry closer

Research-industry cooperation practices and opportunities to accelerate innovation

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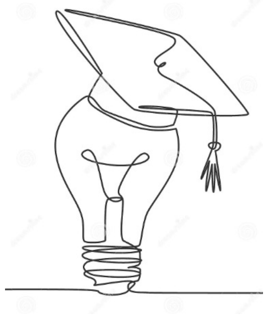


Studies

- ✓ STE Technical challenges.
- ✓ CST and CSP applications.
- ✓ Costs and future trends.
- ✓ Decarbonization needs and the value of STE.
- ✓ Regulatory proposals.

Seminars
Round tables
Events

- ✓ Opened spaces to align industry needs and research initiatives.
- ✓ explain the value of STE to society, and stakeholders.

Regulatory framework support

- ✓ Create stable regulatory framework to maximize the STE value.
- ✓ Foster a STE pipeline: improvements in R&D and scale economies.
- ✓ To accelerate decarbonization in electricity generation and industry.

Barriers

- ✓ Bring industry concerns to R&I parties.
- ✓ Maximize support to CSP industry: current regulatory framework barriers to R&D in existing plants.

Takeaways

Protermosolar can be your partner of the Spanish market

Thanks

Follow us:

davidtrebolle@protermosolar.com

Synchronous pumped heat electricity storage for the energy transition from fossil to renewables

Escarlata Muñoz
Malta Iberia Pumped Heat Electricity Storage S.L.U.

Presentation to SUPEERA Workshop
November 15th, 2022

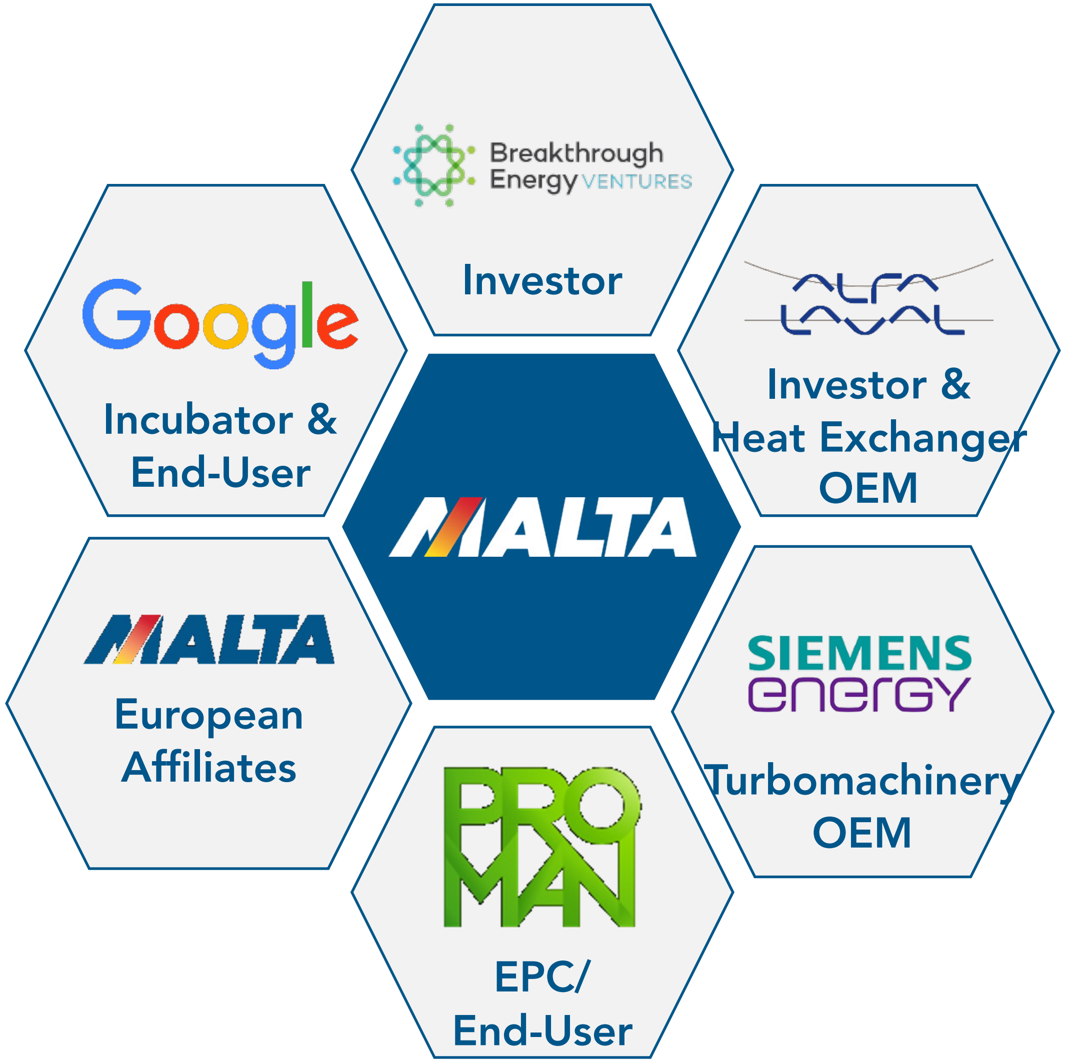
Malta Affiliates and Major Partners

Strong commitment in Europe

- Malta Iberia Pumped Heat Electricity Storage SLU
- Malta Hochtemperatur Wärmepumpen Stromspeicher GmbH

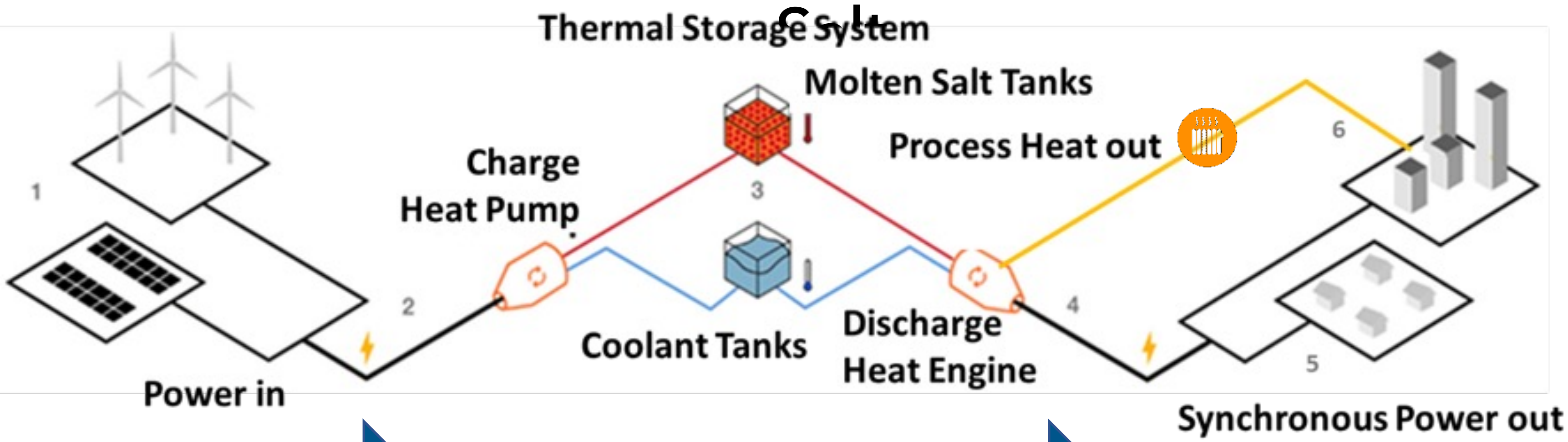
Renowned Original Equipment Manufacturers (OEM) and Engineering Partners

- Heat Exchanger OEM – Alfa Laval
- Turbomachinery OEM – Siemens Energy
- Detail Engineering - Proman



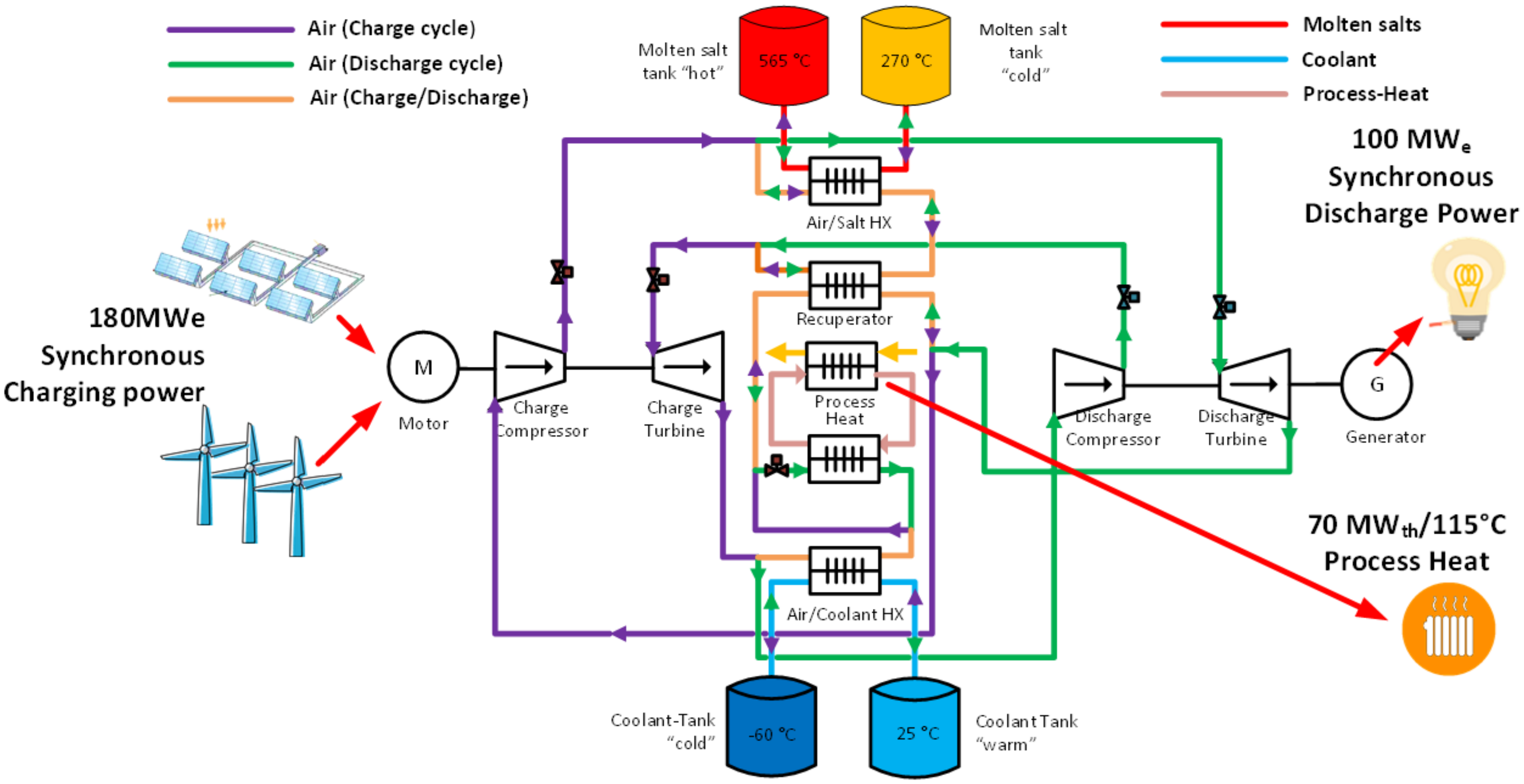
Introduction to Malta

Synchronous
Long Duration (8hours to 8days)
Grid Scale (100+ MW)
Thermal Storage using Molten Salt



Power → To Heat → To Power and Heat

Unique Grid-Scale Synchronous Charging and Discharging



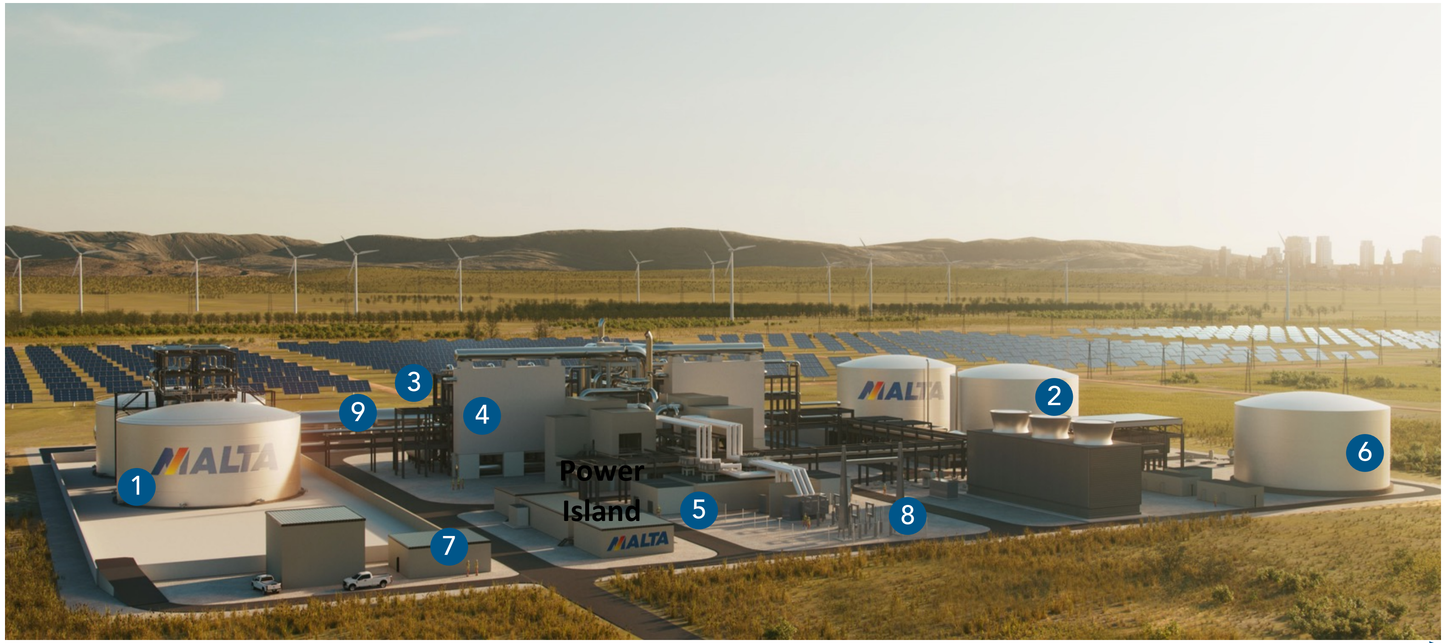
Malta makes mature synchronous utility scale long duration molten salt storage competitive for all variable renewables

Malta M100 Site Layout - 100 MW, 10 Hrs

- ~6 hectars total footprint
- System modular design can accommodate irregular land sizes (tanks, ICS, power island can be arranged independently)
- No geographic limitations
- 2X duration increase (10 h → 20 h) adds 4 additional tanks, ~15% land increase)

Standard Layout readily scaled to meet increased capacity and storage duration needs

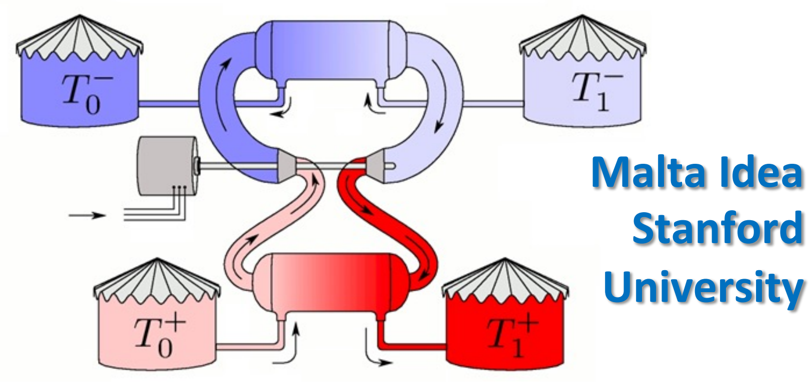
~200 m

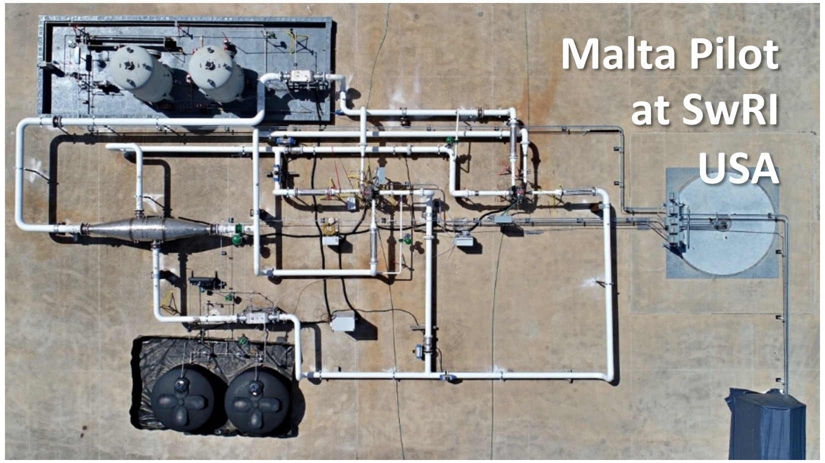


~300mft

1 Salt tanks
2 Coolant tanks
3 High Temp HX
4 Low Temp HX
5 Turbomachinery
6 Fire Control
7 Controls
8 Switchyard
9 Inventory Control System (Air Loop Storage)

How Malta collaborates with research institutes or other research-related entities in the field





Original idea was born by Robert Laughlin at Stanford University (USA) as "Mass Grid Storage With Reversible Brayton Engines"

First kW scale Pilot demonstration of shared hot, cold, and recuperator heat exchangers, liquid hot thermal storage and liquid cold thermal storage—and functions as a small-scale pilot system of the Malta technology implemented at Southwest Research Institute (SwRI) in San Antonio (Texas)

Envisaged cooperation with DLR to test innovative air / molten salt heat exchangers at the TESIS molten salt test loop of DLR in Cologne, Germany

Future R&D collaboration opportunities

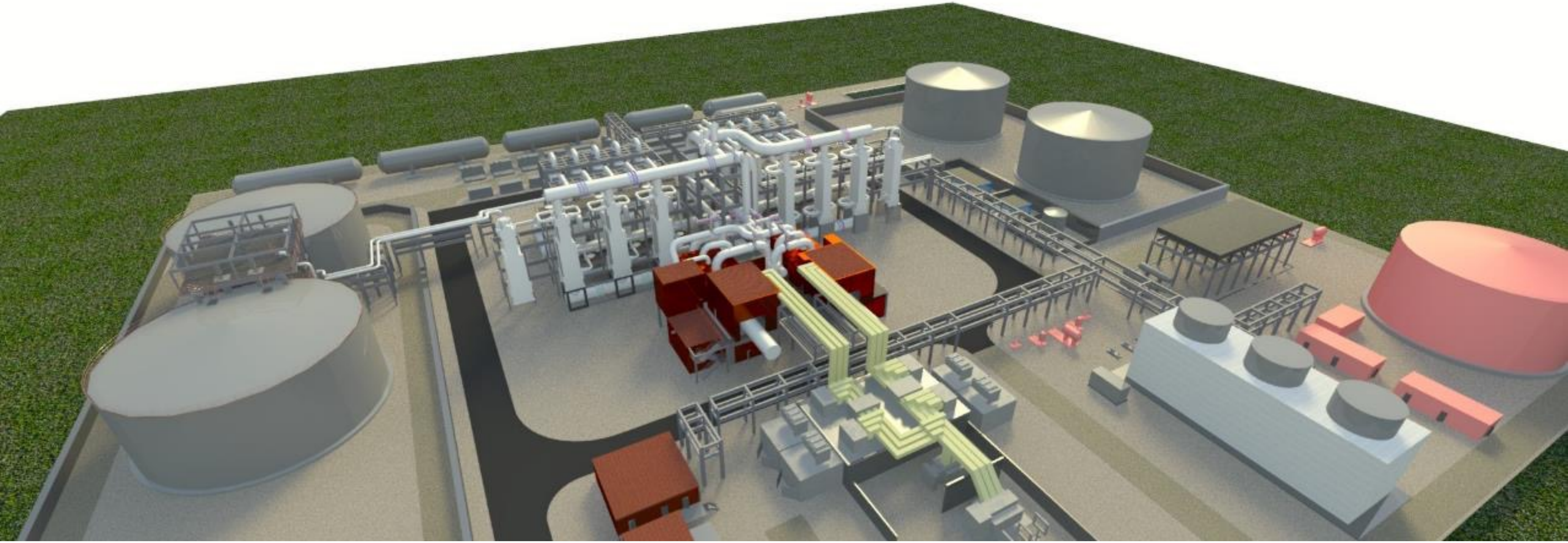
- Development, testing and qualification of innovative components for Malta's molten salt Pumped Heat Electricity Storage – challenge is to find molten salt test loops
- Modelling of national and transnational power grid to optimize share and operation strategy of synchronous long duration Energy storage in the Energy transition
- Analysis of barriers for long duration storage in European and national power system regulations
- Scientific accompaniment in Malta's first European utility scale demonstration of molten salt Pumped Heat Electricity Storage

Thank You

Long Duration
8 - 24+ Hours

Grid Scale
100 MW+

Low Cost
<200€/kWh



SENER

SUPEERA

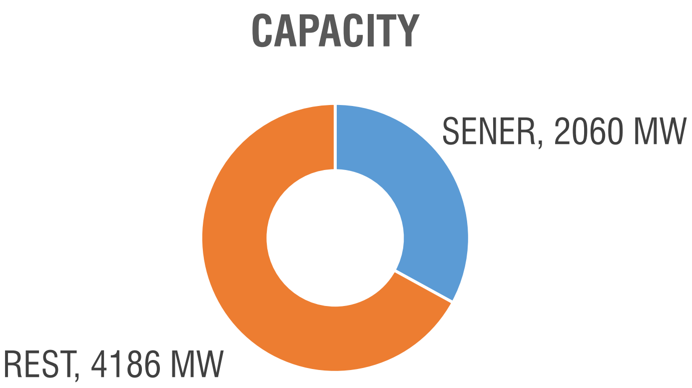
Support to the coordination of national research and innovation programmes in areas of activity of the European Energy Research Alliance

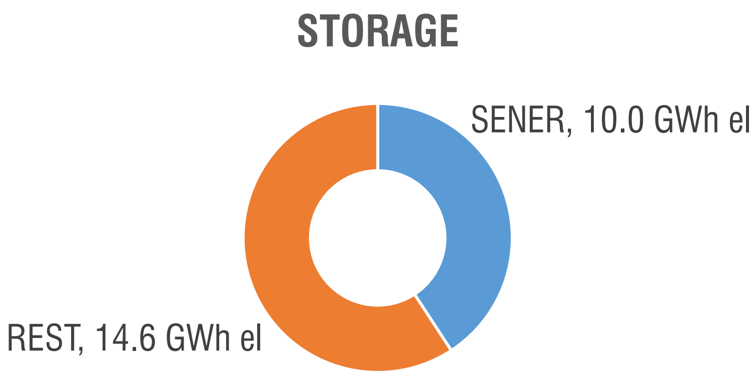
R&D and CSP: How close are they?

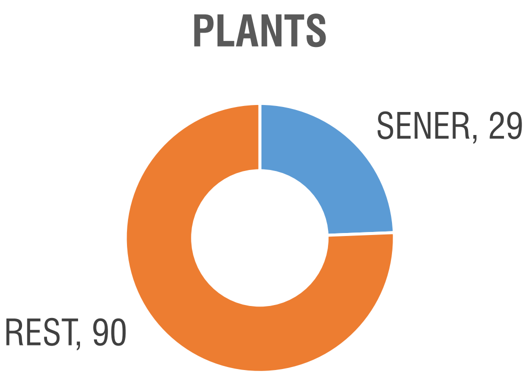
Bringing research and industry closer: accelerating innovation and uptake of new technologies

Energy storage & Concentrated Solar Thermal Energy

SENER in the CSP Industry







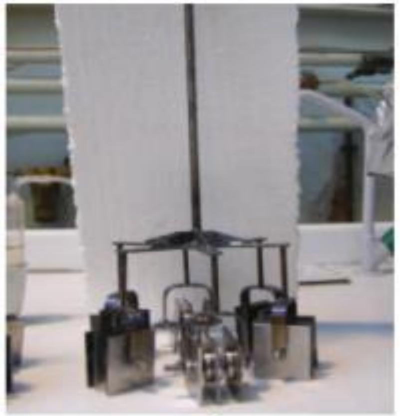
<u>Source</u>: DOE Global Energy Storage Database. Plants in Operation, 2022

R&D in CSP – *RECEIVER, Plataforma Solar de Almería*

Advanced Molten Salt Central Receiver
Prototype

Advanced Molten Salt Central Receiver
GEMASOLAR

R&D in CSP – *MOLTEN SALTS, Ciemat*



R&D in CSP – *POTS, Andasol-1 plant*

R&D in CSP – *Challenges Today*

The most urging challenges that CSP is facing today are PRICE & RELIABILITY:

- *Price can be reduced by…*
  - *Increasing capacity deployment, e.g., developing 2200 MW instead of 220 MW*
  - *Considering appropriate parameters when calculating LCOE: extended life (¿25 to 30 years?), price index, incentives for secure supply and capacity…*
  - *Maximizing hybridization with PV and other technologies*
  - ***R&D: continuous improvement of current technology is good, but breakthrough/out-of-the-box technologies can make a higher, significant difference*** *(70% of CAPEX in a CSP plant is supply!, dominating LCOE)*

R&D in CSP – *Challenges Today*

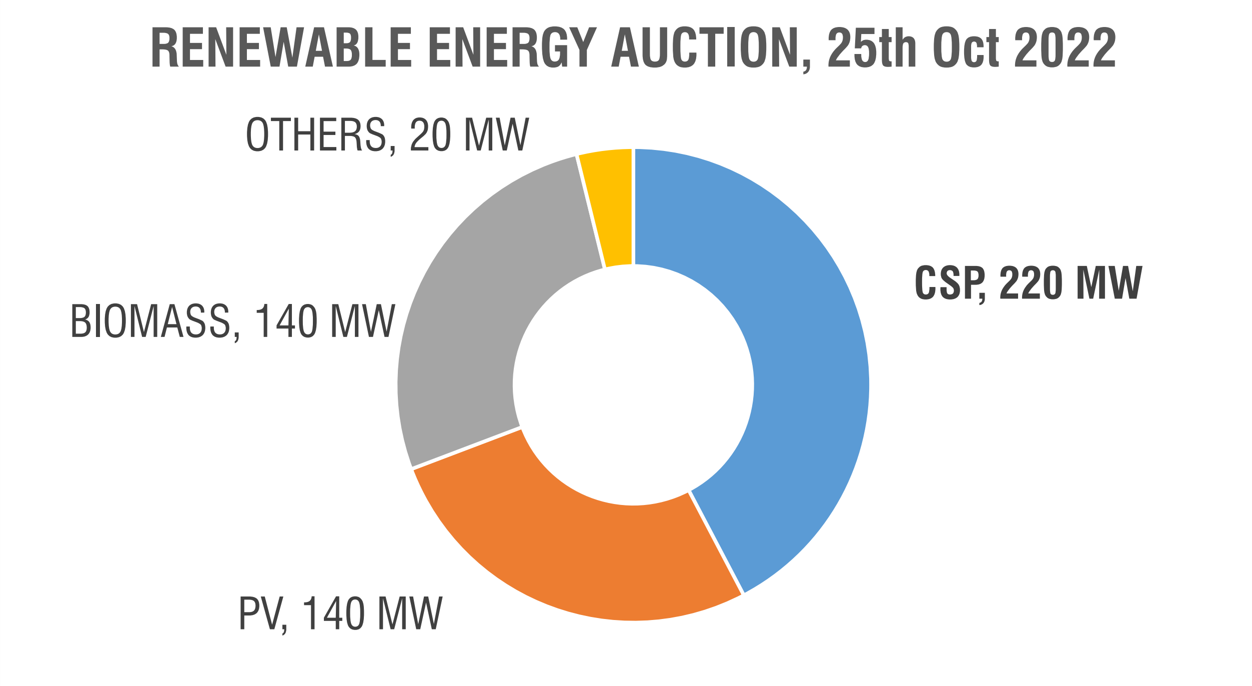
The most urging challenges that CSP is facing today are PRICE & RELIABILITY:

- *Reliability is mandatory for the Grid Operator:*

  However, all commercial molten salt tower plants in the western hemisphere (Gemasolar, Crescent Dunes, Noor III and Cerro Dominador) have experienced critical failures in the Hot Tank as well as in other components of the Power Block (Steam Generator System and BOP). These failures have led to unscheduled outages of several months, which is not acceptable at all for the Grid Operator (and for the investors!)

  A much higher focus on the current, critical problems of the CSP Industry is demanded to the R&D community

R&D in CSP – *Challenges Today*



NO PLANT HAS BEEN AWARDED

due to Price

Source: Ministry for the Ecologic Transition, Spain

R&D in CSP – *Challenges Today*

Gemasolar, Crescent Dunes, Noor III and Cerro Dominador
have experienced serious incidents in the Hot Tank, in addition to other issues

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

THANK YOU!

Sergio Relloso
SENER New Technologies Business Unit

sergio.relloso@sener.es
www.sener.es

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

www.supeera.eu

Thanks

Spyridon Pantelis

EERA

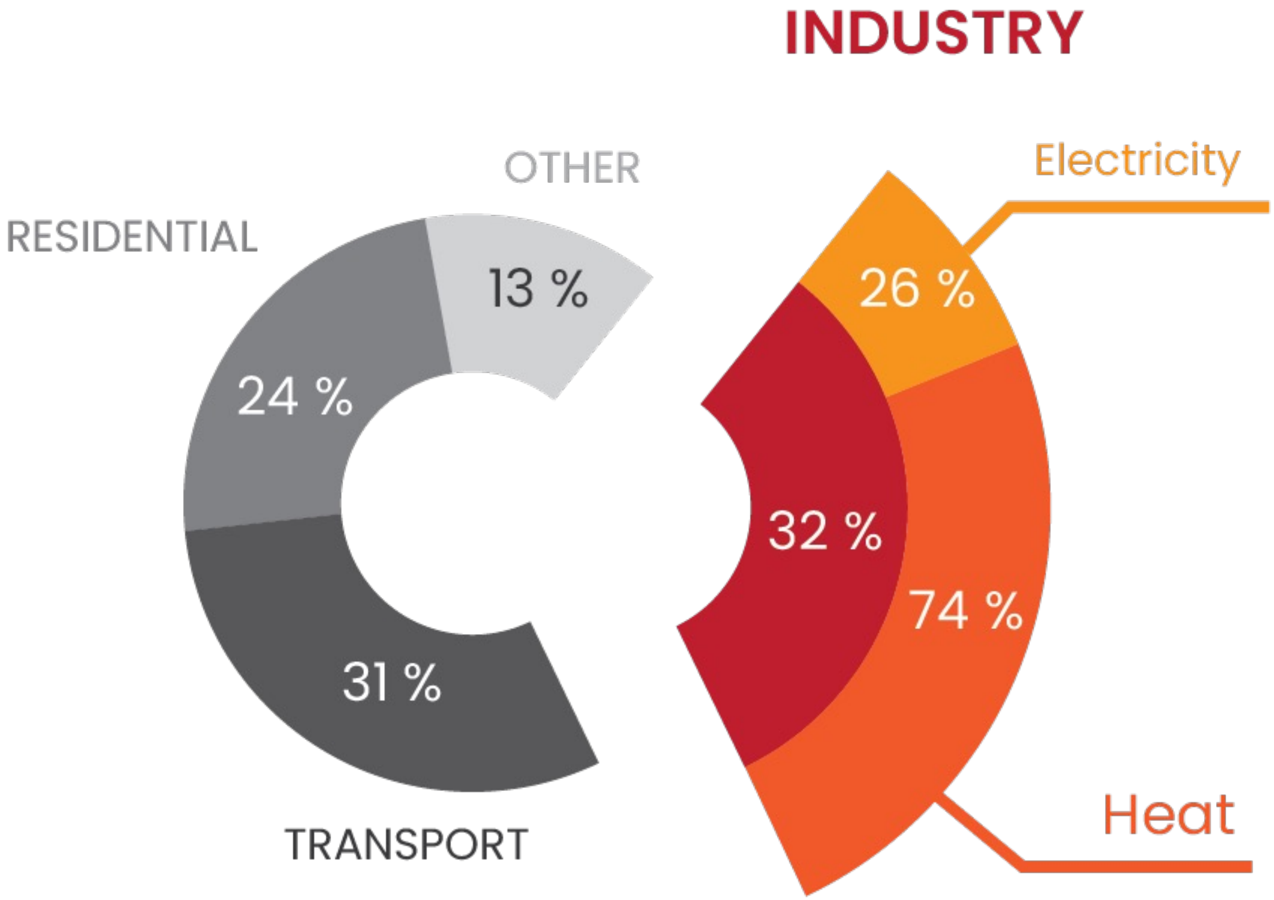
Email: s.pantelis@eera-set.eu

Integrating concentrated solar heat in industrial processes

Miguel Frasquet

CEO, Solatom

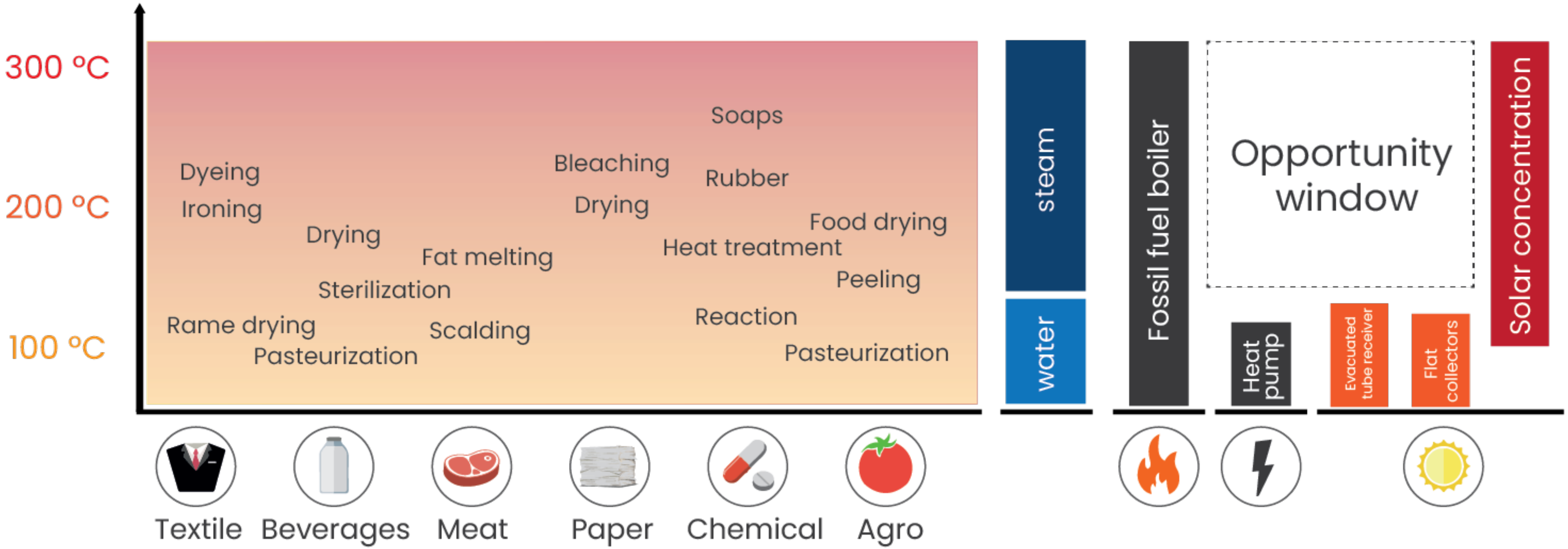
The industry needs to transition towards **carbon neutrality**



Ref: IRENA

92 % of the industry continues to burn fossil fuel

The **opportunity** for CST technologies -> **industrial heat**



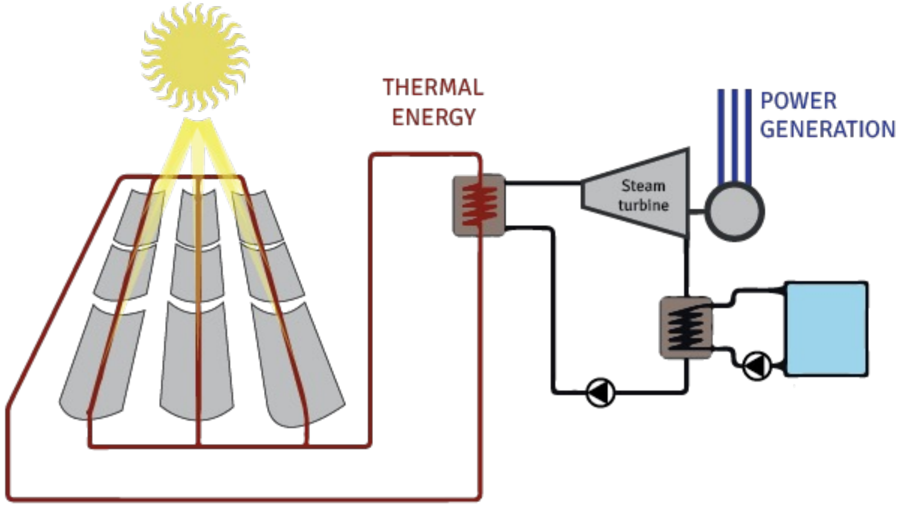
SOLATOM

Pre-assembled linear fresnel module **FLT20**

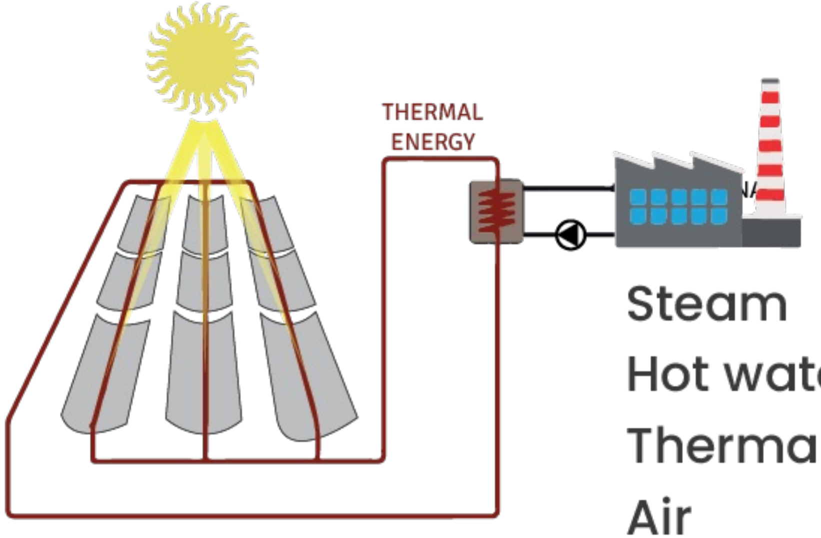
Investors:

- enagas
- bp ventures
- Ship2B
- Katapult Accelerator

CONCENTRATED SOLAR POWER - CSP

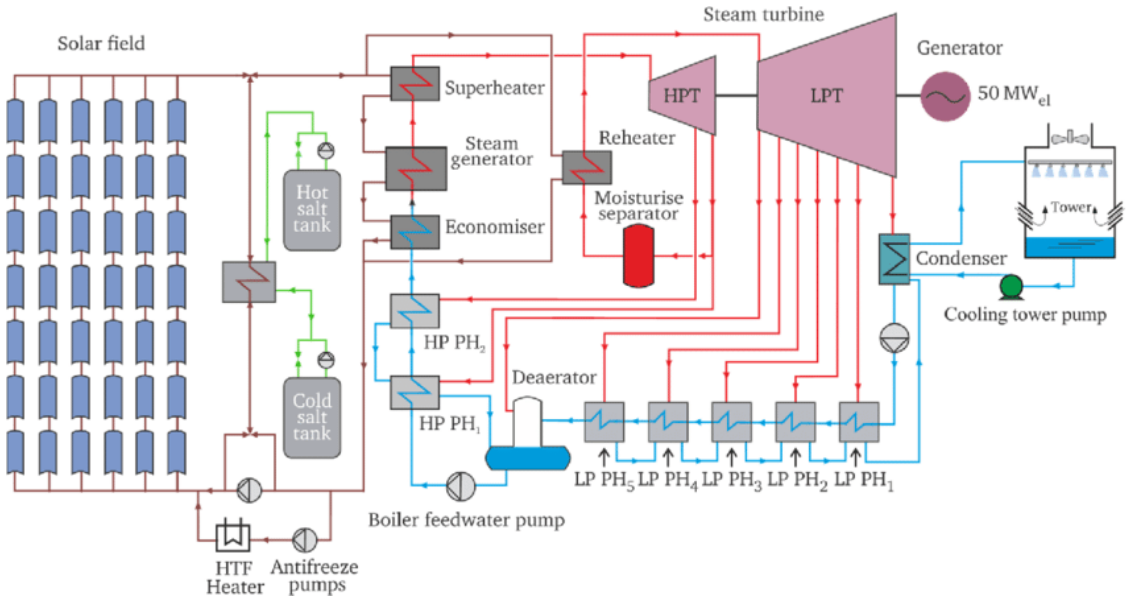


SOLAR HEAT INDUSTRIAL PROCESSES - CST

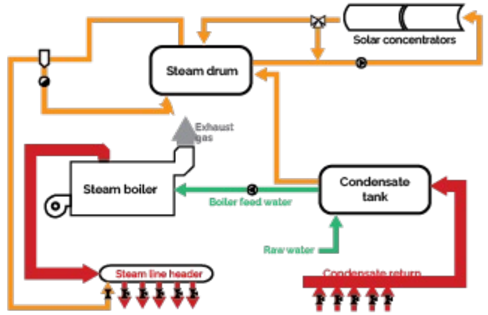


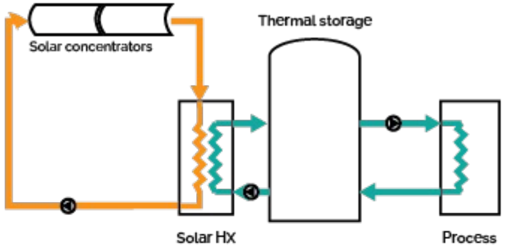
Steam
Hot water
Thermal oil
Air

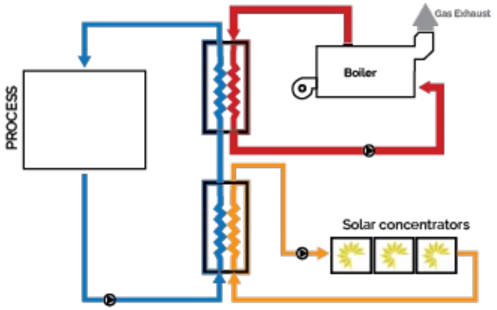
CONCENTRATED SOLAR POWER – CSP



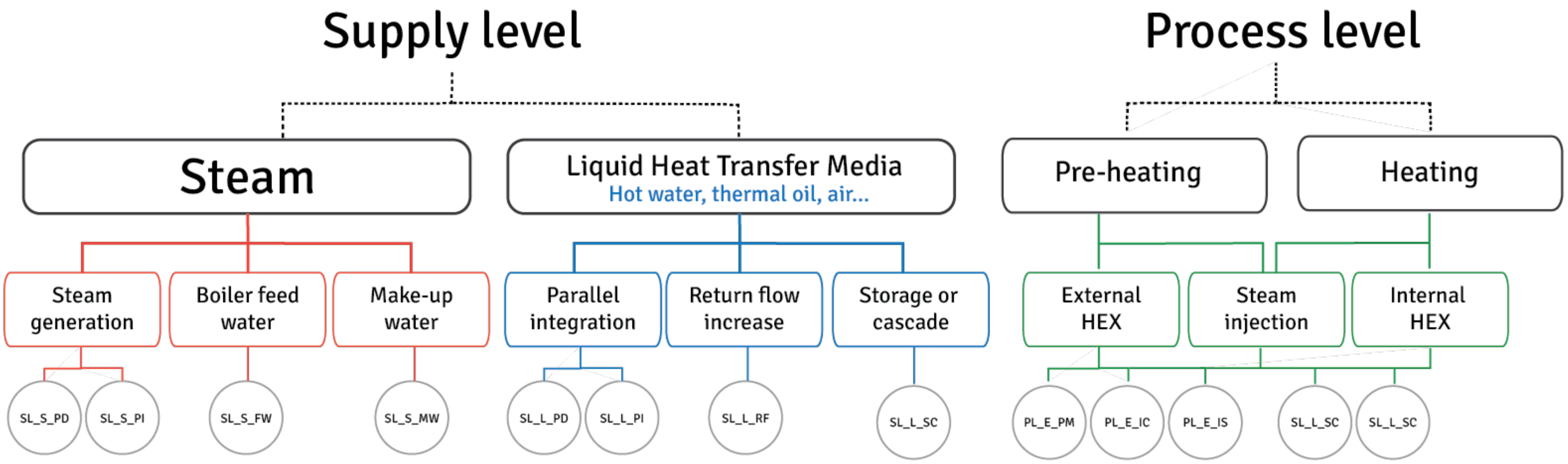
SOLAR HEAT INDUSTRIAL PROCESSES – CST







Integration classification from IEA SHC-Task 49



https://task49.iea-shc.org/Data/Sites/1/publications/150218_IEA%20Task%2049_D_B2_Integration_Guideline-final1.pdf

SOLATOM's solution - **MODULAR DESIGNS**

Direct boiler integration

Direct steam generation SKID

Indirect steam generation SKID


Nordana

Collaboration with research institutes

Advantages

- Brand neutral
- State of the art
- R&D as core business
- International scope

Disadvantages

- Specific interests
- Sometimes lack of commercial experience
- Timing

The steam solution for net zero industries

Miguel Frasquet, PhD
CEO

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www.mfrasquet.com

C/ Pedro Duque, 7, 46022 Valencia. Spain

Tel: (+34) 691 902 188
info@solatom.com - www.solatom.com

SUPEERA Workshop

Almería, November 15th, 2022

Thermal storage integration into STE plants: A Success story from Spain

Eduardo Zarza

CIEMAT-Plataforma Solar de Almería,
Apartado 22, Tabernas, E-04200 Almería
Tfno.: 950387931
E-mail: eduardo.zarza@psa.es

Integration of thermal storage into STE plants

- In Spain there are 19 STE plants, out of a total number of 49 plants, with thermal storage and a total installed power of 919 MWe.

- The integration of thermal storage into STE plants have several benefits:

    - Dispatchability

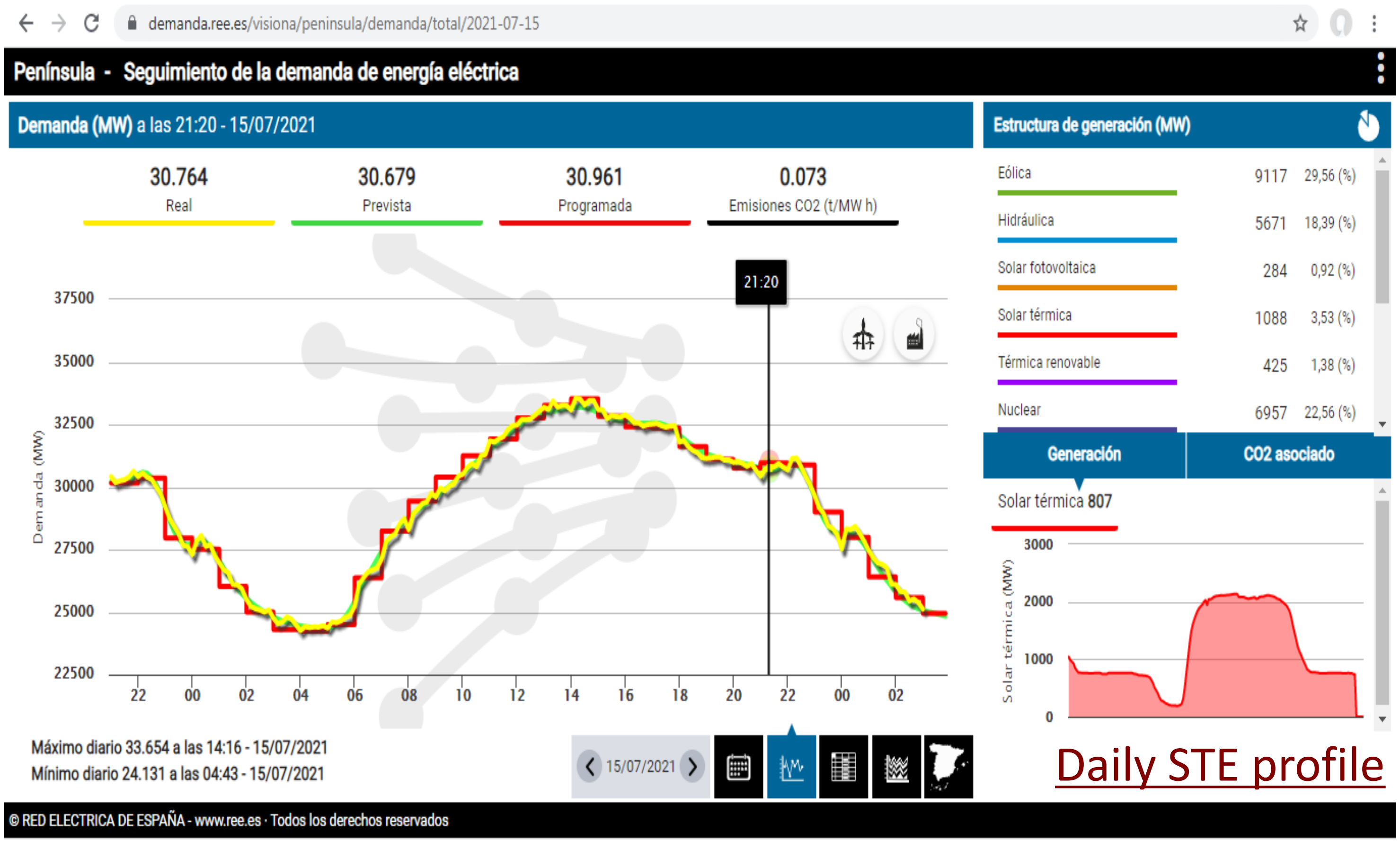
    - Higher yearly efficiency of the plant

    - Enhanced plant control under solar radiation transients

Location of STE plants in Spain

Integration of thermal storage into STE plants

High dispatchability

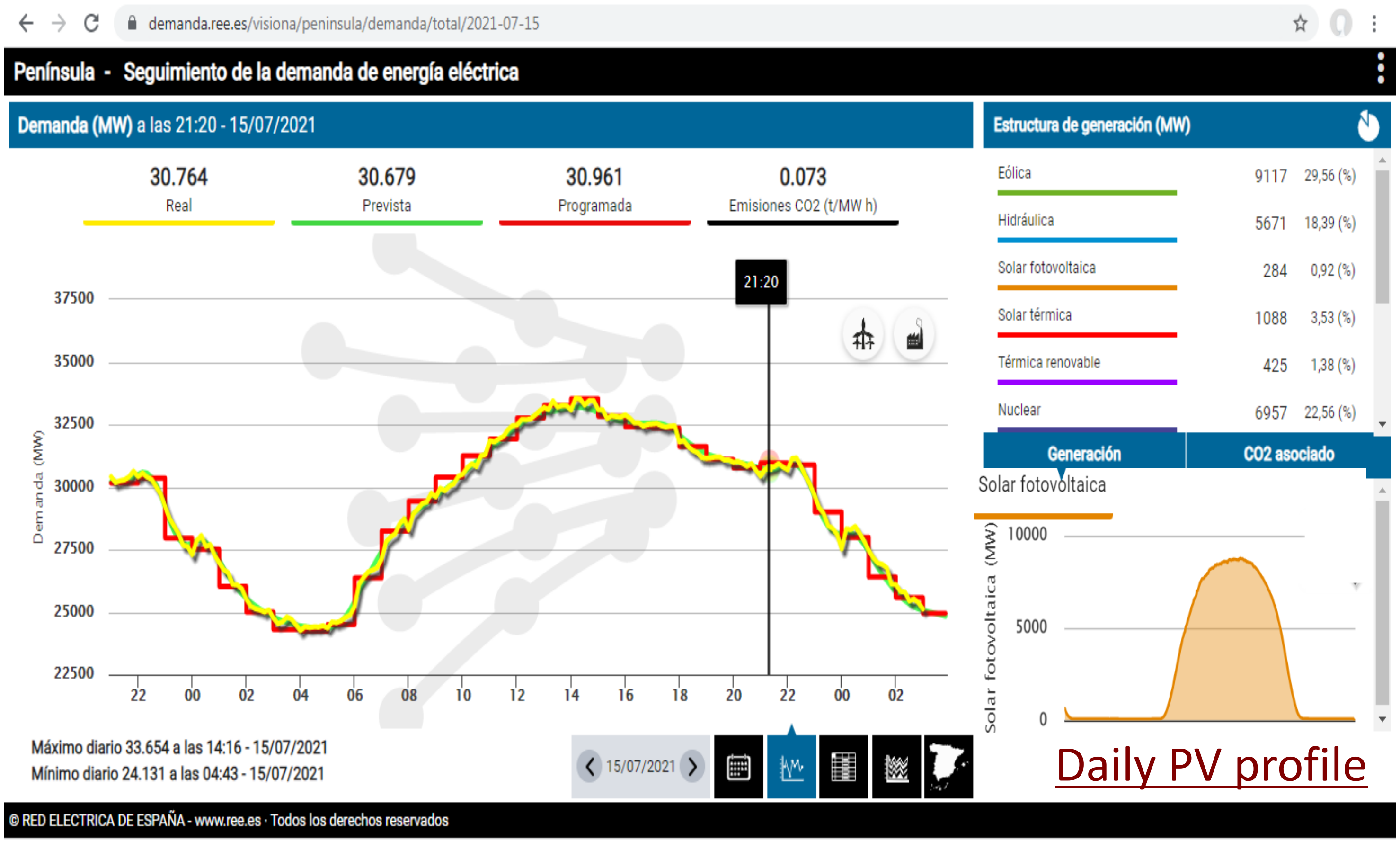


Daily STE profile

(https://demanda.ree.es/visiona/peninsula/demanda/total/)

Integration of thermal storage into STE plants

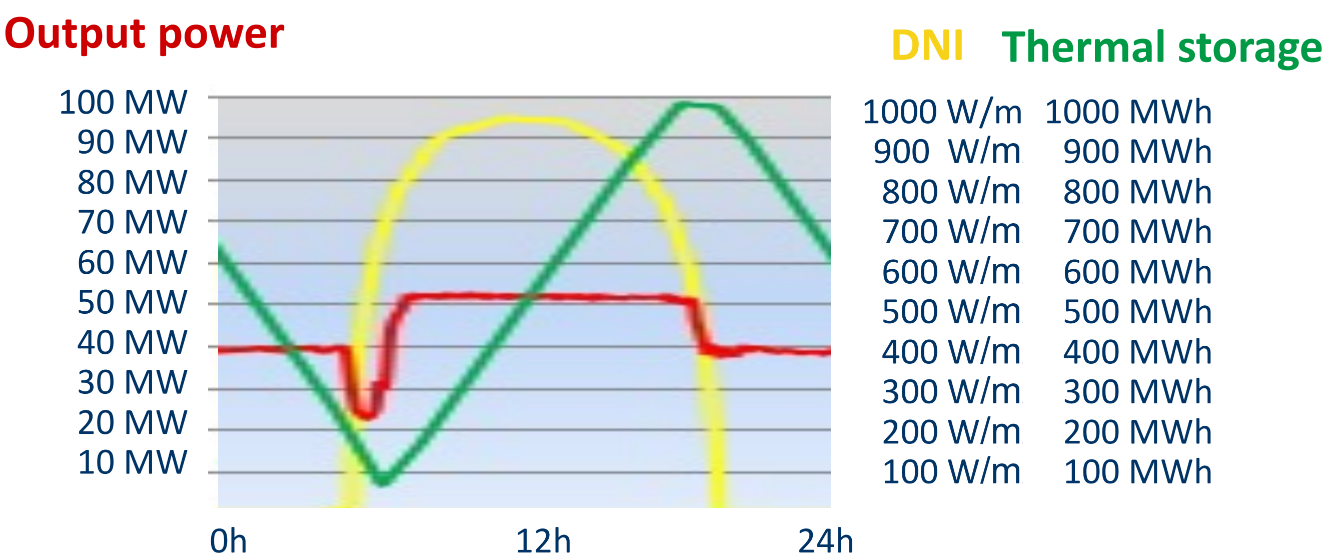
High dispatchability



(https://demanda.ree.es/visiona/peninsula/demanda/total/)

Integration of thermal storage into STE plants

Typical daily operation of a 50 MW STE plant



SUPEERA

SUPEERA Workshop

Thermal storage integration into STE plants: A Success story from Spain

End of slide show

! Thank you ¡

Eduardo Zarza

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SUPEERA

SUPEERA Workshop

Almería, November 15th, 2022

Thermal storage for electricity production

Rocío Bayón
Thermal Energy Storage Unit
PSA-CIEMAT, Madrid

Almacenamiento Térmico de Energía

Dr. Rocío Bayón
rocio.bayon@ciemat.es

GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA E INNOVACIÓN

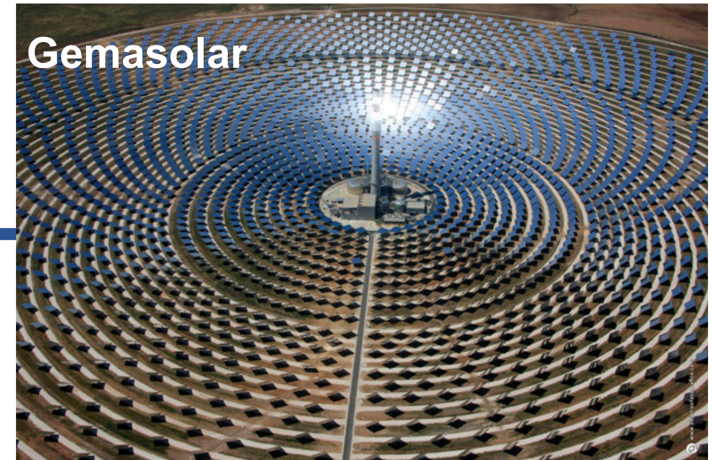
Ciemat
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

PSA

Thermal Energy Storage in commercial CSP plants

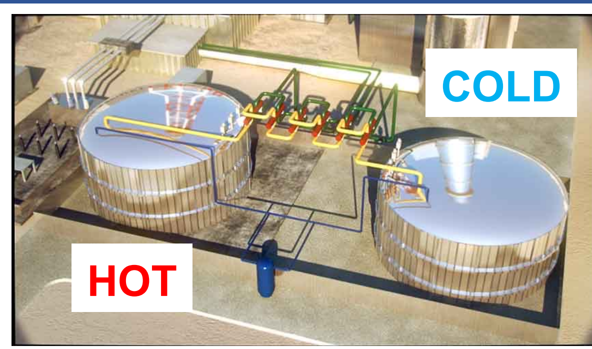
Parabolic trough collectors (PTC)

Central receiver (CR)



- HTF = oil
- **Indirect storage**
- HTF ≠ storage medium
- Cold tank=293º
- **Hot tank= 393ºC**
- Storage capacity = **4-8 h @ nominal power**

Two tanks with MOLTEN Solar salt
wt-60%$NaNO_3$+40%KNO_3



- HTF= solar salt
- **Direct storage**
- HTF = storage medium
- Cold tank=293º
- **Hot tank= 565ºC**
- Storage capacity = **Up to 15 h @ nominal power**

Almacenamiento Térmico de Energía

Thermal Energy Storage in commercial CSP plants with direct steam generation (DSG)

Central receiver (CR)

Linear Fresnel (LFC)

Steam drums/Ruths accumulators

- HTF= water
- **Direct storage**
- Storage capacity = **0,5-1 h @ power below nominal**
- **Only for transients**

Some new LFC plants in China

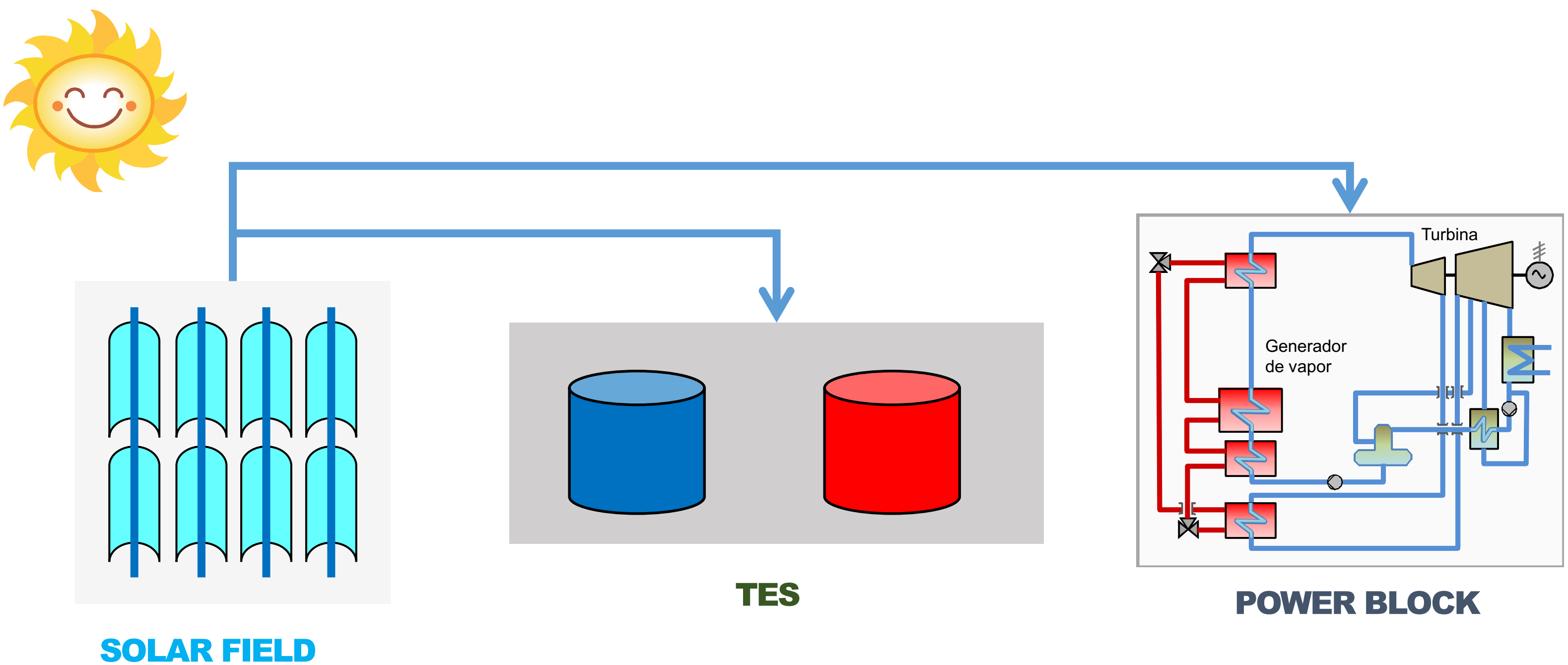
1
- HTF= water + storage = concrete
- Storage capacity = 14 h

2
- HTF and storage = MS
- Storage capacity = 15-16 h

Almacenamiento Térmico de Energía

CSP plant + TES how does it work?

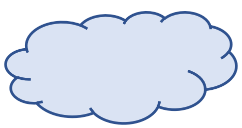
WHEN THERE IS SOLAR RADIATION

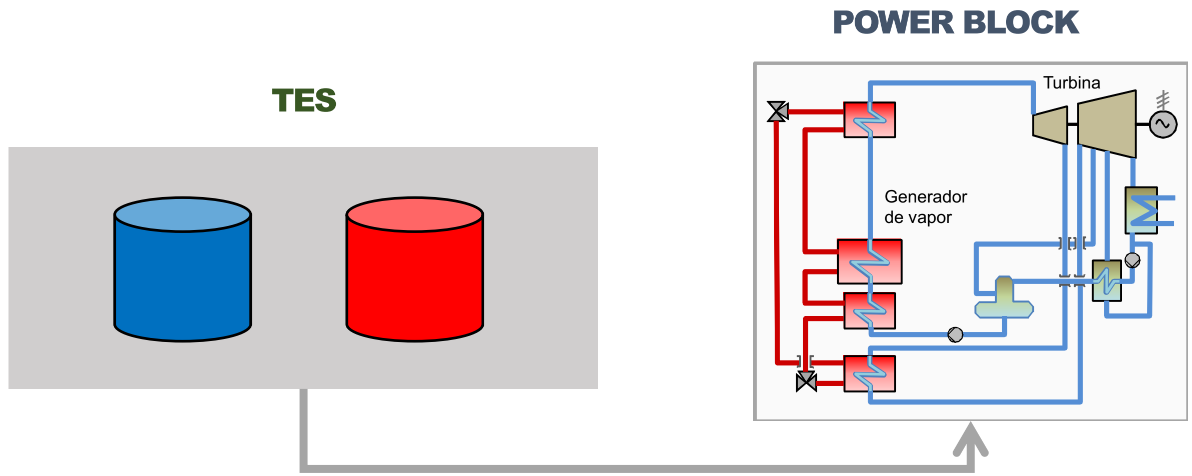


- **Solar field** produces **electricity** and **charges** the TES
- Molten Salt goes from cold to hot tank

CSP plant + TES how does it work?

WHEN THERE IS NO SOLAR RADIATION

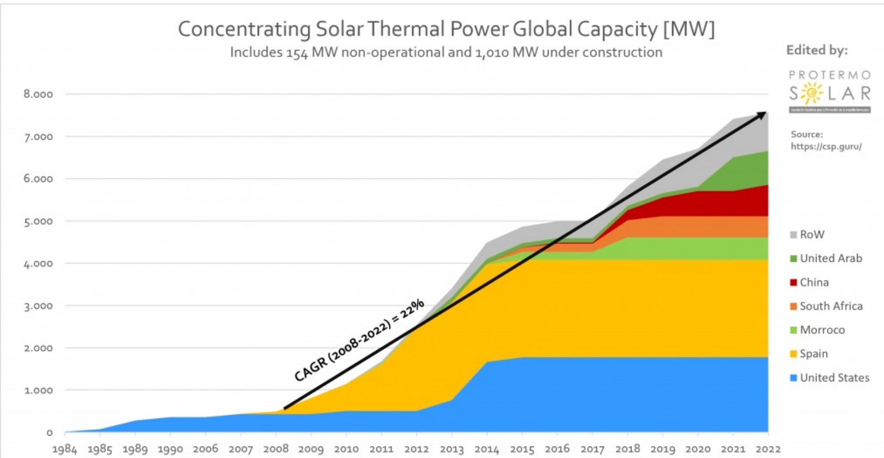


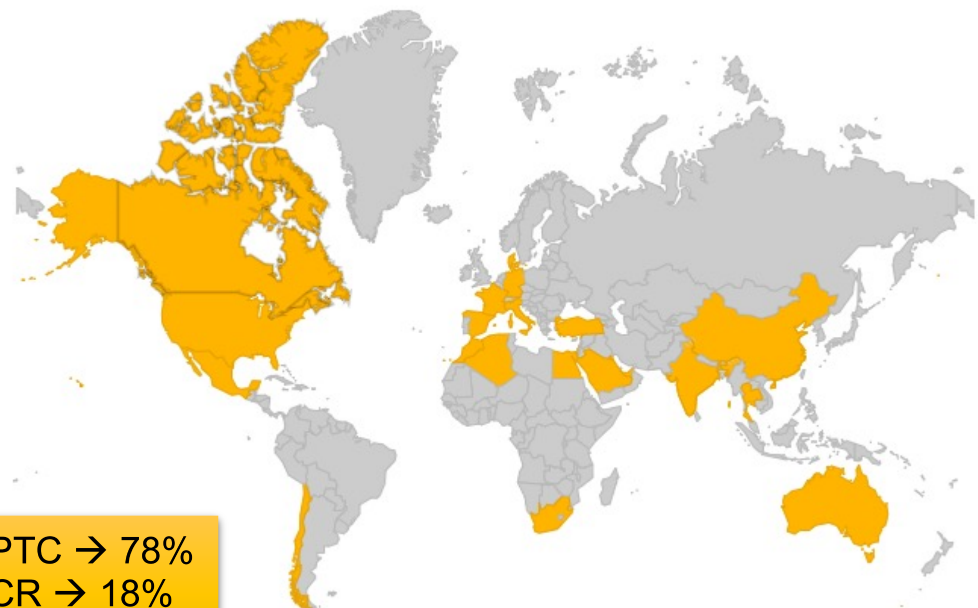


- Molten Salt goes from hot to cold tank
- **TES** produces **electricity**

CSP plants in the world

https://www.protermosolar.com/proyectos-termosolares/proyectos-en-el-exterior/





Numbers for 2020

- **115** plants in operation ➔ 6397 MWe
- **42** plants with **TES** (300 h @ nominal power →**13.434** MWh)

PTC → 78%
CR → 18%
LF → 4%

- ○ < 1h → Ruths→ HTF=water
- ○ ~ 2-3 h → Demonstration projects (Na, concrete, MS)
- ○ > 4 h → MS (direct or indirect)

https://solarpaces.nrel.gov/by-country

Almacenamiento Térmico de Energía

Thermal storage with molten solar salt

Energy density	280 MJ/m^3 (ΔT=100 ºC) 770 MJ/m^3 (ΔT=275 ºC)
High capacity	Up to 15 h @ nominal power
Lifetime	25-30 years
Discharge mode	Grid synchronic
Commercially assessed?	Yes → TRL 9
Does it have to be linked to a CSP plant?	No

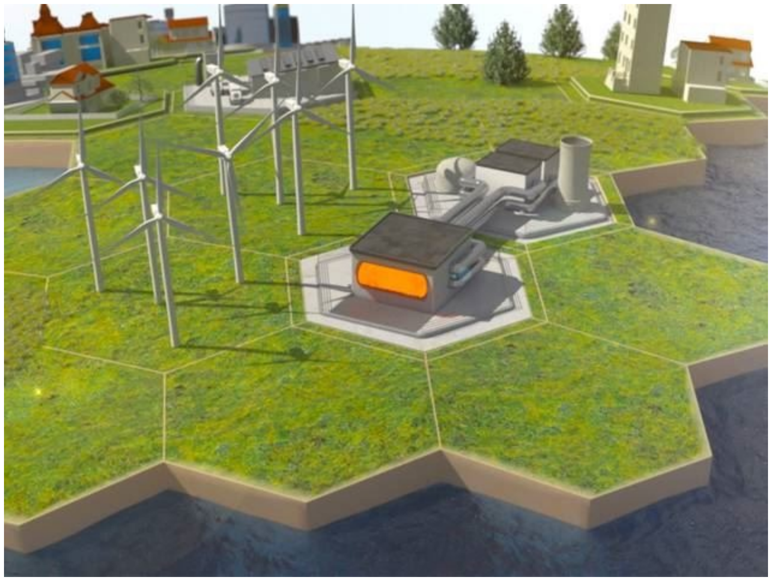
Almacenamiento Térmico de Energía

Other possibilities for thermal storage in the electricity mix

Store electricity surplus as thermal energy

Heat storage power plants

Approach of SIEMENS-GAMESA

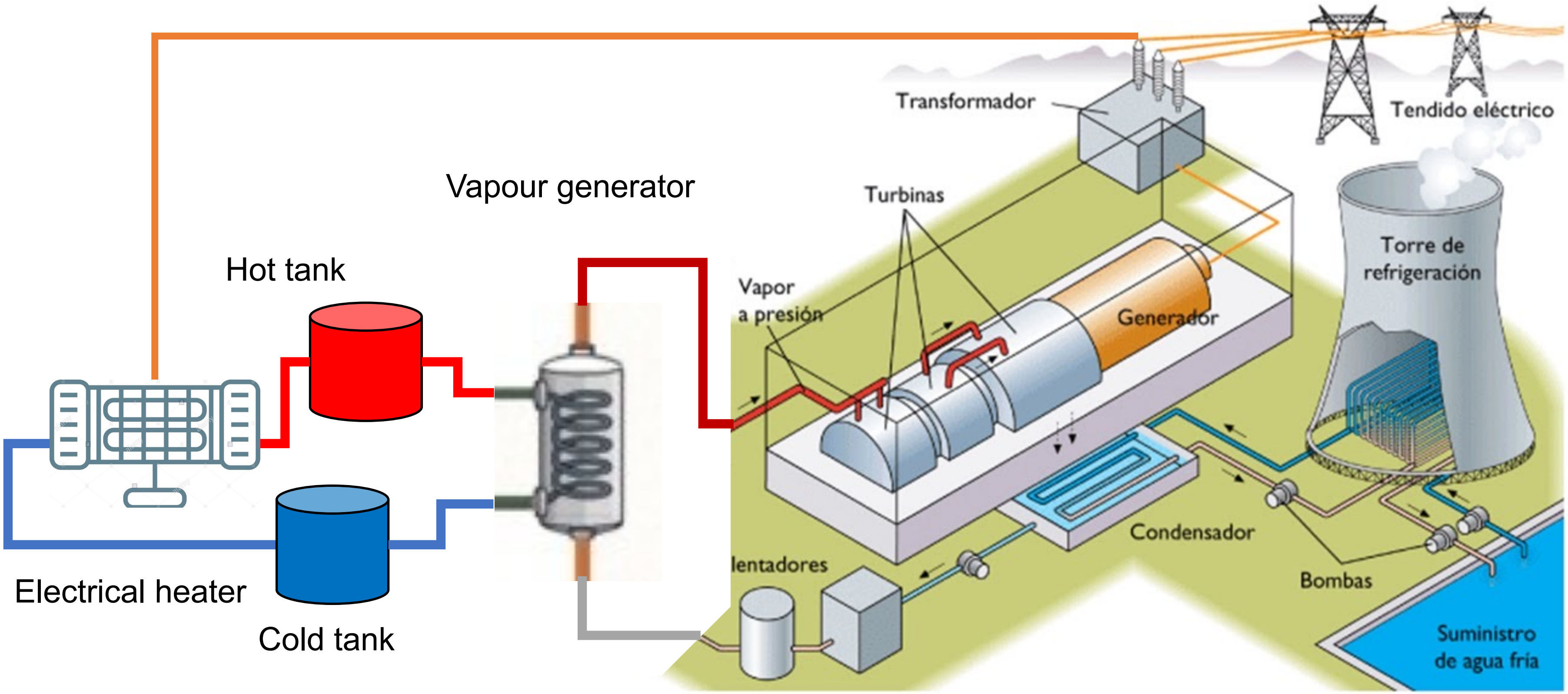


https://balkangreenenergynews.com/siemens-gamesa-unveils-worlds-first-electrothermal-energy-storage-system/

- 1000 Tm volcanic rocks
- HTF: air up to 750 ºC
- Electricity is regenerated in a gas turbine
- 130 MWh for one week
- Short term goal ➔Storage of several GWh

Implementation in dismantled coal power plants

TRL 1-2



THANKS FOR YOUR ATTENTION!

Digitization to accelerate CSP development

Considerations for an open discussion

Cristóbal Villasante | Tekniker | 15/11/2022

Tekniker
MEMBER OF BASQUE RESEARCH & TECHNOLOGY ALLIANCE

WHO WE ARE

R&D Centre
(not-for-profit Private Foundation) |
Applied research spanning 41 years

Our mission is to deliver growth and wellbeing to society at large via R&D&I and to further the competitiveness of the business fabric in a sustainable manner

Specialised in **Manufacturing**

TOTAL REVENUE

23.875.000 €

2021 PROVISIONAL DATA

PEOPLE

283

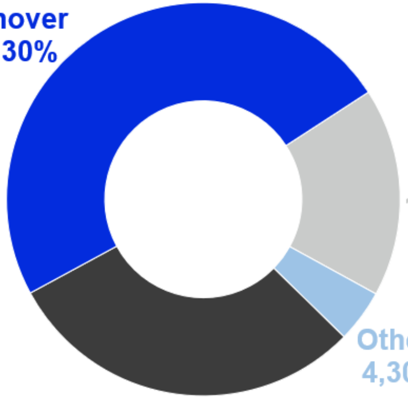
37% Women
63% Men

PhD resources
58 doctors
27 doctoral students

82% university degrees

2021 DATA

R&D REVENUES | 2021



2021 PROVISIONAL DATA

EUROPEAN PROJECTS
History

268
PROJECTS

33 YEARS
OF EXPERIENCE

23 %
LED PROJECTS

4,3 M€
ANNUAL AVERAGE INCOME

Distinction
PUBLICATIONS

62
2021 INDEXED PUBLICATIONS

66 %
SCIENTIFIC PUBLICATIONS IN Q1

2021 DATA

ADVANCED MANUFACTURING

Optimising and developing **new processes** to deliver new features and improve **manufacturability, precision and, ultimately, competitiveness.**

A basic knowledge of the **materials** and a command of cutting-edge technologies such **as laser and white room processes**, including the development of high-added value **mechatronic products and process industrialisation & optimisation.**

SURFACE ENGINEERING

Improving material properties to incorporate more functionalities.

Materials that interact with each other and the environment through the **surface** that do not only allow us to create **new products,** but **also extend component life cycles** to develop and implement new **surface solutions** at an industrial scale.

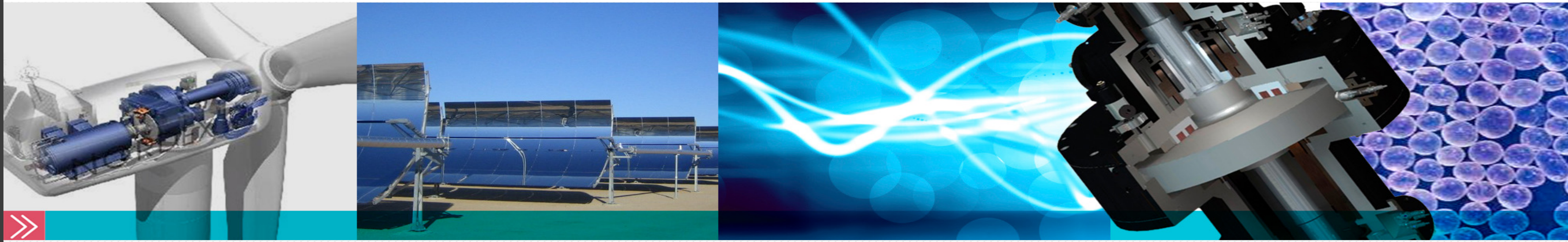
EICT FOR PRODUCTION

Advances in the fields of **ICTs, control, automation and electronics** to make products "smart" when interacting with sensors, actuators, components, machines, robots and other types of systems.

PRODUCT ENGINEERING

Accelerating product development cycles for our customers, from the moment ideas are generated until they are launched into the market by means of **technological assets** to facilitate technology transfers and reduce technical-economic risks.

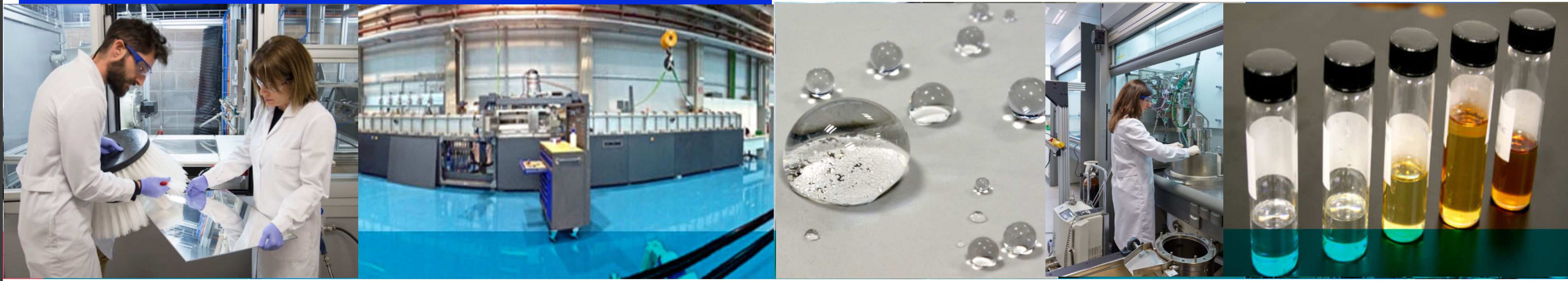
Facilitators in the **integration of technologies belonging to different disciplines,** integrating **regulatory requirements** and/or specific needs to be met to **access the market.**



GENERATION	ENERGY MANAGEMENT	ENERGY USE & EFFICIENCY
Concentrated Solar Power	Heat Recovery	Industrial Processes and residential use
WIND	Energy Storage (Heat & electricity)	Mobility
Photovoltaics	H2 Generation	H2 Use

Heat, Power & e-fuels

MATERIALS



ADVANCED COATINGS

- Advanced coatings for:
  - Receivers (selective and anti-reflective coatings)
  - Reflectors (anti-soiling and super-reflective surfaces)
- Development of production means and procedures: PVD, Solgel, …

  Real tubes of up to 4m. can be coated
- Lab for characterisation of materials and coatings (ENAC certified)
- Accelerated testing of mirrors and coatings (cleaning processes effect)

HEAT TRANSFER and THERMAL STORAGE MEDIA

- Heat Transfer Fluids (HTFs):
  - Development, characterization and monitoring
  - Nanotechnology for the improvement of key parameters
- Molten Salts:
  - Structural and chemical analysis
  - Degradation analysis
  - Nanotechnology for performance improvement
- Accelerated degradation tests

DESIGN and VALIDATION

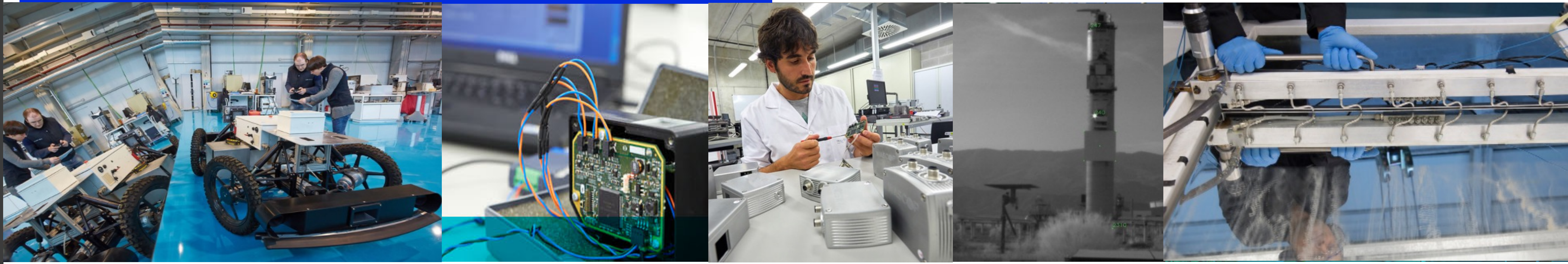
ADVANCED SYSTEMS and COMPONENTS

- New designs of heliostats (SHORT)
  - Global mechatronic design
  - New tracking concepts
  - Sensors and self-calibrating solutions
- New CSP power plant concepts (MOSAIC).
- Customized systems for control and verification of assembly process
- Geometric characterization
- Failure Diagnostic Service

THERMOHYDRAULIC SYSTEMS

- Improved thermal designs
  - Modelling and simulation
  - Control design and implementation
  - Optimal management
- Test-bench for components testing up to 350ºC and 20 bar.

OPERATION and MAINTENANCE



SMARTCSP

Industry 4.0 approach for an effective CSP deployment, Operation and Maintenance

- Ad hoc sensors (reflectivity/dust, tilt, wind, …)
- Sensors integration (Smartmirror patented by TEKNIKER-CENER)
- Automatic inspection on field (receivers, reflectors, leaks)
- Big Data Analysis.
- Advanced control (predictive, MPC)

DEVELOPMENTS for IMPROVED O&M

- New systems for the automatic calibration of heliostats
- Low water consumption cleaning systems
- Geometric characterization of facets and collectors.
- Predictive maintenance based on the analysis of HTFs
- Pumping systems analysis and optimization for self-consumption reduction

What should digitalization bring to CSP/CST?

The CSP/CST sector should learn from other sectors and benefit from experience in the application of ICT (Information, Communication and Sensing Technologies) in mature industrial fields such as automotive, communication or manufacturing.

Lean manufacturing can also be a complementary and necessary area of development in order to deliver Plug and Play solutions.

Bringing tasks from the field to more controlled environments.

BAD NEWS ☹

- **CSP industry behaves isolated**
  - CSP is not incorporating innovations included in other industrial sectors
- **CSP has neither the size nor the investment capacity of other industries**

GOOD NEWS ☺

- **This can and should be changed**
- **Need for dispatchable green energy is clear**
- **Potential market is huge**
- **Arriving late can have some advantages:**
  - We can take advantage of the developments already made by others
  - Only a wise integration/use is needed

We don't need to do all the same path, but we can jump many steps

E.g. fixed phone line networks are expensive and will never be installed in many countries, but they will be directly incorporated into mobile communications.

What should digitalization bring to CSP/CST?

LCOE REDUCTION	CONFIDENCE	SYSTEM INTEGRATION
CAPEX ↓ OPEX (O&M) ↓ YIELD ↑	RELIABILITY ↑ QUALITY CONTROL ↑ • COMMISIONING • OPERATION UNCERTAINTY ↓ • FINANTIAL COSTS ↓ • SAFETY MARGINS ↓ • OPTIMAL OPERATION	DISPATCHABILITY ↑ ANCILLARY SERVICES & PARTICIPATION TO THE ELECTRICITY MARKET ↑ WIND/PV CURTAILMENT ↓ OPTIMIZED CSP/PV PLANTs RELIABLE HEAT SUPPLY

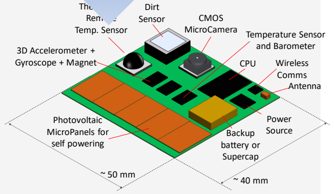
Digitalisation should simplify and reduce hardware production, installation, operation and maintenance costs while increasing energy generation, reliability and manageability using sensors, software, data analytics, artificial intelligence and cost-effective computing power.

LCOE REDUCTION: Illustrative case study: Heliostats

CAPEX

RELAX REQUIREMENTS:

LONG-TERM STABILITY ↓

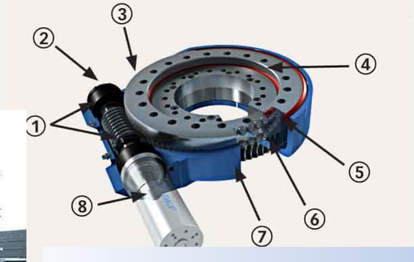


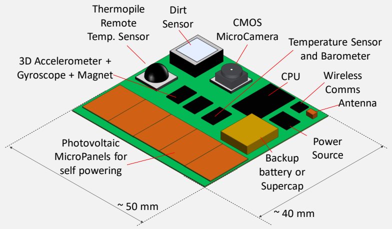
IMPLEMENTATION TIME/COST↓

CIVIL WORKS ↓

CHEAPER COMPONENTS (DRIVES, STRUCTURES, ETC.)

Increasingly expensive steel and manufacturing costs are replaced by intelligence thanks to increasingly cheaper electronics, software and computation.





SHORTER AND CHEAPER IMPLEMENTATION (Plug-and-Play)

Complete systems integrated and calibrated in the factory under controlled conditions
Smart calibration reduces installation times and costs by automatic & parallel calibration (critical process for heliostats)

AVOID CIVIL WORKS AND ELIMINATE COMPONENTS

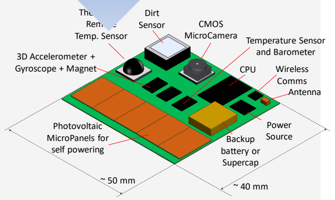
Wireless control, sensors, communication and power supply avoid trenches, wiring, etc

LCOE REDUCTION: Illustrative case study: Heliostats

CAPEX

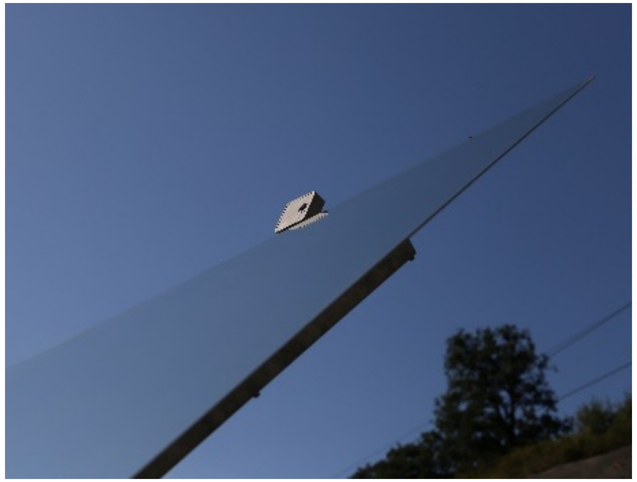
RELAX REQUIREMENTS:

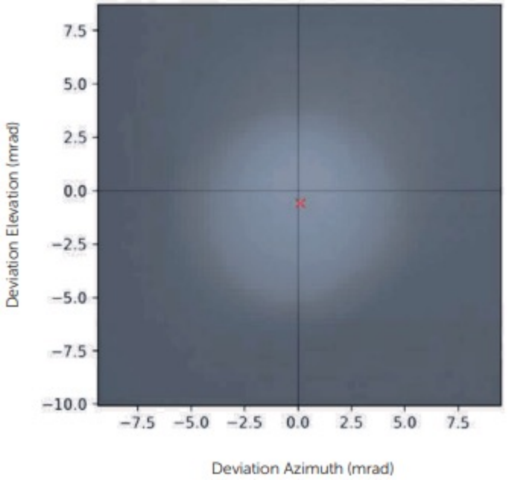
LONG-TERM STABILITY ↓



IMPLEMENTATION TIME/COST↓

CIVIL WORKS ↓





Tekniker MEMBER OF BASQUE RESEARCH & TECHNOLOGY ALLIANCE

CENER CENTRO NACIONAL DE ENERGÍAS RENOVABLES

EASY: Innovative small size heliostat for substantial cost reduction

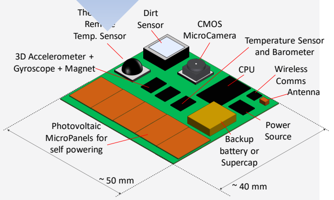
SHORT: Scalable HeliOstat calibRation sysTem

LCOE REDUCTION: Illustrative case study: Heliostats

CAPEX

RELAX REQUIREMENTS:

LONG-TERM STABILITY ↓



IMPLEMENTATION TIME/COST↓

CIVIL WORKS ↓

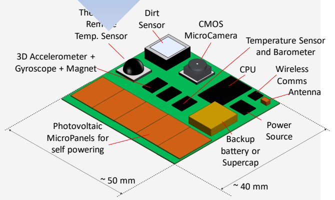
Heliogen

LCOE REDUCTION: Digitalization contribution

CAPEX

RELAX REQUIREMENTS:

LONG-TERM STABILITY ↓



IMPLEMENTATION TIME/COST↓

CIVIL WORKS ↓

OPEX

MORE SENSORS (ON-LINE MEASUREMENTS)

& BETTER CONTROL AND DATA ANALYSIS FOR:

- SELF-DIAGNOSIS
- AUTOMATIC/ RELIABLE OPERATION
- OPT. MAINTENANCE SCHEDULING
- LESS INSPECTION AND MAINTENANCE WORK
- …

YIELD

MORE SENSORS (ON-LINE MEASUREMENTS)

& BETTER CONTROL AND DATA ANALYSIS FOR:

- SELF-CALIBRATION
- OPT. OPERATION
- MORE OPERATING HOURS
- MORE POWER OUTPUT
- …

Initiative for Global Leadership in Concentrated Solar Power

—

Updated Implementation Plan

March 2022 (Original version – November 2017)

AREA OF ACTIVITY nº 7: CROSS-CUTTING ISSUES

R&I Activity 7.1: Digitalization of CSP plants for a more efficient monitoring, operation and maintenance

Title: Digitalization of CSP plants for a more efficient Monitoring, Operation and Maintenance.	
Previous related research activities: STAGE-STE (2014-2018), Solarpaces Task II, CAPTure (2015-2020), PHOTON (2017-2019), SOLWARIS (2018-2021), …	Achievements since 2017: - Guidelines - Different developments for solving particular issues up to TRL6
Targets: - Reduce O&M Cost - increase reliability and lifetime - Boost performance along lifetime of the plant - Tailored systems for plant monitoring.	Monitoring mechanism: - Validation of systems in already existing plants - Integration of certain developments in the new plants. - Demonstrations at commercial scale
Description: In order for CSP technology to be deployed on a massive scale, it must guarantee a high level of reliability that gives investors' confidence. In addition to capital cost, solar thermal power plants today still need to reduce operating and maintenance costs while increasing reliability and performance. This is the only way to gain the confidence of developers and investors in the technology and to ensure that CSP plays the key role in the energy transition that it must play, increasing the flexibility of the energy system and boosting the share of renewables (including non-dispatchable ones such as PV and wind) thanks to its dispatchability and energy storage capacity. Likewise, the plants must be much more automatic and easy to operate, taking advantage of the full potential of sensor technology, automation and IoT. As other industries have done, by "going digital," the CSP can increase efficiency, reduce costs, optimize the use of resources (e.g., water) and develop customized applications for easy and reliable operation of the CSP plants. All systems shall be demonstrated at pre-commercial scale through their implementation in commercial CSP plants.	
TRL:5-8	
Total budget required: 12 M€	

Expected deliverables: Development of the new generation of Characterization, Monitoring, Inspection, Maintenance and Control systems easy to integrate in existing and new CSP plants. Based on the experience gained in the last two decades, this should include the following developments, reaching a pre-commercial state: - Cost-effective integration of sensors into components and systems to obtain collectors and heliostats with self-diagnostic, self-calibration and autonomous operation capabilities. - On-line measurement of concentrated solar flux, receiver temperature and atmospheric attenuation for tower plants - On-site diagnostics and optical characterization of collectors and heliostats. - Field diagnosis of CCP receivers (leakage detection, ball joint leakages, mirror and glass cover breakage, H2 permeation, etc.) - Advanced cleaning systems and anti-soiling treatments for mirrors - Automatic and continuous monitoring of HTF degradation as well as improved treatments for HTF treatment and recovery. - Introduce AI techniques for early fault diagnosis and preventive maintenance in addition to improved operation. - Boost intelligence and integration of solar components for an improved O&M - Optimal energy management strategies and control for integrating CSP systems in hybrid power plants (e.g., CSP and CPV). - Advanced control for boosting the use of CSP-TES systems as flexible generation resource able to provide ancillary services to the power system. - Digitalization of CSP plants integrated with storage systems (smart energy meters + communication devices + intelligent control and management tools a strategies) for improving solar generation dispatchability and participation to the electricity market. The developments should reach a pre-commercial state.		Timeline: 3-5 years
Party/Parties: Spain, Germany, Denmark, Belgium, Cyprus, Israel, Turkey, Italy, Portugal, Greece, France	Implementation instruments: - Horizon Europe Programme - Clean Energy Transition Partnership - Contributions from European CSP/STE companies - Greek next R&D Framework Programme (2021-2027) (under preparation, expected to be published not before mid-2022) - In-kind contribution from research and partner organizations	Indicative financing contribution: N/A

Thank you

Suggestions?

Questions?

Proposals?

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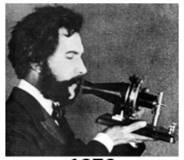
Tel: +34 943 20 67 44
www.tekniker.es

Cristóbal Villasante
cristobal.villasante@tekniker.es

Back-up slides

HISTORICAL EVOLUTION OF TELECOMUNICATION



1876
Graham Bell creates
the telephone

1910
First Telephone in Car?

1922
The First Car Radios
Are Introduced

1973
The First
Mobile Car Phone

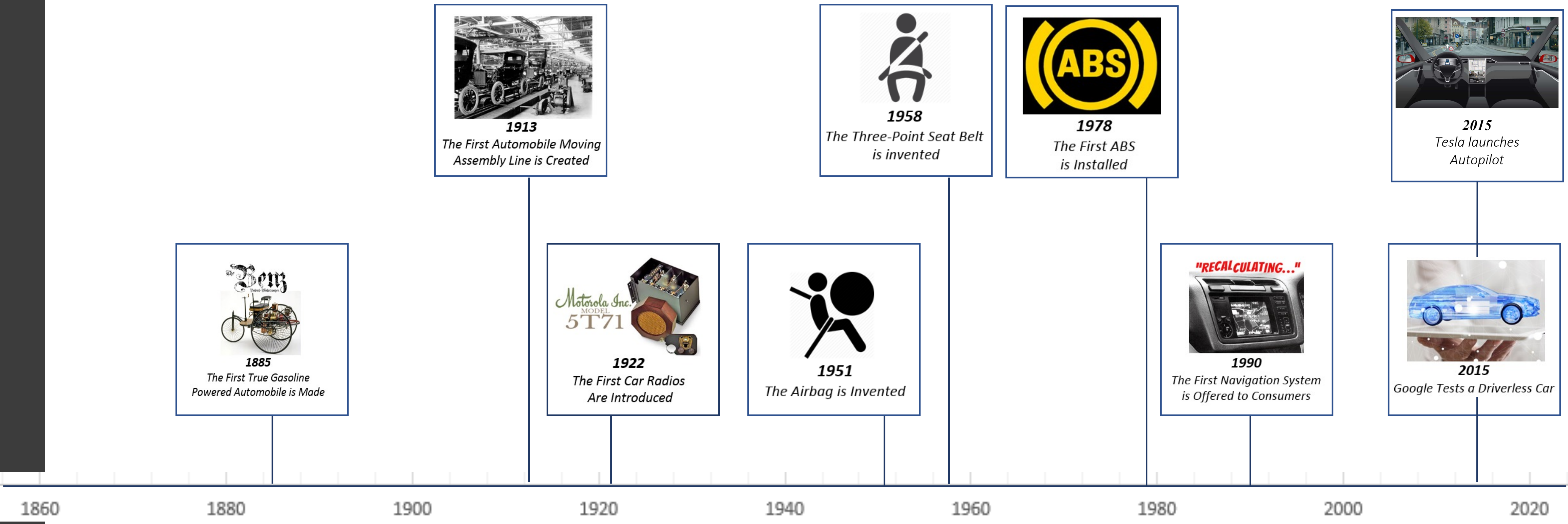
1999
Phones with Internet Connection

2000
Over 100 Million Mobile Phones

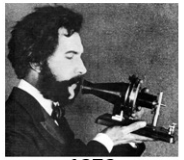
2012
6 Billion Mobile Phones
(87% of word population)

1860 1880 1900 1920 1940 1960 1980 2000 2020

HISTORICAL EVOLUTION OF AUTOMOTIVE INDUSTRY



HISTORICAL EVOLUTION OF CSP INDUSTRY



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The First True Gasoline Powered Automobile is Made

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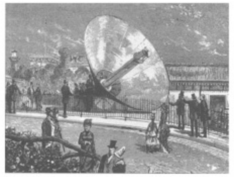
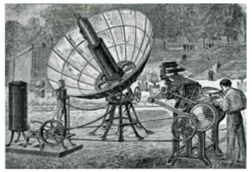


1878
Mouchot's engine at the Universal Exhibition in Paris

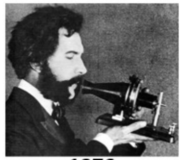


1882
Abel Pifre solar press at the Jardin des Tuileries in Paris

1901
Solar Steam Engine (water pumping near LA)

1913
CSP Experimental Plant Built by Frank Shuman (Cairo)

HISTORICAL EVOLUTION OF CSP INDUSTRY



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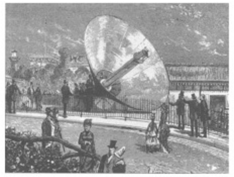
2007-2008
PS10, Andasol (Spain) and Nevada Solar One (US) re-launch CSP

2018
Noor II & Noor III Commissioned
World CSP Capacity reaches 5GW

1860 1880 1900 1920 1940 1960 1980 2000 2020



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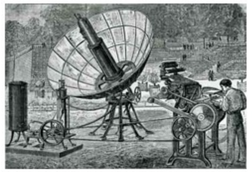

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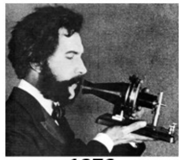
CSP Experimental Plant Built by Frank Shuman (Cairo)

1984-1990
354 MW SEGS Solar Complex, California

1981
Solar One Completed
1995
Converted into Solar Two



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Has CSP evolved as much as others?

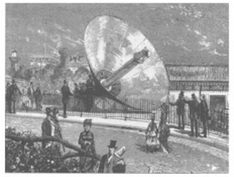
Do we build, commission and operate the plants in a different way than 80´s?

Did we take advantage of ICT as other industries does?

2012
6 Billion Mobile Phones (87% of word population)

2015
Google Tests a Driverless Car

1860 1880 1900 1920 1940 1960 1980 2000 2020



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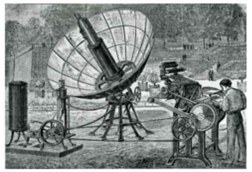

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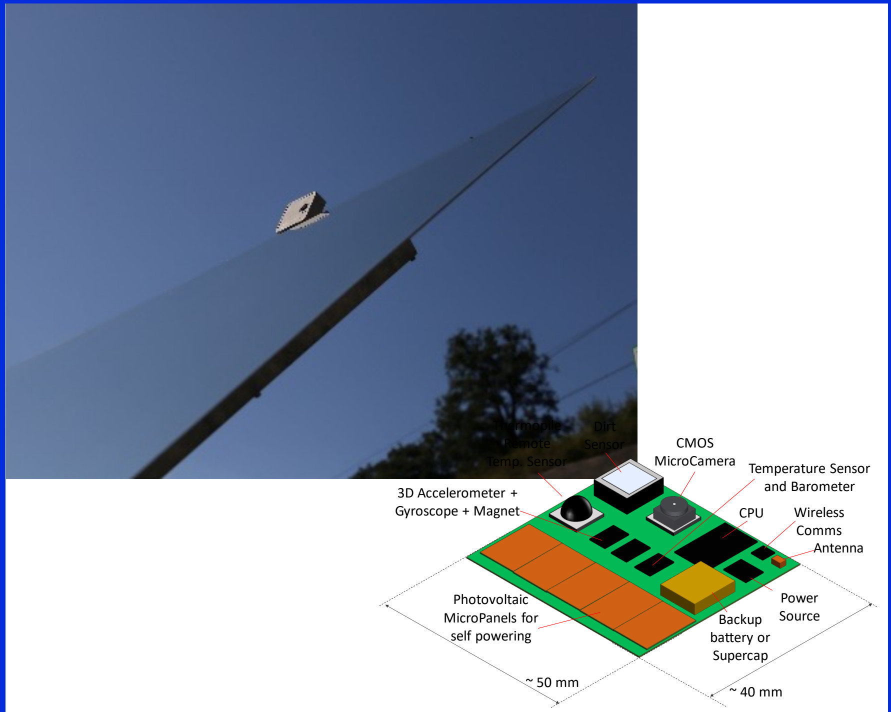
What should digitalization bring to CSP/CST?

LCOE REDUCTION

CONFIDENCE

SYSTEM INTEGRATION

CSP Digitalization

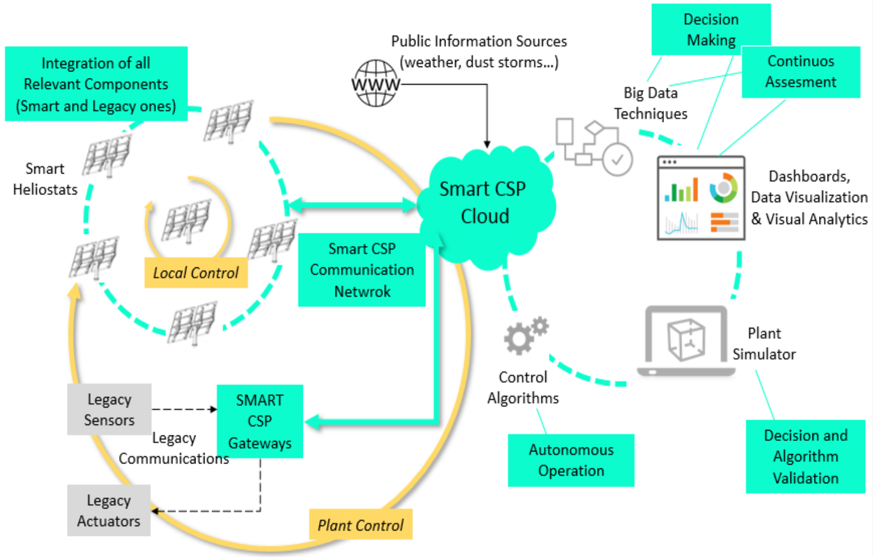


SMART COMPONENTS (Plug and Play)

Components or systems incorporating sensors, controllers, communication systems, etc. for self-diagnosis, self-calibration, autonomous operation, collaborative operation, etc.

New functionalities (including calibration, connectivity, etc.) from the production line

Smartmirror as an exemplary case



SMARTCSP PLANT

Integrate all relevant actors

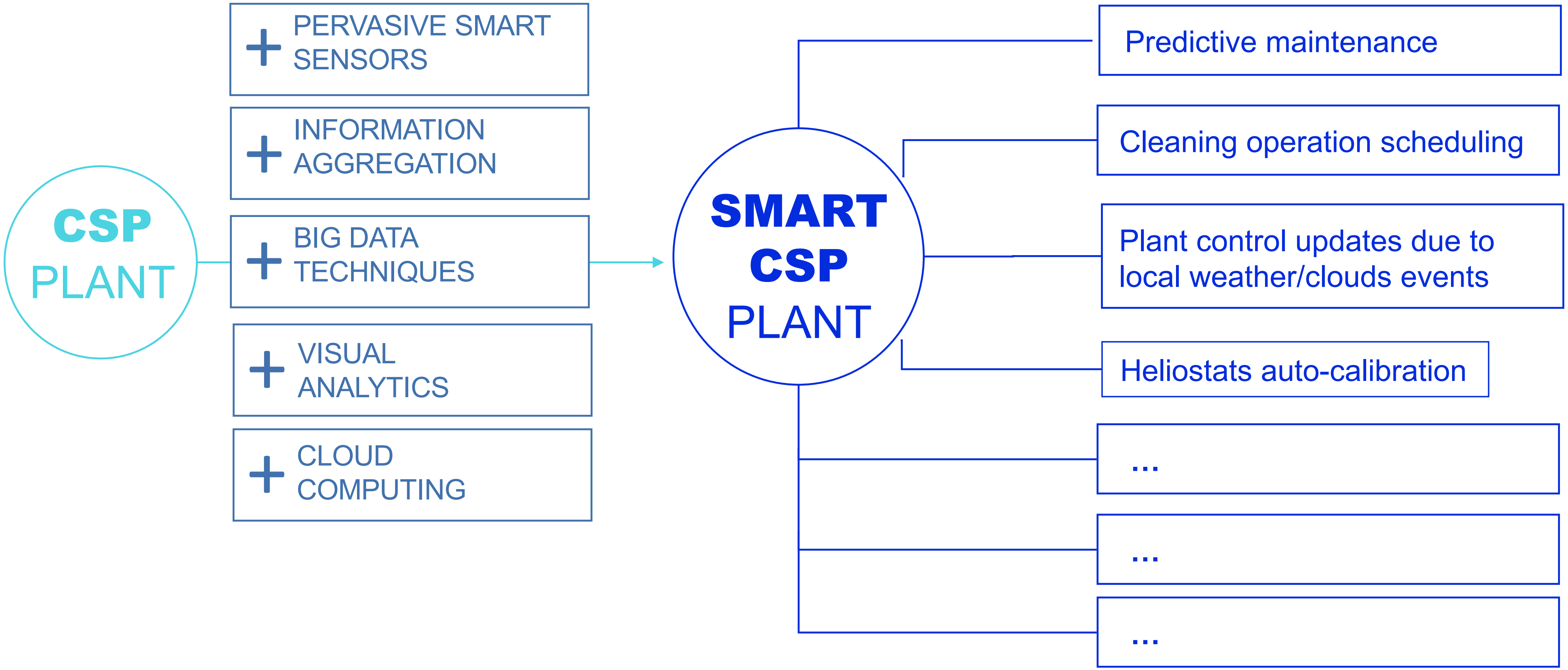
Implement Cognition and Big-Data techniques

Enhance simulation environments

Provide interoperable interfaces

Integrate the infrastructure system architecture

CSP Digitalization



INDUSTRY 4.0 APPROACH FOR AN EFFECTIVE CSP COST REDUCTION

Energy Storage & Energy Transition Challenges & Concerns

Javier García-Barberena
Strategy and Business Development Manager

On behalf of:

Dr. Marcelino Sánchez
Department of Solar Energy Technologies & Storage

National Renewable Energy Center of Spain (CENER)

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SolarPACES
Solar Power & Chemical Energy Systems
September 27-30, 2022
Albuquerque, NM, USA
28th SolarPACES Conference

GOBIERNO DE ESPAÑA
VICEPRESIDENCIA TERCERA DEL GOBIERNO
MINISTERIO PARA LA TRANSICIÓN ECOLÓGICA Y EL RETO DEMOGRÁFICO
MINISTERIO DE CIENCIA E INNOVACIÓN
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01 CONTEXT

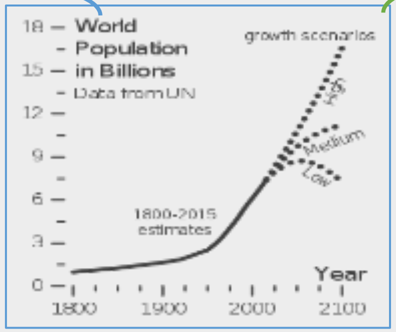
What are the main challenges of the world today?

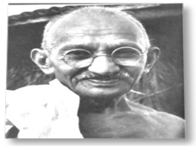
DRIVERS

CHALLENGE

World population?

Limited Resources?





"THE WORLD HAS ENOUGH FOR EVERYONE'S NEED, BUT NOT ENOUGH FOR EVERYONE'S GREED."

— MAHATMA GANDHI

CENER NATIONAL RENEWABLE ENERGY CENTRE

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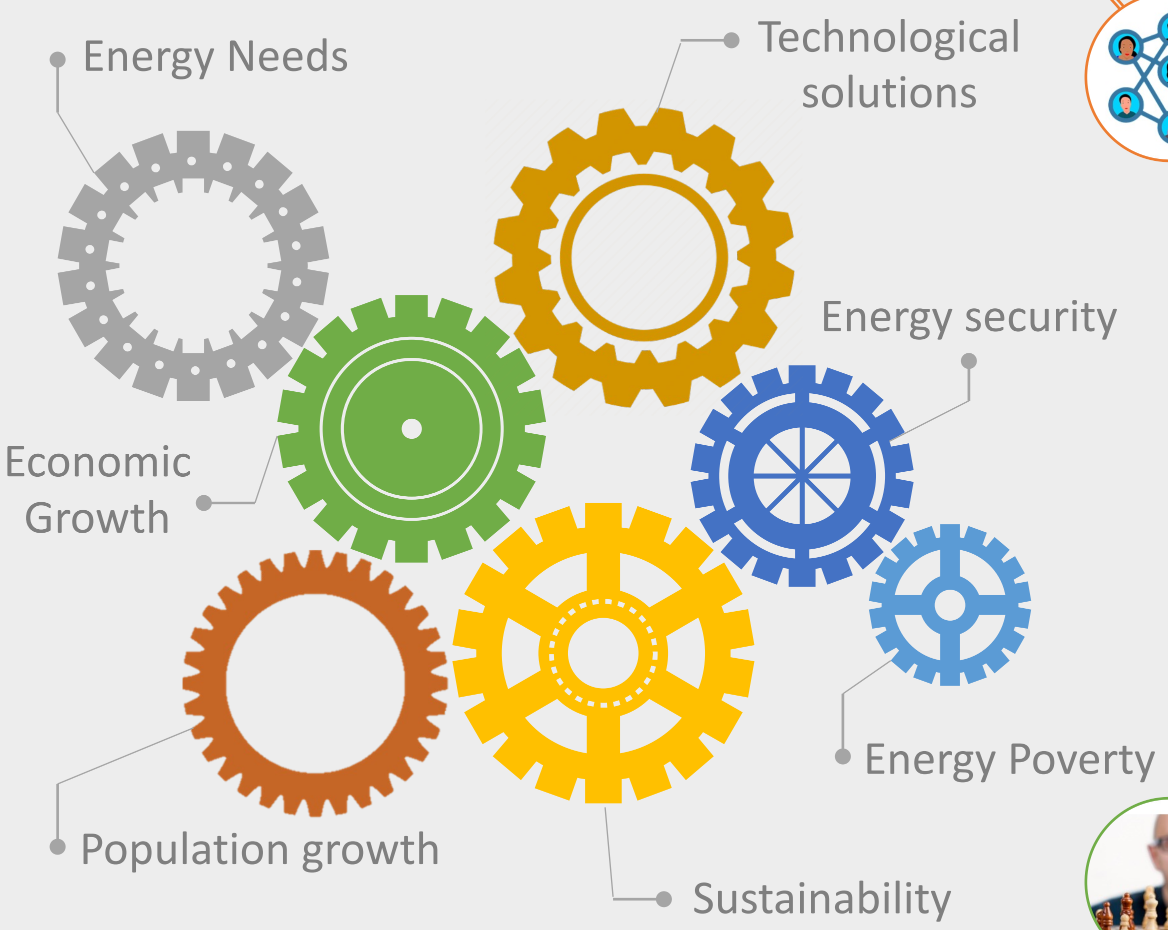
01 CONTEXT

The Energy Transition Challenge



SOCIAL:
Social justice and welfare of human beings

ECONOMICAL:
Sustainable growth

ENVIRONMENTAL:
Welfare of Planet

TECHNICAL:
Technology as engine of progress

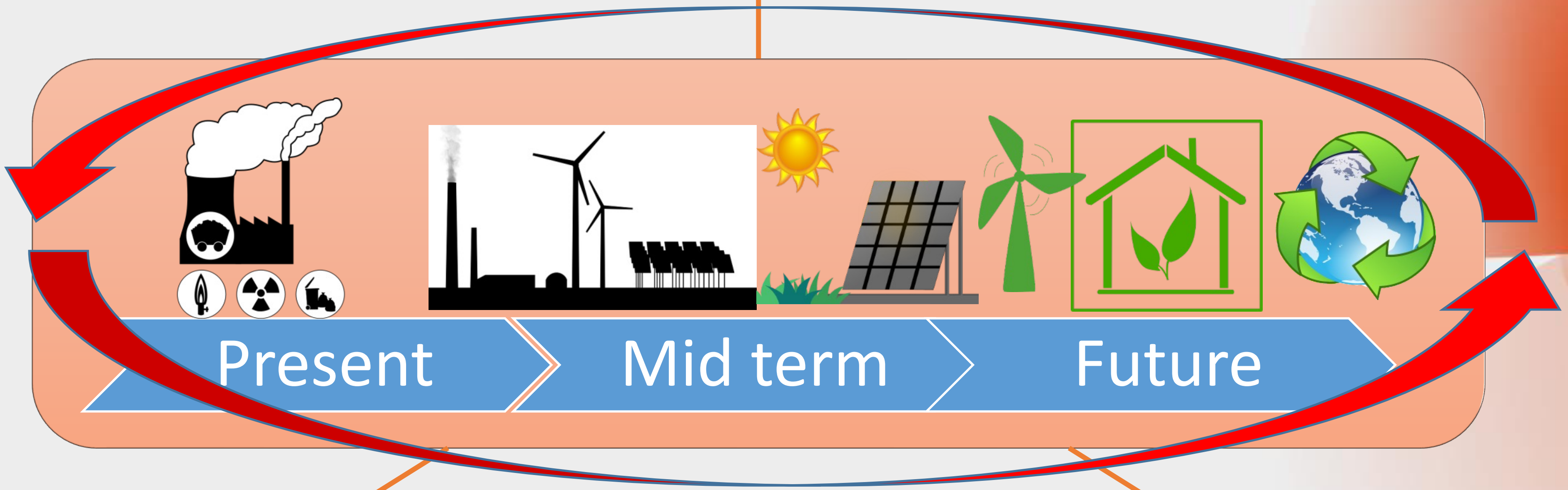
STRATEGICAL:
World leadership

4

01 CONTEXT

The Energy Transition Challenge

All these aspects are interrelated and need to be **considered as a whole**. Taking into account not only the present but also its evolution over time and the future vision.



Our energy present (based on fossil fuels) is **conditioning the future** and also our envisaged future (our energy policy) is conditioning our present.

This makes the energy transition a complex problem that is not free of particular interests when the **general interest should take precedence**, as it is a global problem of worldwide dimensions.

02 CONCERNS

Green Transition Policy

Hydrogen

Ref. Ares(2022)3...

EUROPEAN COMMISSION

supplementing Directive (EU) 2018/2001 of the European Parliament and of the Cou... by establishing a Union methodology setting out detailed rules for the production o... renewable liquid and gaseous transport fuels of non-biological origin

(c) the renewable liquid and gaseous transport fuel of non-biological origin is pro... the same one-hour period as the renewable electricity p...

(i) during the same one-hour period ... under the renewables power purchase agreement; or

(ii) from renewable electricity from a storage asset ... same network connection point as the electrolyser ... during the same one-hour period in which the ele...

European Comm... memb...

Scrapped | EU's controversial 'additionality' rules for green hydrogen are history after European Parliament vote

The requirements for hourly proof of dedicated renewable energy supply will no longer apply, reducing the risk of a potential 'mass exodus' of developers to the US — but not everyone is pleased

...endment 13 to the latest overhaul of the Renewable Energy Directive (RED), due to ...oted on by MEPs today, would also relax the proposed rules requiring green ...rogen producers to account for the provenance of all their renewable electricity on an ...urly basis.

Instead, producers would be allowed to source electricity from the grid, provided they could verify it as renewable electricity by securing power purchase agreements (PPA) from renewables installations for the equivalent amount.

The balance between PPA purchases and grid purchases would be accounted for on a quarterly basis until 2030, and thereafter on a monthly, quarterly or annual basis, as decided by the European Commission (EC).

reuters.com · jul. 06, 2020

...EU lawmakers ban nuclear from green transition fund, leave ...

...All **EU** member states agreed last week that the ...new **fund** should exclude **nuclear** and fossil fuels ...projects, including natural **gas** projects - a ...position also shared by the **EU** Commission. But...

Tiempo estimado de lectura: 2 min

...ttps://www.reuters.com/artic.../us...

reuters.com · jul. 06, 2022

EU parliament backs labelling gas and nuclear investments as ...

BRUSSELS, July 6 (**Reuters**) - The European Parliament on Wednesday backed **EU** rules labelling investments in **gas and nuclear** power plants as climate-friendly, throwing out an attempt to block...

https://www.reuters.com/.../eu-parliament-vote-green-gas-nuclear-rules-2022-07-06

Gas & Nuclear

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02 CONCERNS

Green Transition Policy

APPROPRIATE POLICY MAKING IS CRUCIAL
We need to have a clear ***vision of the future we want to create***

TRANSPARENT, CLEAR AND INCLUSIVE POLICIES ARE REQUIRED
Holistic approach considering all aspects (everything, anytime)

WELL DEFINED LONG TERM STRATEGIES ARE NEEDED
Targeted strategies to meet the present and future **challenges**

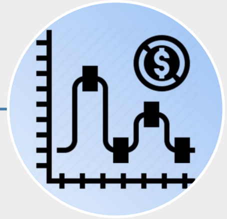
WE SHOULD SEEK FOR A COMMON EUROPEAN APPROACH
To take advantage of our **strength as community**

02 CONCERNS

Cost Analysis and the LCOE

Is the LCOE the right parameter to make the cost analysis? And to base the auctions upon it?

The **levelized cost of electricity** (**LCOE**), or **levelized cost of energy**, is a measure of the average net present [cost of electricity generation] for a generator over its lifetime.



Real price of energy is affected not only by the amount you can generate but also **by the amount you can sell** to the system, therefore also **by the regulatory framework**

02 CONCERNS

Cost Analysis and the LCOE

SOME FACTS:

- Combined Cycles in Spain have been selling much less energy than in former times due to the penetration of RE in the system (many CC @ 2-4% capacity)

- **Recently, coal and gas plants doubled their electricity production from 1.6% to 3.2% and from 11.9% to 22.6%** respectively. These increases were due to:
  - ✓ The rise in exports to France and
  - ✓ The fall in
    - cogeneration (from 10.8% to 7.6%),
    - hydro (from 14.5% to 6.8%), and
    - wind (from 24% to 21.9%), mainly due to the dry year.

- **The increase in RE energy limited by technical restrictions** with reductions of 345 GWh in PV, 333 GWh in wind and 323 GWh in solar thermal, which implies profound asymmetries compared to their installed capacity.

**** Data from the Technical Committee For Monitoring The Operation Of The Iberian Electricity System (CTSOSEI) 2022 summary till August***

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02 CONCERNS

Cost Analysis and the LCOE

Better cost & value analysis and KPIs are needed to ensure an economically feasible and valuable energy system

Is the LCOE the right parameter to make the cost analysis? And to base the auctions upon it?

The **levelized cost of electricity** (**LCOE**), or **levelized cost of energy**, is a measure of the average net present cost of electricity generation for a generator over its lifetime.

Real price of energy is affected not only by the amount you can generate but also **by the amount you can sell** to the system, therefore also **by the regulatory framework**

Local-content benefits are never considered. Local content is linked both to the reinforcement of local industries and **to energy security and independence.**

02 CONCERNS

Energy Mix & Flexibility

Which kind of Energy system do we want to have in the future?

Although there is no clear path to the energy transition, there is a consensus that there will be an energy mix in which renewable energies will play a predominant role

Are we in the right path to reach the optimum energy mix?

SOME EXAMPLES:

A) Lets install all RE NOW

→ What about the excess of RE in the system?

- ✓ what will be the selling price of electricity @ noon in a system overloaded with PV
- ✓ How this can affect investors and the whole system cost

B) Lets install new Nuclear Power stations as green and base load electricity

→ How this energy mix system based will be affected by the inclusion and promotion of new nuclear stations?

- ✓ In terms of cost?
- ✓ In terms of Flexibility?

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02 CONCERNS

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→ What about the excess of RE in the system?

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- ✓ How this can affect investors and the whole system cost

Cheap and **massive storage systems are needed** in the short term to **increase the flexibility and dispatchability** of the entire electricity system.

03 MASSIVE ENERGY STORAGE

Thermal Energy Storage Systems (TESS)

Able for storing large amount of energy (up to 1GWh already commercially demonstrated)

Long life solutions (> 20 years)

Sustainable, recycled (e.g slag), reusable (e.g. fertilizes), non-toxic, non-hazardous materials

Competitive costs (5-70 €/kWh)

- Hybrid solutions not only for heat storage but also for storing electricity through Power-to-heat-to-Power solutions (coupling sectors)

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03 MASSIVE ENERGY STORAGE

Concentrating Solar Power (CSP) and TESS

It is remarkable the **large storage capacity** in relation to its nominal power (4-12 full load hours of storage / 50-200 MW).

24/7

European leadership in both technologies CSP and TESS

CSP/STE technologies can also:

- Supply high temperature heat for **solar fuels** and thermochemical processes.
- Supply medium/high temperature heat for **industrial processes**.

CSP plants integrate TESS based on Molten Salts, **enabling dispatchable renewable energy** which produces electricity following the demand.

The role of the **CSP/STE** technologies has been crucial to **demonstrate and deploy the TESS**.

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04 CONCLUSIONS

Configuring The Energy Transition

Many **opportunities for all technologies.** There is room for all of them and they are **all necessary** today for the energy transition.

To find the optimal energy mix it is **essential to exploit the contributions of different technologies** to the energy system as a whole in terms of **sustainability, energy independence, flexibility**, and every other relevant factor.

Of course **final system cost** shall also be considered, but this is **neither the only nor the main factor**.

Today's **energy policies** will condition our future decisions and will **set the guidelines for the future energy system**.

04 CONCLUSIONS

The Role of TESS and CSP

Thermal storage in particular has many options and needs to be developed in **power-to-heat-to-power** applications and for **process heat** and **thermal consumption.**

TESS as **retrofitting of existing plants,** particularly:

- **Dismantled Coal power plants** (reuse power cycles)
- **Nuclear power plants** (increasing **dispatchability**)

The use of Concentrating Solar systems to supply dispatchable solar electricity & heat to industry **should be promoted and encouraged**

CSP combined with TESS will limit the European energy dependence, avoid volatility of energy prices and **increase stability** and competitiveness of **European industry**


DISCUSSION PLEASE!

Thanks for your attention

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ENEA

Italian National Agency for New Technologies,
Energy and Sustainable Economic Development

The thermal energy storage systems at support of new renewable power networks

Bringing research and industry closer: accelerating innovation and uptake of new technologies. Energy Storage & Concentrated Solar Thermal Energy

Plataforma Solar de Almería, Spain, Tuesday, 15 November 2022

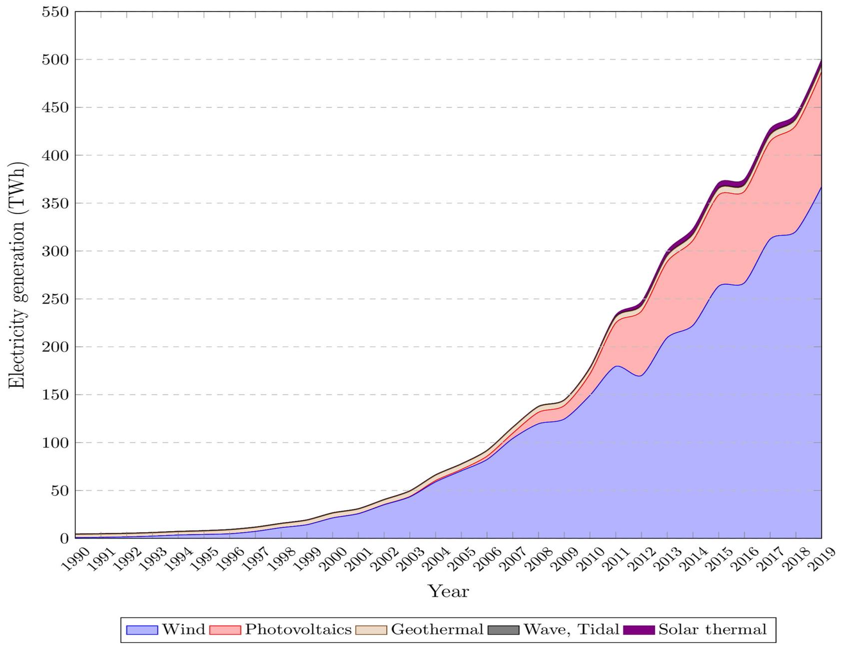
Dr. Walter Gaggioli, PhD
Head of Solar Thermal and Smart Network Division

The impact of the energy transition on power grid

The rising share of variable renewable electricity plants and the continuing decentralization can have a strong impact on the power systems:

- alterations of the electricity markets;
- supply security;
- stability and reliability of the power networks;

*In 2050 variable renewable energy should comprise more than 60% of power generation and **thermal energy storage is one the enabling technologies for this transition***



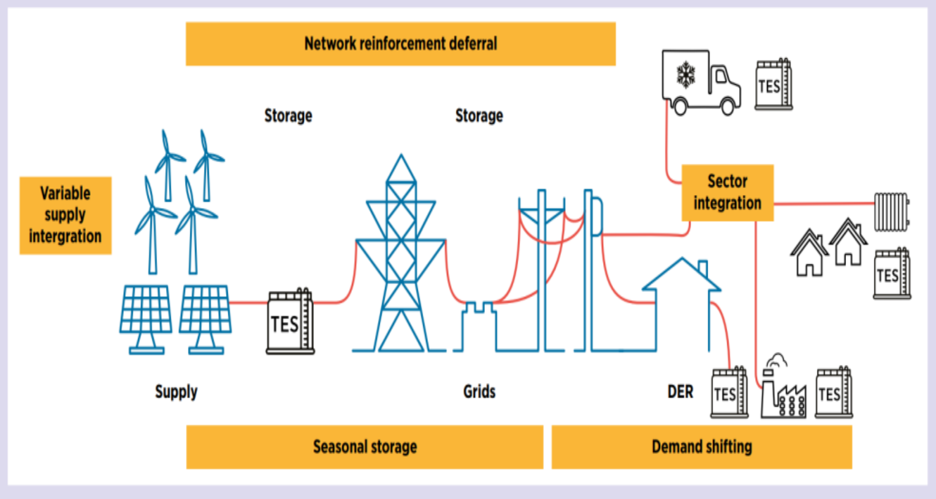
Development of electricity from variable renewable energy technologies (excluding hydro) in EU-28 between 1990–2019, inTWh (Eurostat,2014, Eurostat,2021)

Source: On the economics of storage for electricity: Current state and future market design prospects R. Haas and others

ENEA

Services offered by TES systems for power grids

- **Buffering;**
- **Time-shifting;**
- **Extension of the production period;**
- Dispatching services;
- **Integration with other renewables (hybrid renewables power plant)/waste heat;**
- **Integration power and heat production**;



Innovation outlook: Thermal energy storage – 2020 IRENA

The global decline in coal-fired power generation offers further opportunities for TESs: **Conversion of existing coal-fired power plants to power-to-Heat – to power units;**

The role of thermal energy storage systems in the renewable power network

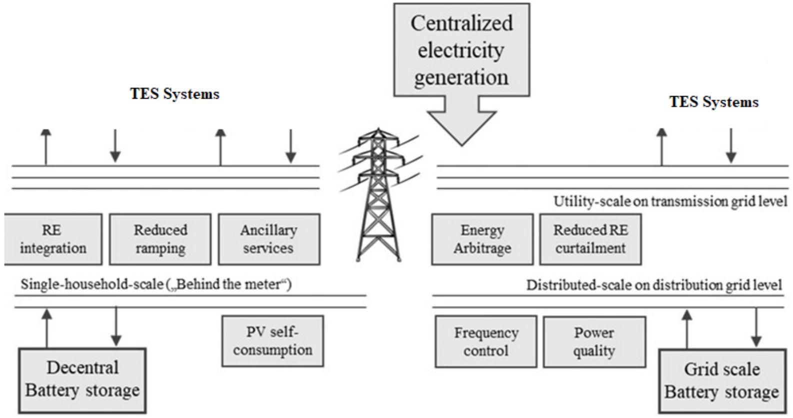
Currently, **molten-salt TES is the technology most used in the sector** due to its advanced technological readiness and its application with concentrated solar power (CSP) plants.

Molten-salt storage capacity of over 21 GWh is currently installed worldwide.

TES can reduce the power system costs through two major mechanisms:

- it can reduce both the **steady-state costs** (i.e., by shifting load from peak to off-peak periods) and **ramping costs** (i.e., associated with meeting rapid changing demand or intermittent generation resources) in power system operations;

- it can also reduce **the capacity payments in power systems** by decreasing the amount of installed generation capacity needed to maintain system reliability in the long term;



Barriers for using of the TES systems in the new renewable power grid

Employing TES technologies requires:

- **Upgrade of incentives renewable policies;**
- Upgrade of Regulatory framework;
- Knowledge and awareness in society, public sector and industry;
- Research gaps and project demonstration (case studies, hybrid plant, Slow uptake of renewable heating technologies);

Aside from energy storage and flexible power generation, other methods of **enhancing grid operational flexibility include improving transmission networks, demand-side energy management**.

Readiness using of the TES systems in the new renewable power grid

Deploying TES technologies:

- Energy arbitrage: TES technology ready;
- Congestion management: TES technology ready; new regulatory framework;
- Renewable peak shaving: TES technology R&D actions; new regulatory framework;
- Secondary regulation (min): TES technology R&D actions; new regulatory framework;
- Primary regulation (sec): TES technology suitable only in combination with battery system R&D actions; new regulatory framework;

Lack of energy (electricity, heat) **balancing markets and price signals**: for an improved value proposition for different TES technologies, **time-of-use tariffs and price signals for time shifting would likely be a driver for the uptake of TES**

Thanks for your attention!

INVESTIGATION OF THE POTENTIALITIES OF CLOSED CYCLE SORPTION TES FOR INDUSTRIAL APPLICATIONS

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Research Engineer
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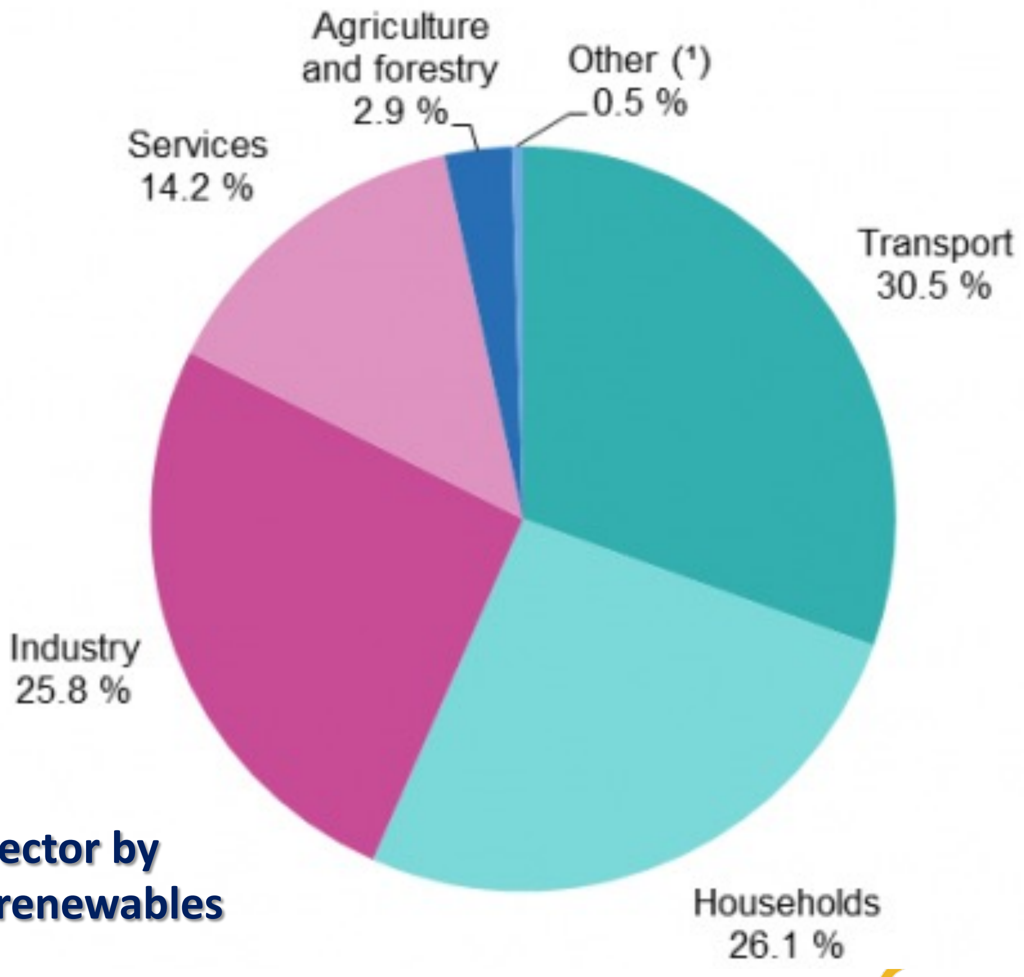
Some Facts

Despite the fact that 2020 emissions were lower than in 2019 as a result of the COVID-19 crisis and subsequent countermeasures, GHG concentrations in the atmosphere continue to rise.

- **In 2019, global GHG emissions increased for the third year in a row, reaching a new high of 52.4 GtCO2e.**
- **According to preliminary estimates, fossil CO2 emissions in 2019 set a new high of 38.0 GtCO2.**
- **In contrast, global GHG emissions in 2030 need to be approximately 25 and 55% lower than in 2017 to put the world on a least-cost pathway t limiting global warming to 2 °C and 1.5 °C, respectively.**
- **Process or facility heating/cooling represent an important share of the primary energy demand in the industrial sector.**
- **Industrial processes have a significant impact on grids**



The challenge is to reduce energy consumption in the industrial sector by combining consolidated and cutting-edge technologies based on renewables

What can TES do to reduce the impact of industrial processe on the GRID?

SHORT PERIOD

1. Screening of technologies for TES systems
2. Modelling of alternative applications of the identified technology
3. Simulation and optimization of different layouts
4. Comparisons

ACTIONS/1

TASK 1: Identification of possible alternative application for heat storage in INDUSTRIAL field

THE BACKGROUD

Solar energy is regarded as one of the most promising substitutes for traditional energy sources in the industrial field

…HOWEVER…

its intermittent and unstable nature is a major drawback, leading to an UNACCEPTABLE mismatch between supply and demand.

In such a context, solar heat storage is an appropriate method of CORRECTING the time and power mismatch

ACTIONS/2

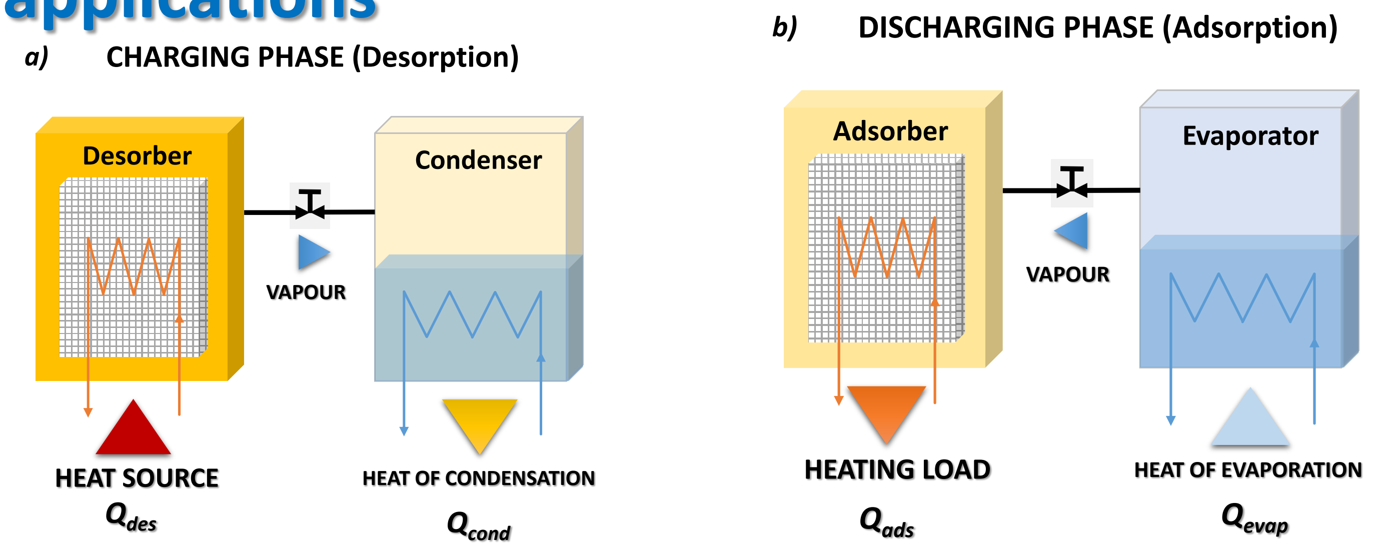
MOREOVER

Thermal storage systems today are perceived as crucial components in solar energy applications:

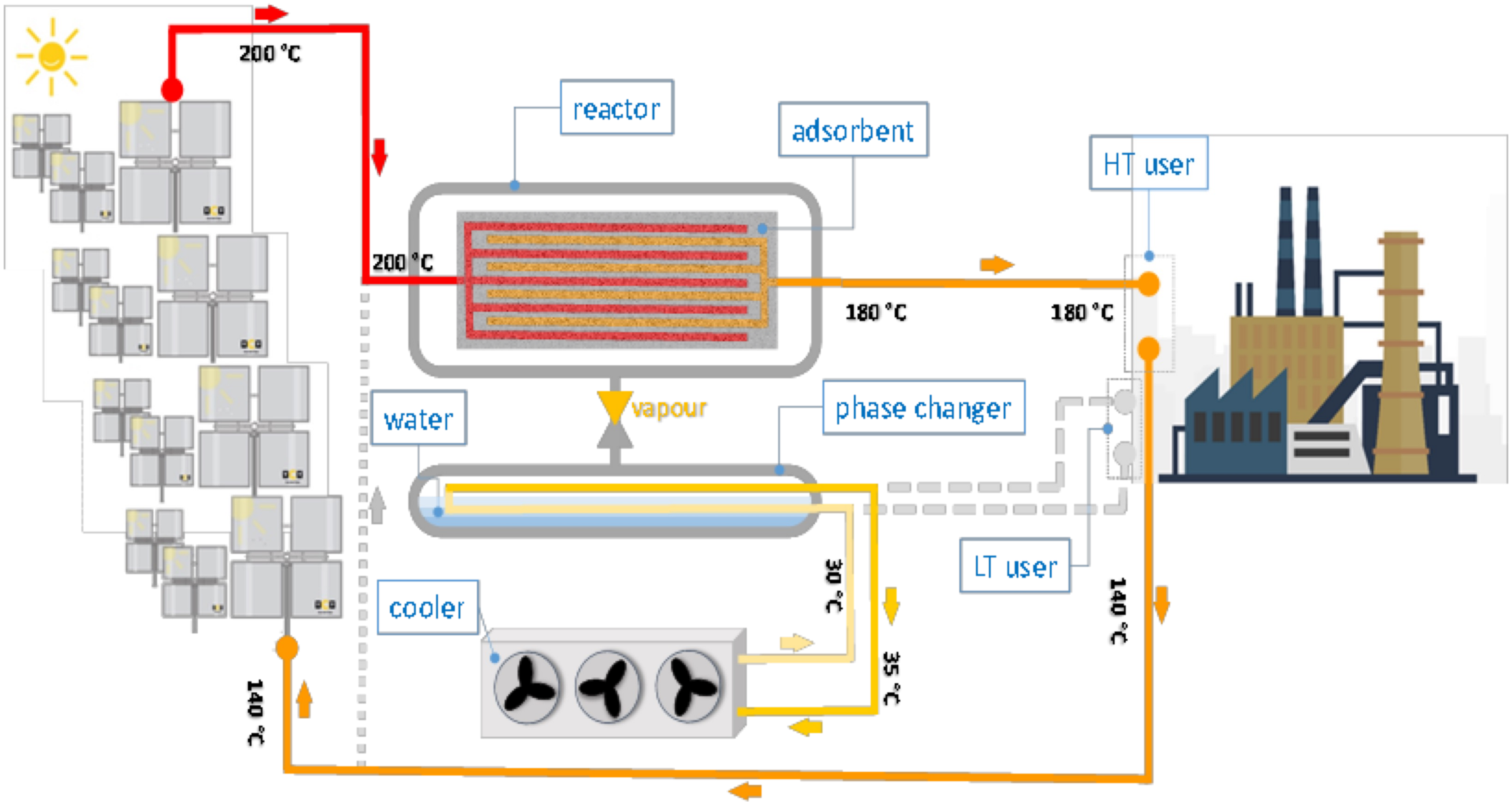
- **enhance the fraction of solar heat utilisation and…**
- **…make solar energy products more practical and attractive**

THE IDEA: investigate the possibilities of CLOSED CYCLE sorption system coupled with solar HEAT for industrial applications

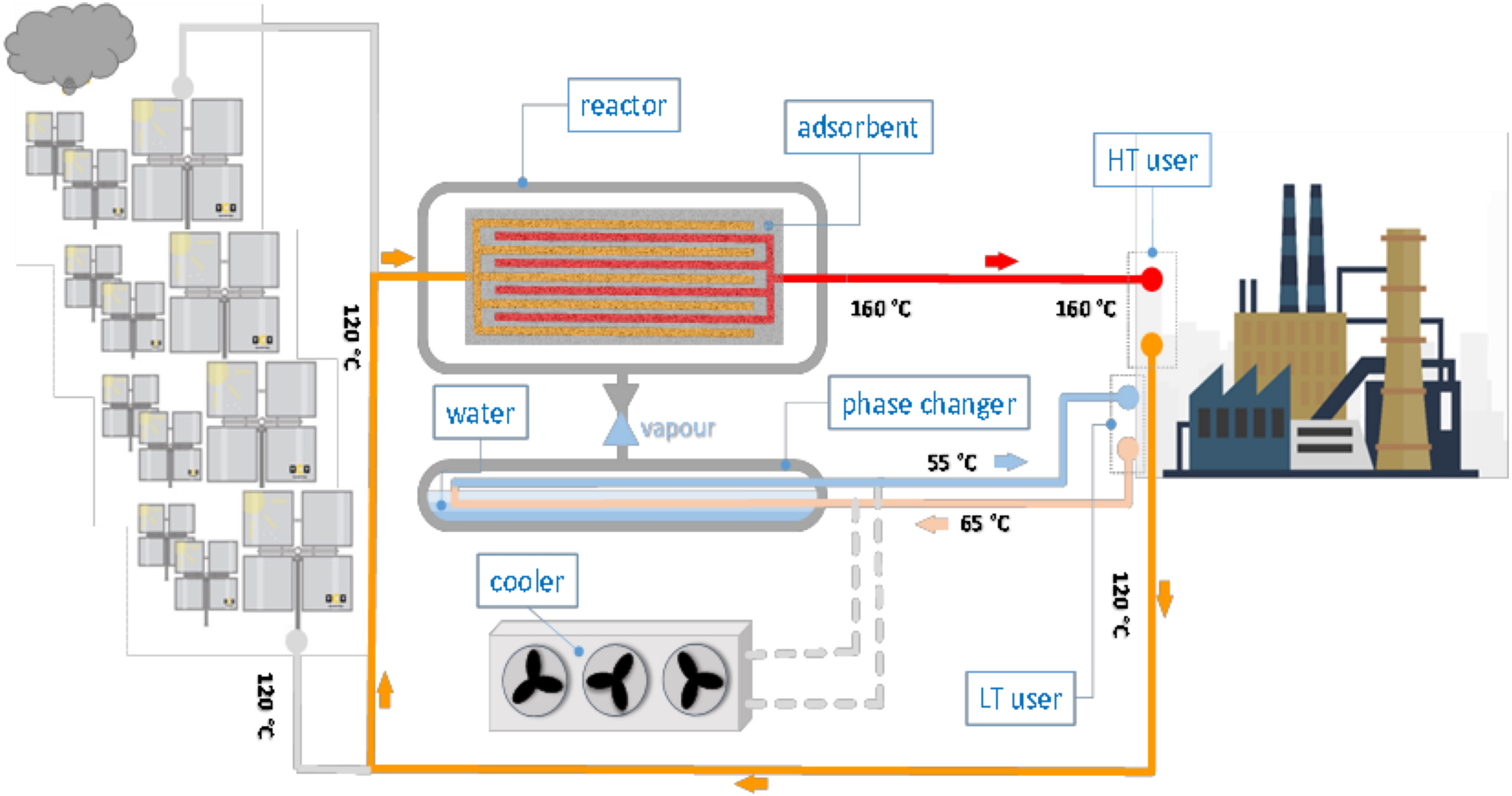
It's HALF HPing cycle



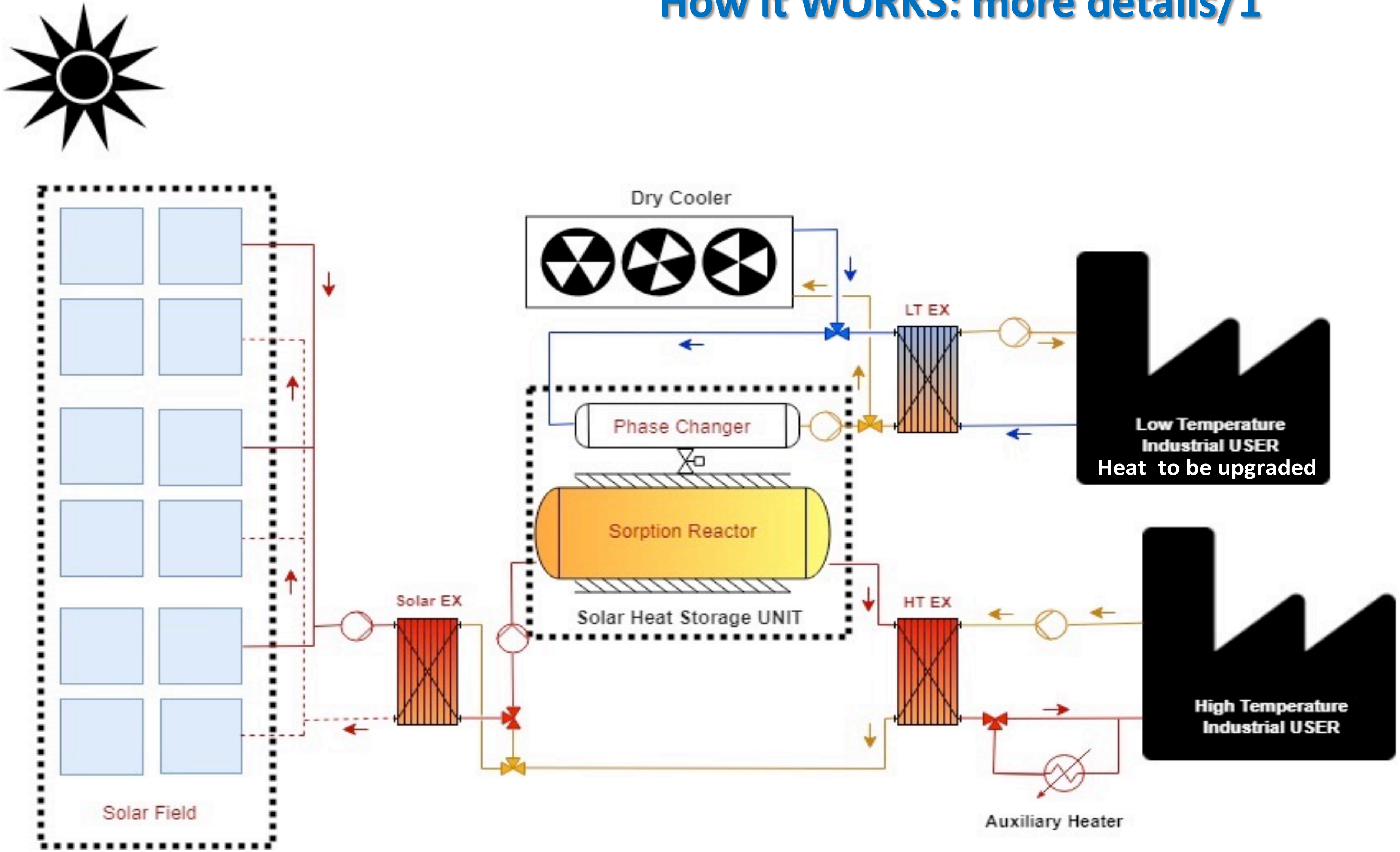
How it WORKS: charging stage



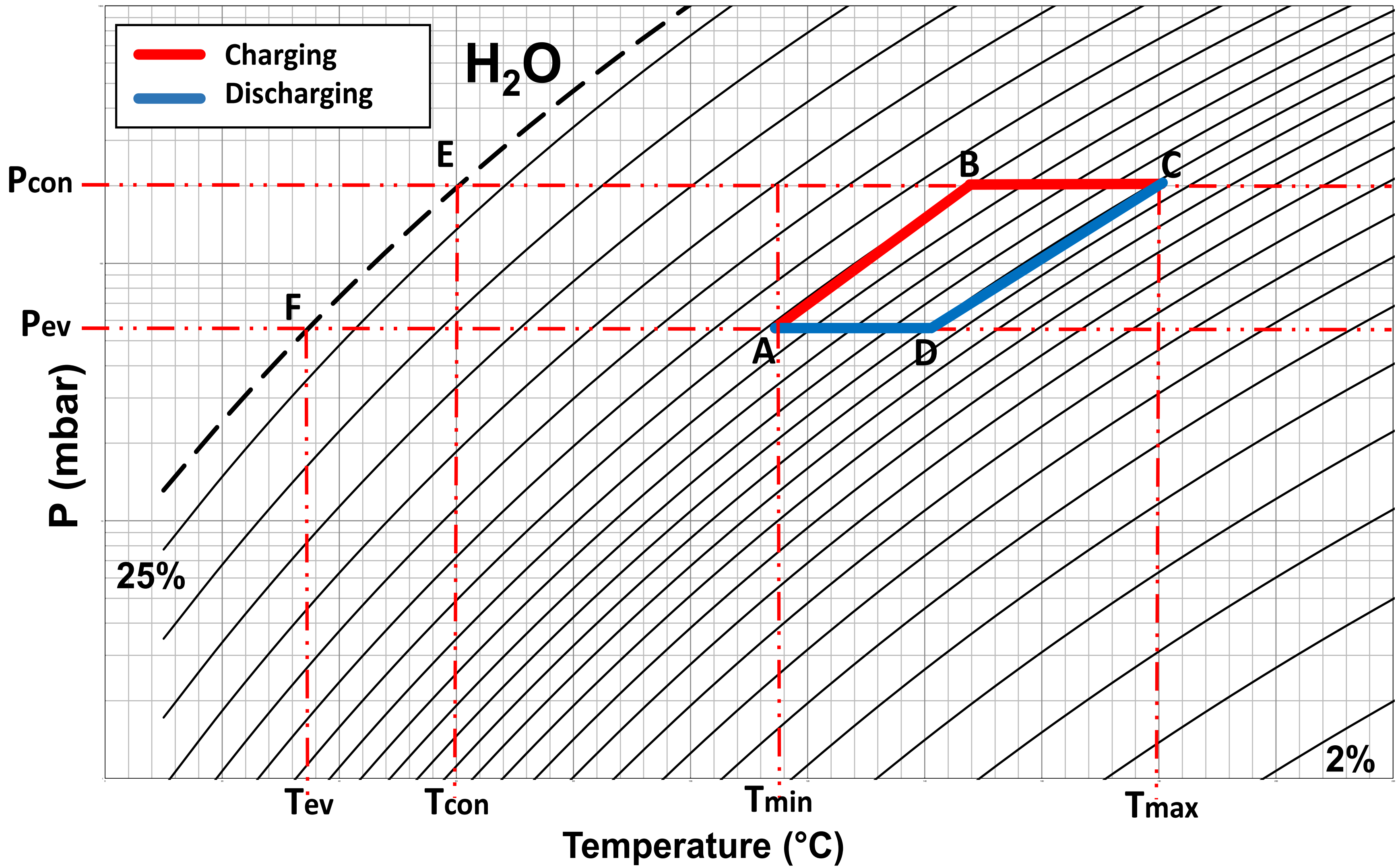
How it WORKS: discharging stage



How it WORKS: more details/1



How it WORKS: more details/2



WHY?

To demonstrate (once for all) the feasibility of such technology in operating conditions typical of the industrial field.

AS WELL AS

- Mathematically calculate the technical limits of a compact storage based on the adsorption technology with water and commercial adsorbent → materials screening;
- Simulate the application of the storage in a large system environment, which allows active process cooling during discharge with the aim to prove that such systems can allow a storage efficiency higher than 1
- Simulation of a thermal energy storage system with a storage density higher of a factor 2 compared to sensible pressurised water systems;

EVENTUALLY

- To propose a modular lay-out to allow for an easy adaptation to different required heat storage capacities for further future development

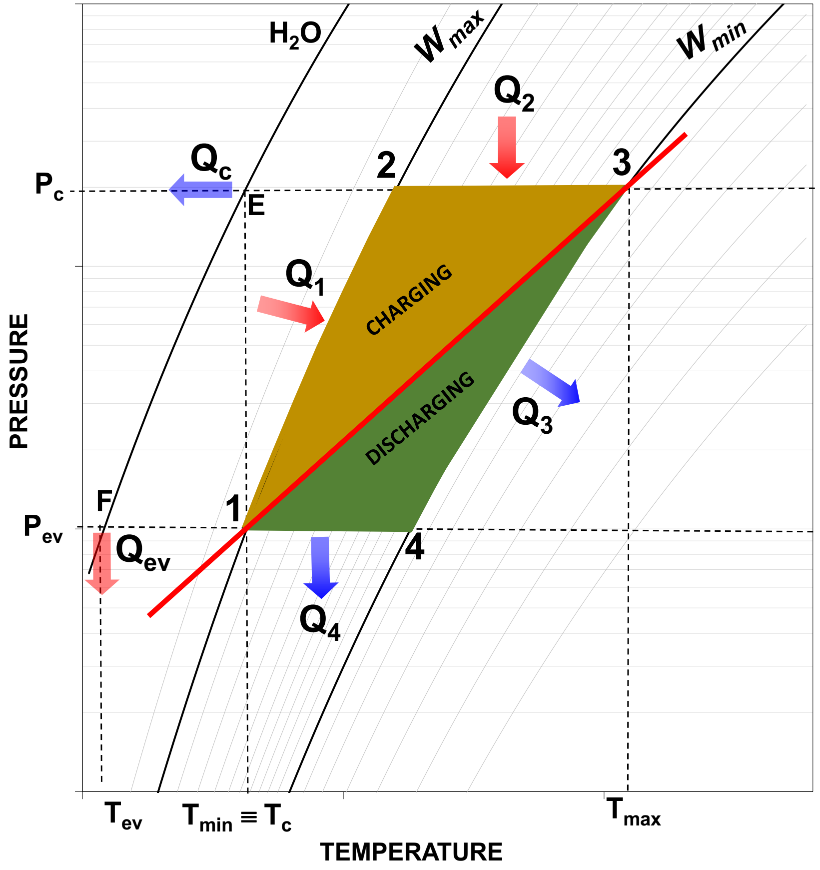
STEP 1: materials screening

	ADSORBATE		
SORBENT	Methanol	Ethanol	Water
Composite $CaCl_2$-silica	x		x
Composite LiBr-silica	x	x	x
Zeolite 4A			x
Zeolite AQSOA®-FAM-Z02			x
Zeolite DDZ-70 UOP			x
Zeolite SAPO-34			x
Composite $Ca(NO_3)_2$-silica			x
Zeolite AQSOA®-FAM-Z01			x
Microporous silica gel			x

- **SG as Host matrix + impregnated salts**
- **Corrosion issues MUST be considered**
- **Not Commercial**
- **OVER-saturation issue**
- **To be investigated in a second stage**

- **Promising**
- **Commercial**
- **Low cost (< 1€/kg)**
- **Stable**
- **Not corrosive**

STEP 1: materials screening/KPI



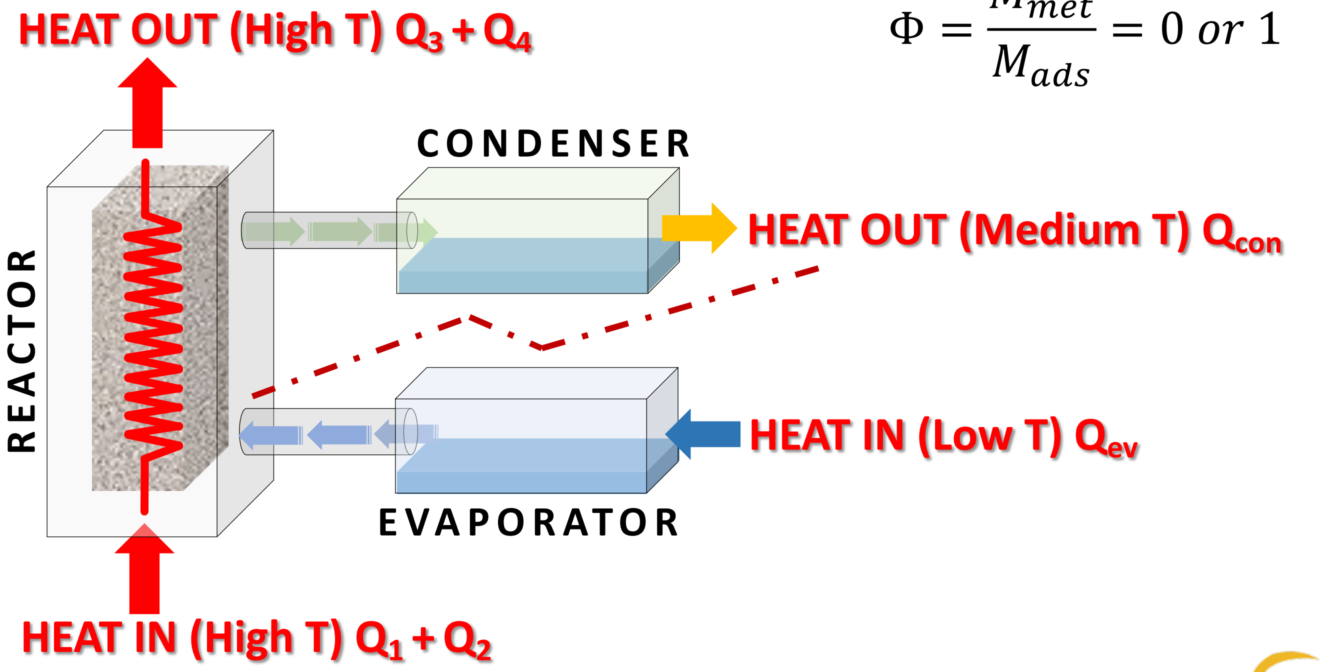
$$\eta_{t=0} = \frac{Q_3 + Q_4 + Q_{ev}}{Q_1 + Q_2 - Q_{con}}$$

$$\eta'_{t=0} = \frac{Q'_3 + Q'_4 + Q_{ev}}{Q'_1 + Q'_2 - Q_{con}}$$

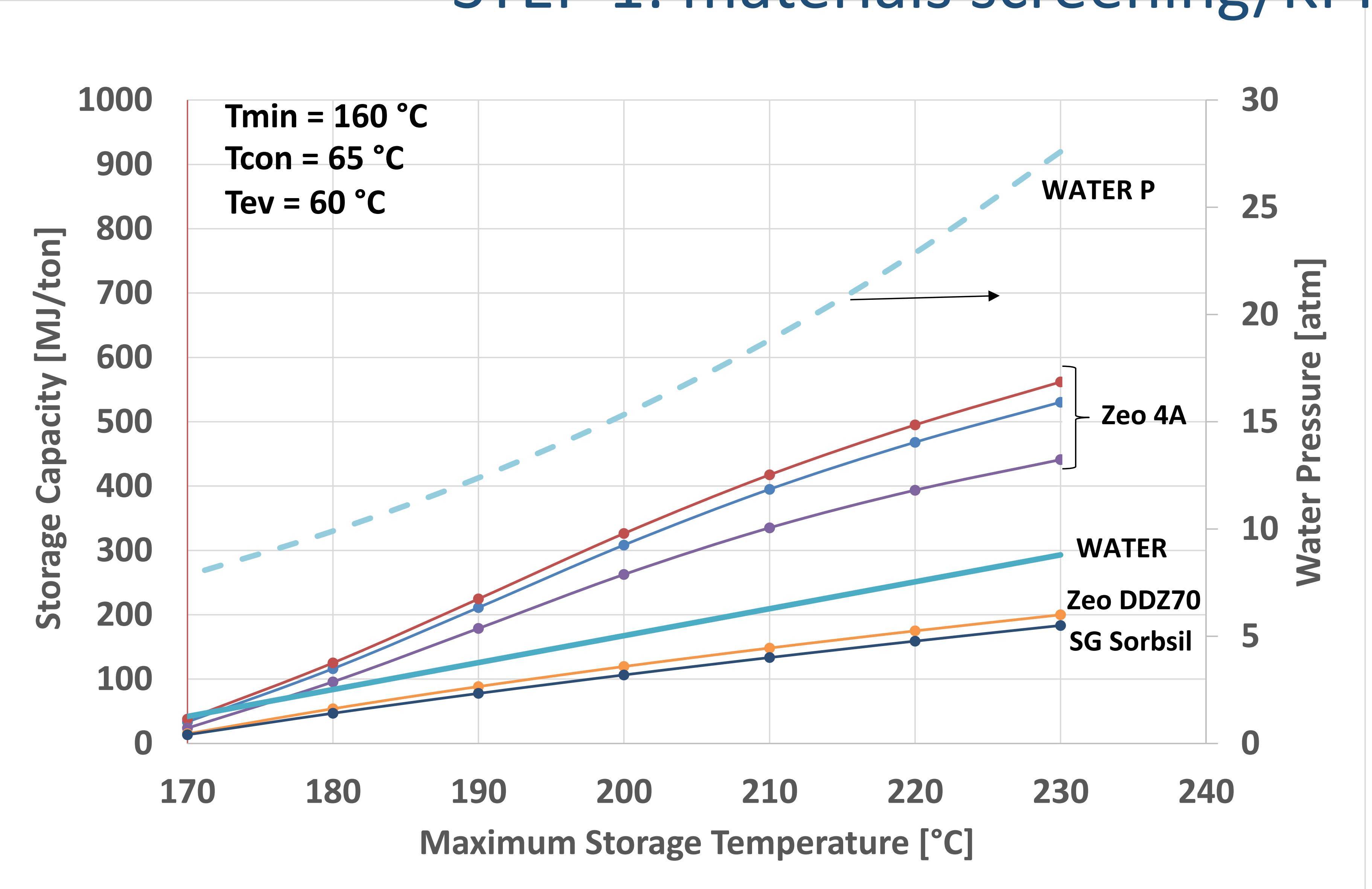
$$\eta_{t=inf} = \frac{Q_4 + Q_{ev}}{Q_1 + Q_2 - Q_{con}}$$

$$\eta'_{t=inf} = \frac{Q'_4 + Q_{ev}}{Q'_1 + Q'_2 - Q_{con}}$$

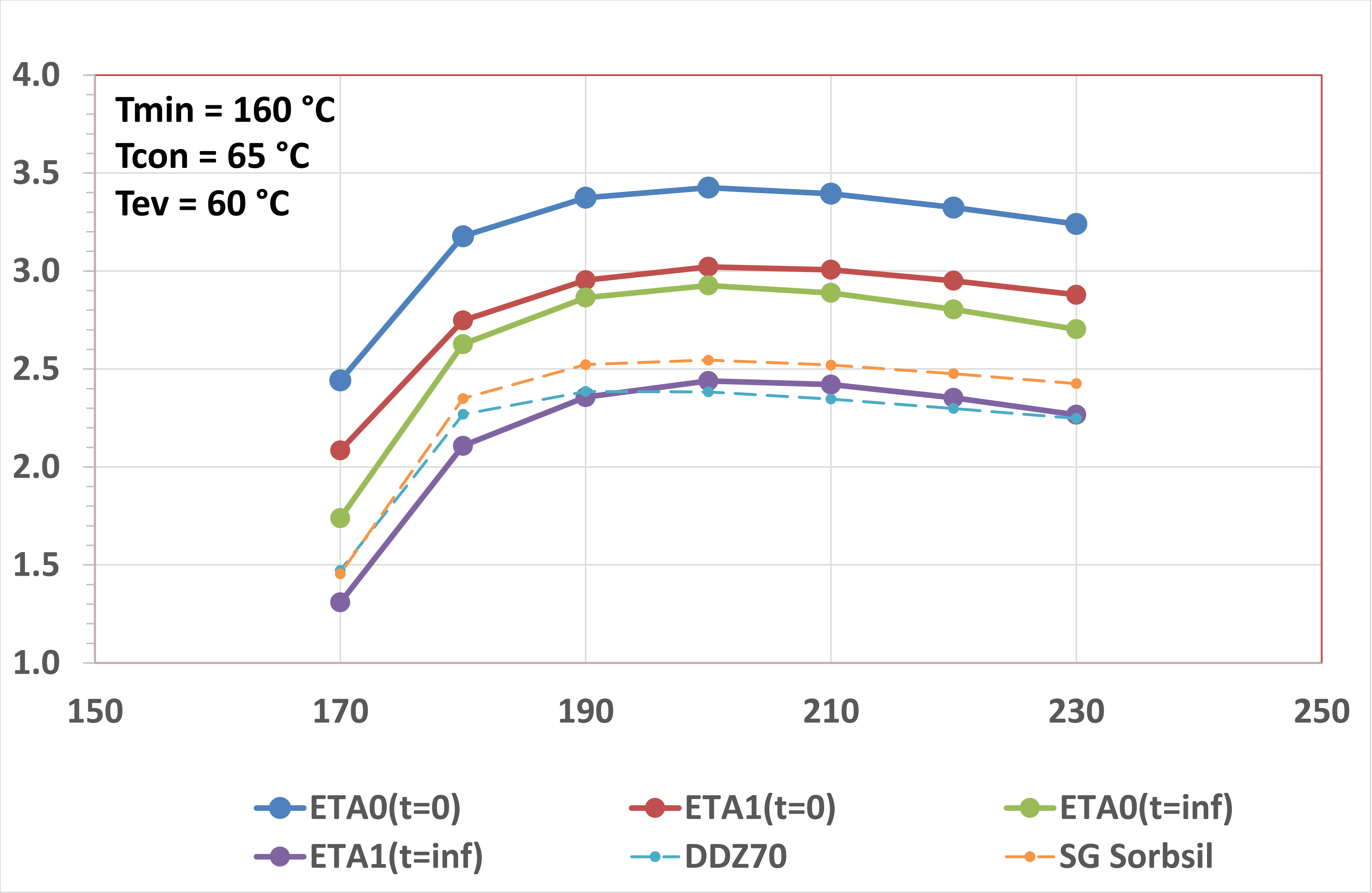
$$\Phi = \frac{M_{met}}{M_{ads}} = 0 \; or \; 1$$



STEP 1: materials screening/KPI



STEP 1: materials screening/KPI



Conclusions

- **The presented study is currently at a preliminary stage.**
- **The material screening carried out proved that some commercial and innovative sorbents (Zeolite FAM Z-02) are not suitable to be used in the proposed application.**
- **Cheap and widely available adsorbent materials are suitable for the proposed application.**
- **Composite materials, even with good potentialities and a very high storage capacity, present several issues related to their corrosive behaviour and over-saturation risk.**
- **The exploitation of low temperature condensation heat and evaporation cold is a key feature that allows the achievement of interesting efficiency (> 1.5).**
- **The study demonstrated the thermodynamic applicability of sorption storage in the industrial field.**

Dr. Eng. Salvatore Vasta, PhD.
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Hybrid energy storage systems integration into power grid

- SESSION III. The role of energy storage in future power grids

Linda Barelli linda.barelli@unipg.it

Trends

Growth in distributed, converter-based energy sources is reducing system inertia on the grid

Fossil generation assets are being retired

Major sectors of the economy are shifting to electric power, driving massive load growth on the power system

Aging of electric infrastructure makes more difficult to keep up with more varied and distributed generation and demand

Challenges

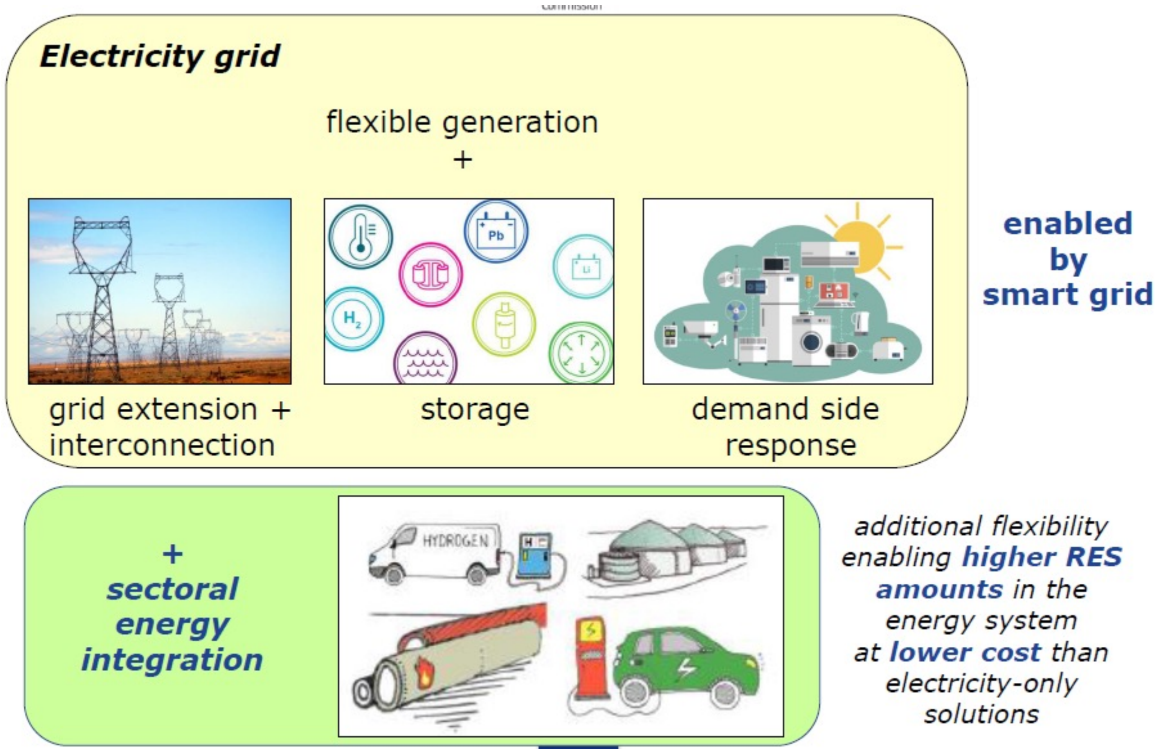
Intermittency and congestion → RES plant curtailment

Weakening System Stability (due to inertia loss)

Reduced Visibility of Grid Assets. As distributed energy resources increase TSOs must keep grid frequency within safe operating parameters amidst reduced visibility of load and generation on the grid.

Integrating New Technology (e.g. energy storage technologies) Under Old Policies and Regulatory frameworks

Decarbonization @2050: what does res integration imply?



***Need of additional flexibility** to bridge geographical and temporal variations*

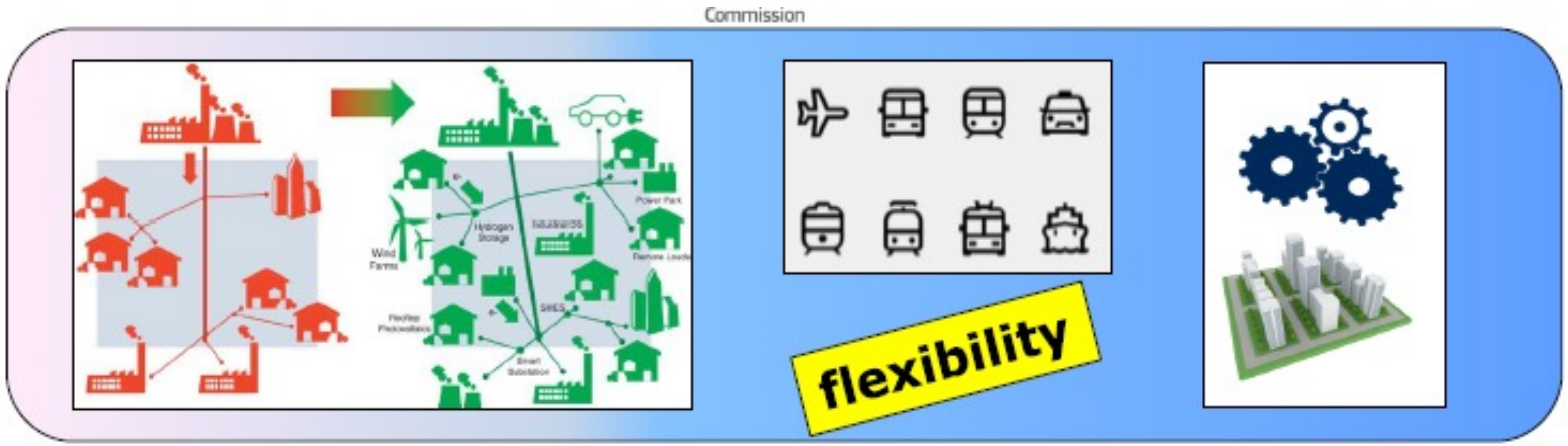
-> overall energy system change

- increased distributed generation
- increased electrification

***-> need for energy storage:** it represents one of the flexibility options and thereby increases the operational efficiency of the overall energy system*

-> sector coupling: in multi-energy systems multiple energy vectors and sectors are optimally integrated, increasing the overall system performance (technically, economically, environmentally)

Key focus for energy storage systems: *hybridization*

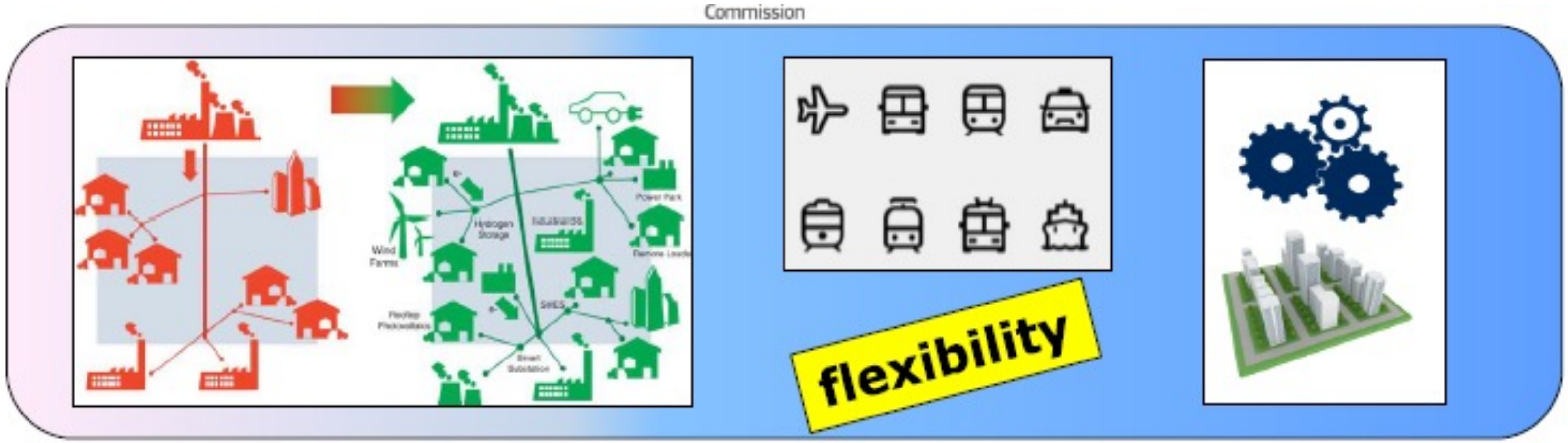


Requirements for ***STORAGE of RENEWABLE ENERGY (RE) & RE CARRIERS*** due to different applications and flexibility:

(1) different scales and timescales for storing &

(2) response times for discharging as well as technologies improvement

Key focus for energy storage systems: *hybridization*



- ***Combining complementary storage technologies***, *<u>hybridization allows multi-operation modes of the ESS, merging the positive features of base-technologies and extending their application ranges</u>. Potential benefits are:*
  - *increase in cycle efficiency*
  - *devices' lifespan extension*
  - addressing RES variability, enabling high RES penetration
  - enhancing power supply reliability
- ***Potential for integrating power, transport, gas systems***

Smart Power management

- Optimization of base-technologies exploitation
- Real-time management of RES (and loads) variability

➢stochastic approaches are strongly recommended implementing multi-objectives functions

In the next the case of the Simultaneous Perturbation Stochastic Approach is applied to different HESS applications:

➢micro-grid

➢RES large scale generation

Initial assumptions

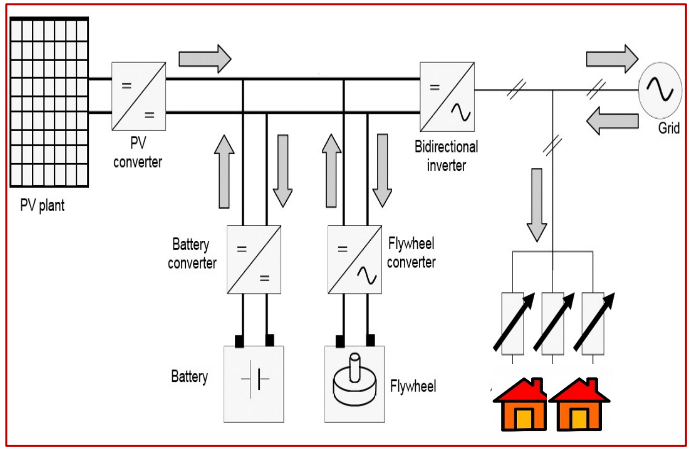
- Set the initial estimate of the vector: $\hat{\theta}_0$
- Define the loss function: $y(\theta)$
- Establish the convergence conditions: $y(\theta_k) < y_{limit}$ and/or $N_{iter}^{k} = N_{max}$

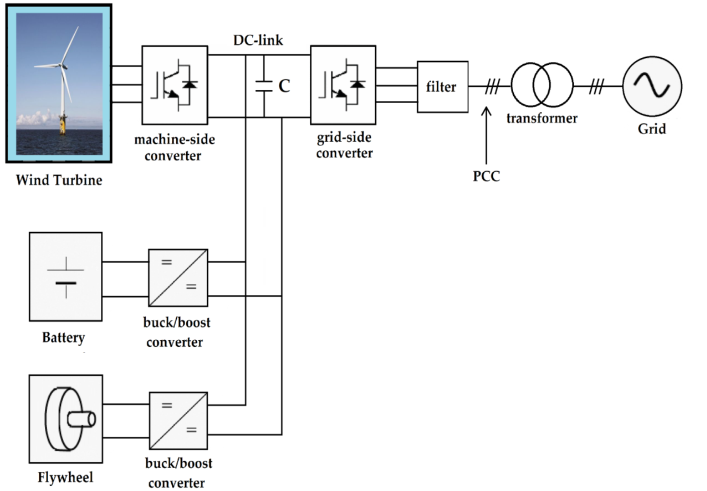
Iterative calculation

- Update the algorithm coefficients: $a_k = \frac{a}{(A+k+1)^{\alpha}}$ and $c_k = \frac{c}{(k+1)^{\gamma}}$ (k, iteration number)
- Determine the perturbed vector: $\hat{\theta}_k^{\pm} = \hat{\theta} \pm c_k \Delta_k$ (Δ_k, vector with elements following a Bernoulli distributions)
- Calculate the gradient of the loss function: $g_k(\hat{\theta}_k) = \frac{y(\theta_k^{+}) - y(\theta_k^{-})}{2c_k} \begin{bmatrix} \Delta_{k1}^{-1} \\ \dots \\ \Delta_{k1}^{-1} \end{bmatrix}$
- Update the initial estimate: $\hat{\theta}_{k+1} = \hat{\theta}_k - a_k g_k(\hat{\theta}_k)$
- Check the convergence condition

Problem solution

- Stop iterating when meeting convergence conditions (or the maximum iterations number).
- Provide the final update of the initial estimate as the optimisation problem solution





Ref.: D.A. Ciupageanu, L. Barelli, G. Lazaroiu. Electric Power Systems Research 187 (2020). doi: 10.1016/j.epsr.2020.106497

HESS application to micro-grid

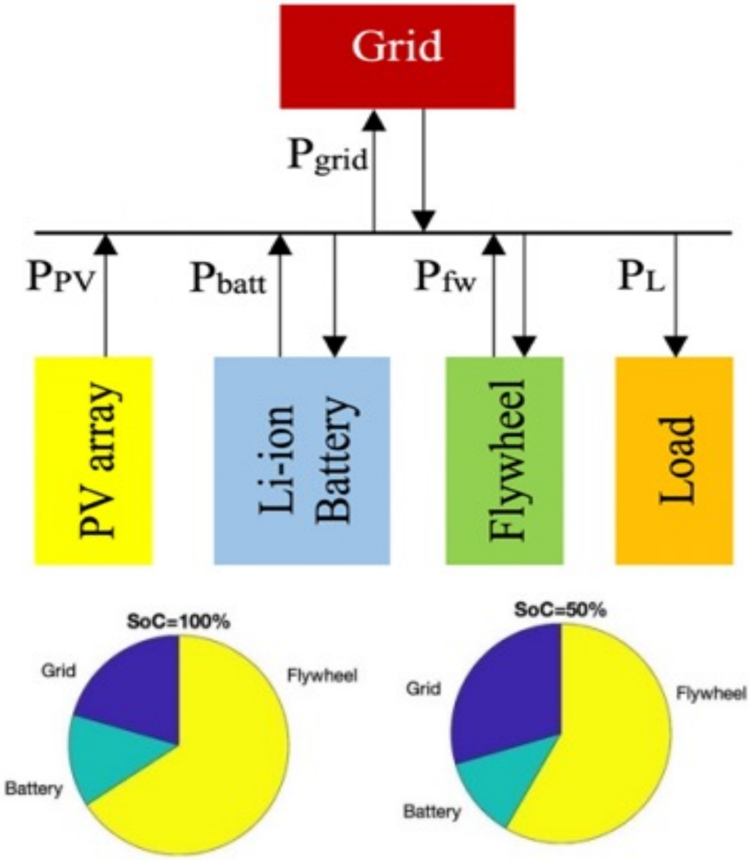
Problem formulation

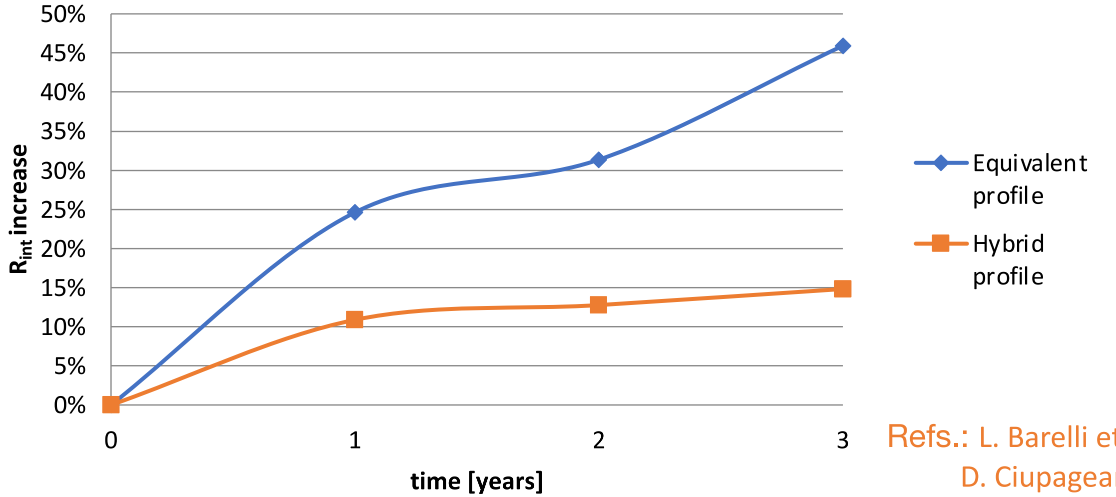
- ***Selected variables***: $\theta = [q_{batt} \quad q_{fw} \quad q_{grid}]$ - shares vector

$P_{batt} = q_{batt} \cdot \Delta P \qquad P_{fw} = q_{fw} \cdot \Delta P \qquad P_{grid} = q_{grid} \cdot \Delta P$

where: ΔP = PV generation and load difference

- ***Problem objectives***:
  - ➢Reduced exchange with the grid: $y_1^k(\theta) = \left(q_{grid} \cdot \Delta P\right)^2$
  - ➢smooth power profile delivered/absorbed by the battery: $y_2^k(\theta) = \left(\frac{q_{batt} \cdot \Delta P}{P_{batt}^{t-1}}\right)^2$
  - ➢multi-objective aggregate: $y^k(\theta) = w_1 \cdot y_1^k(\theta) + w_2 \cdot y_2^k(\theta)$, where $w_1 = w_2 = 0.5$





- strong reduction in *Rint* increase after three years of operation for the hybrid configuration when compared to the non-hybrid one, i.e. +14.9% vs. 47.36%
- Peak-shaving function performed by the flywheel towards the battery implies a battery life extension in hybrid case superior to three times

Refs.: L. Barelli et al. Energy 173 (2019) 937e950. doi: 10.1016/j.energy.2019.02.143
D. Ciupageanu, L. Barelli, A. Ottaviano. D. Pelosi, G. Lazaroiu. ISGT-Europe 2019. doi: 10.1109/ISGTEurope.2019.8905775

HESS application to large scale RES plant: wind

Problem formulation

- ***Selected variables***: $\theta = [q_{batt} \quad q_{fw} \quad q_{grid}]$ - shares vector

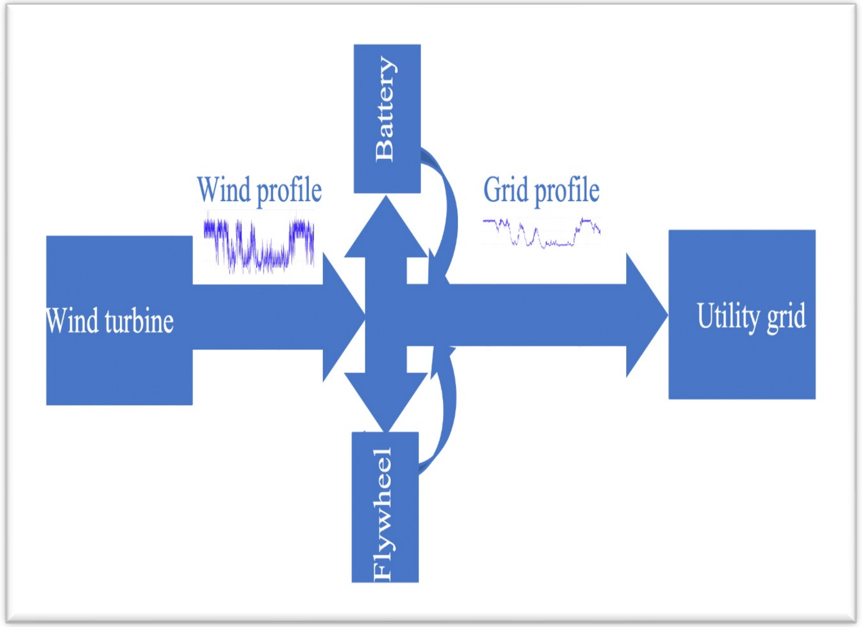
$$P_{batt} = q_{batt} \cdot \Delta P \qquad P_{fw} = q_{fw} \cdot \Delta P \qquad P_{grid} = q_{grid} \cdot \Delta P$$

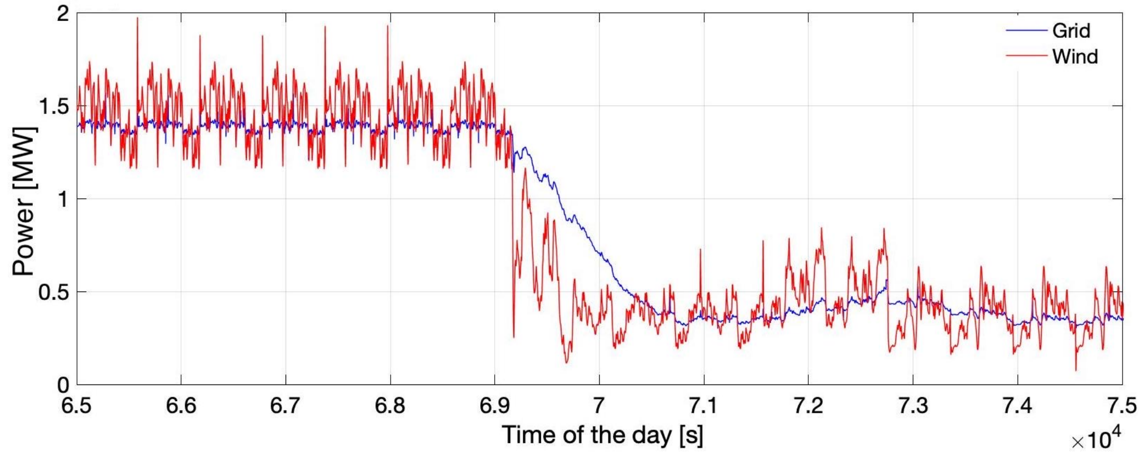
where: $\Delta P = P_{wind}^{t} - P_{grid}^{t-1}$

- ***Problem objectives***:

➢smooth power profile delivered/absorbed by the battery: $y_2^k(\theta) = \left(\frac{q_{batt} \cdot \Delta P}{P_{batt}^{t-1}}\right)^2$

➢multi-objective aggregate: $y^k(\theta) = w_1 \cdot y_1^k(\theta) + w_2 \cdot y_2^k(\theta)$, where $w_1 = w_2 =$





➢ 80% reduction in power ramp at the grid interface

➢ the battery profile power ramp is reduced by 65% compared to the flywheel → highly fluctuating oscillations are managed by the flywheel, while the battery provides energy support.

➢ daily energy delivered to the grid/produced wind energy of 96% as average value over simulated days

Ref.: L. Barelli et al. Journal of Energy Storage. 31 (2020) 101650. doi: 10.1016/j.est.2020.101650

HESS application to large scale RES plant: wind

Problem formulation

- ***Selected variables***: $\theta = [q_{batt} \quad q_{fw} \quad q_{grid}]$ - shares vector

$$P_{batt} = q_{batt} \cdot \Delta P \qquad P_{fw} = q_{fw} \cdot \Delta P \qquad P_{grid} = q_{grid} \cdot \Delta P$$

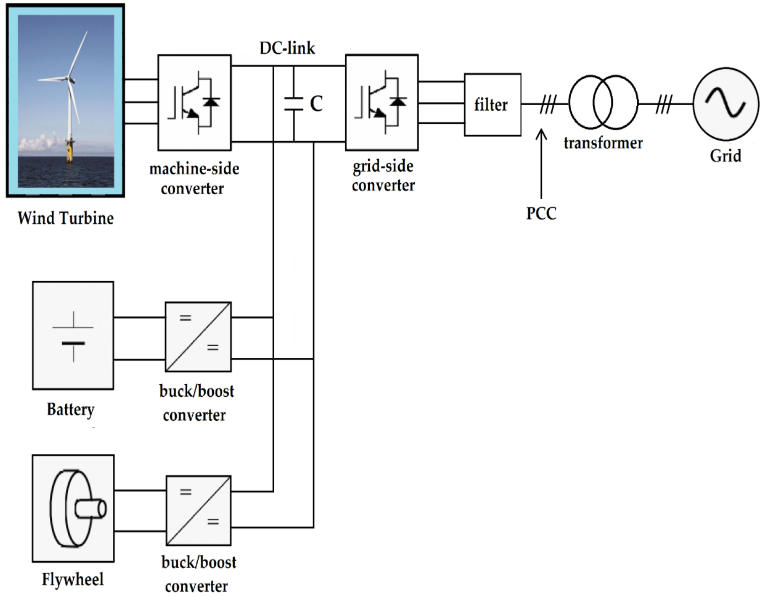
where: $\Delta P = P_{wind}^{t} - P_{grid}^{t-1}$

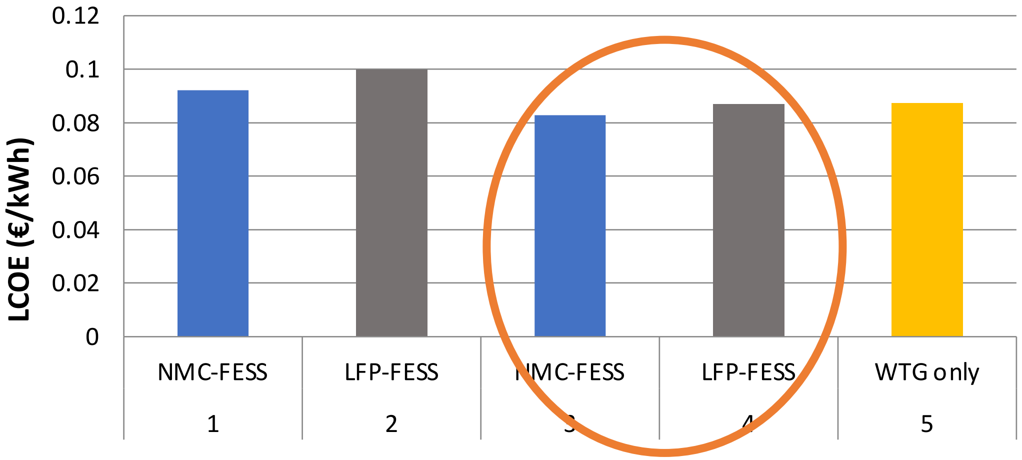
- ***Problem objectives***:

➢smoothing grid profile: $y_1^k(\theta) = \left(\frac{q_{grid} \cdot \Delta P}{P_{grid}^{t-1}}\right)^2$

➢smooth power profile delivered/absorbed by the battery: $y_2^k(\theta) = \left(\frac{q_{batt} \cdot \Delta P}{P_{batt}^{t-1}}\right)^2$

➢multi-objective aggregate: $y^k(\theta) = w_1 \cdot y_1^k(\theta) + w_2 \cdot y_2^k(\theta)$, where $w_1 = w_2 =$ 0.5





➢ NMC battery+FESS → peak-shaving function acting towards the battery allows its lifespan extension. This positively impacts LCOE, which increases only of 5.6% with respect to the reference case.

➢ Considering the remuneration of power reserve ancillary function ("Fast Reserve" call by Terna S.p.A), the LCOE is even reduced of 5.3% with respect to the reference case of energy storage absence.

Ref: L. Barelli et al. Journal of Energy Storage 34 (2021) 102050. doi: 10.1016/j.est.2020.102050

HESS application to large scale RES plant: wave

Problem formulation

- ***Selected variables***: $\theta = [q_{batt} \quad q_{fw} \quad q_{grid}]$ - shares vector

$$P_{batt} = q_{batt} \cdot \Delta P \qquad P_{fw} = q_{fw} \cdot \Delta P \qquad P_{grid} = q_{grid} \cdot \Delta P$$

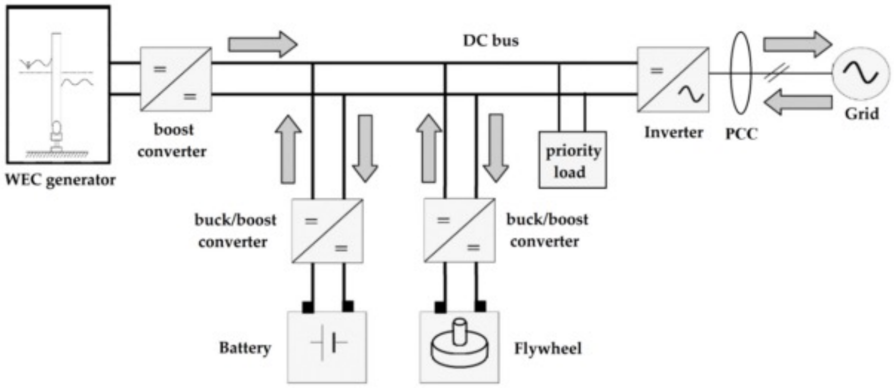
where: $\Delta P = P_{wind}^{t} - P_{grid}^{t-1}$

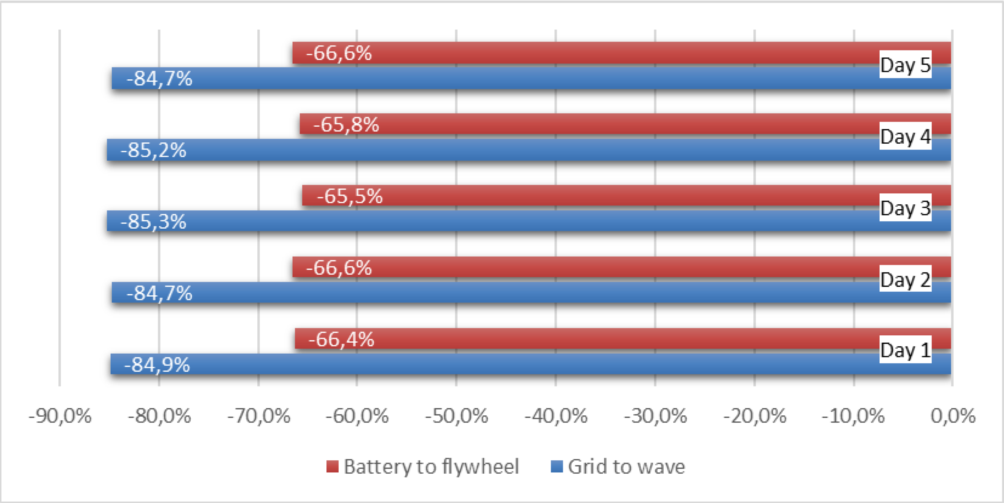
- ***Problem objectives***:

➢ smooth grid profile: $y_1^k(\theta) = \left(\frac{q_{grid}\cdot\Delta P}{P_{grid}^{t-1}}\right)^2$

➢ smooth power profile delivered/absorbed by the battery: $y_2^k(\theta) = \left(\frac{q_{batt}\cdot\Delta P}{P_{batt}^{t-1}}\right)^2$

➢ multi-objective aggregate: $y^k(\theta) = w_1 \cdot y_1^k(\theta) + w_2 \cdot y_2^k(\theta)$, where $w_1 = w_2 =$





With reference to the 90% CDF threshold:

➢ over 80% reduction in power ramp at the grid interface

➢ battery solicitations are reduced of about 65-66% with respect to flywheel fluctuations.

➢ daily energy delivered to the grid/produced wave energy of 95% as average value over simulated days

Ref: Barelli L et al., Open Res Europe 2022, 2:40 - https://doi.org/10.12688/openreseurope.14062.1

HESS application to large scale RES plant: wave

Problem formulation

- ***Selected variables***: $\theta = [q_{batt} \quad q_{fw} \quad q_{grid}]$ - shares vector

$$P_{batt} = q_{batt} \cdot \Delta P \qquad P_{fw} = q_{fw} \cdot \Delta P \qquad P_{grid} = q_{grid} \cdot \Delta P$$

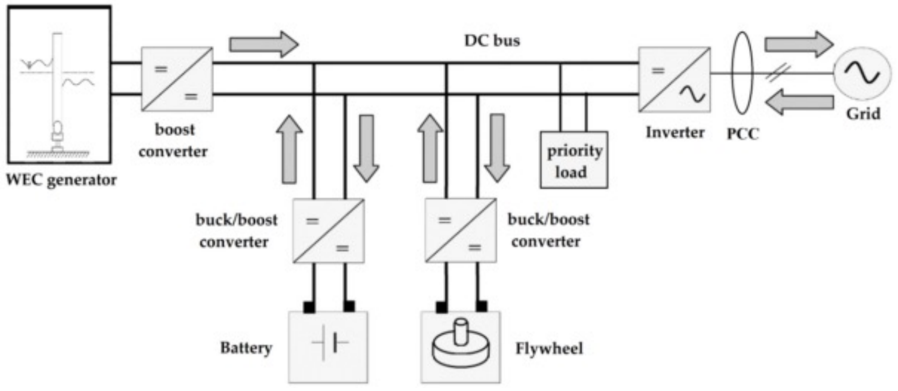
where: $\Delta P = P_{wind}^{t} - P_{grid}^{t-1}$

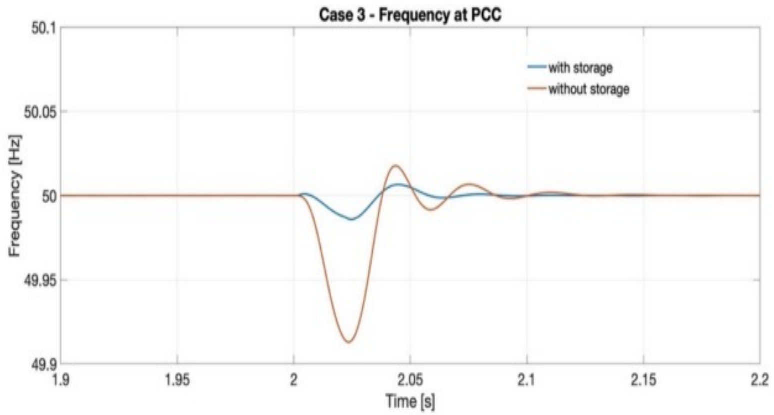
- ***Problem objectives***:

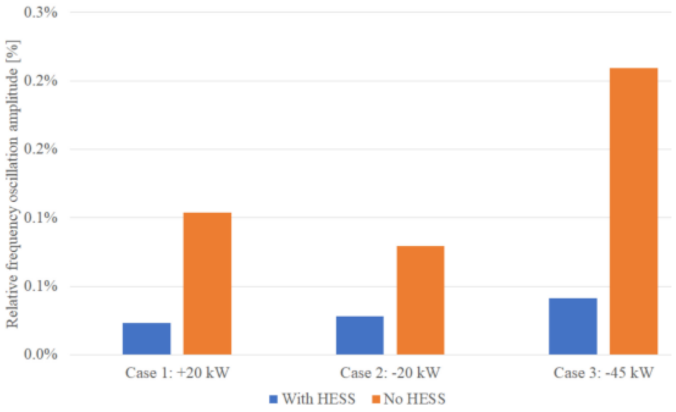
➢smooth grid profile: $y_1^k(\theta) = \left(\frac{q_{grid}\cdot\Delta P}{P_{grid}^{t-1}}\right)^2$

➢smooth power profile delivered/absorbed by the battery: $y_2^k(\theta) = \left(\frac{q_{batt}\cdot\Delta P}{P_{batt}^{t-1}}\right)^2$

➢multi-objective aggregate: $y^k(\theta) = w_1 \cdot y_1^k(\theta) + w_2 \cdot y_2^k(\theta)$, where $w_1 = w_2 =$







Grid Power quality enhancement:

- ➢ peak value of the voltage wave frequency at the PCC is reduced up to 80% (64% min)
- ➢ stabilization is faster with respect to storage absence, reaching the nominal value in a shorter time (up to 42% of reduction for the largest WEC power sudden variation, i.e. Case 3)

Ref: Barelli L et al., Energies 2022, 15(1), 10 - https://doi.org/10.3390/en15010010

Thank you!

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Energy storage in future power grids - potential sustainability challenges

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Universidad Alcala

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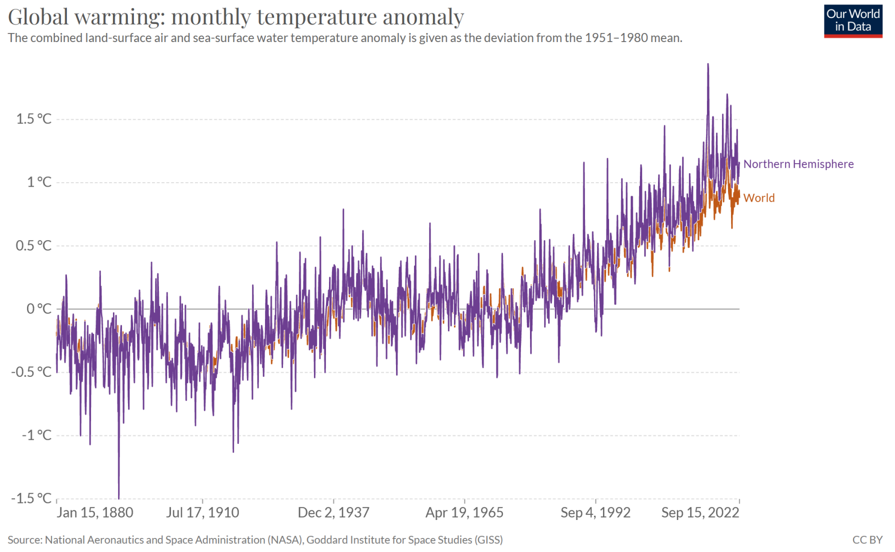
SUPEERA Workshop: Bringing research and industry closer: Energy storage and CSP/CST 15 and 16th of November

Why is the topic sustainability important?

- Climate Change, Planetary limits….
- Sustainability development goals (SDG)
- European Green Deal
- Sustainable Finance & Taxonomy Regulation
- A new Circular Economy Action Plan
- EU Battery directive
- ….



https://ourworldindata.org/explorers/climate-change?facet=none&Metric=Temperature+anomaly&Long-run+series%3F=false&country=ATA~Gulkana+Glacier~Lemon+Creek+Glacier~North+America~South+Cascade+Glacier~Wolverine+Glacier~Northern+Hemisphere~GRL~OWID_WRL

Source: https://www.unep.org/interactive/measuring-progress-environment-sdgs/

European Commission

Green Deal: Sustainable batteries for a circular and climate neutral economy

Source: https://ec.europa.eu/commission/presscorner/api/files/document/print/en/ip_20_2312/IP_20_2312_EN.pdf

Source: https://innovatives-brandenburg.de/de/news/der-europaeische-green-deal

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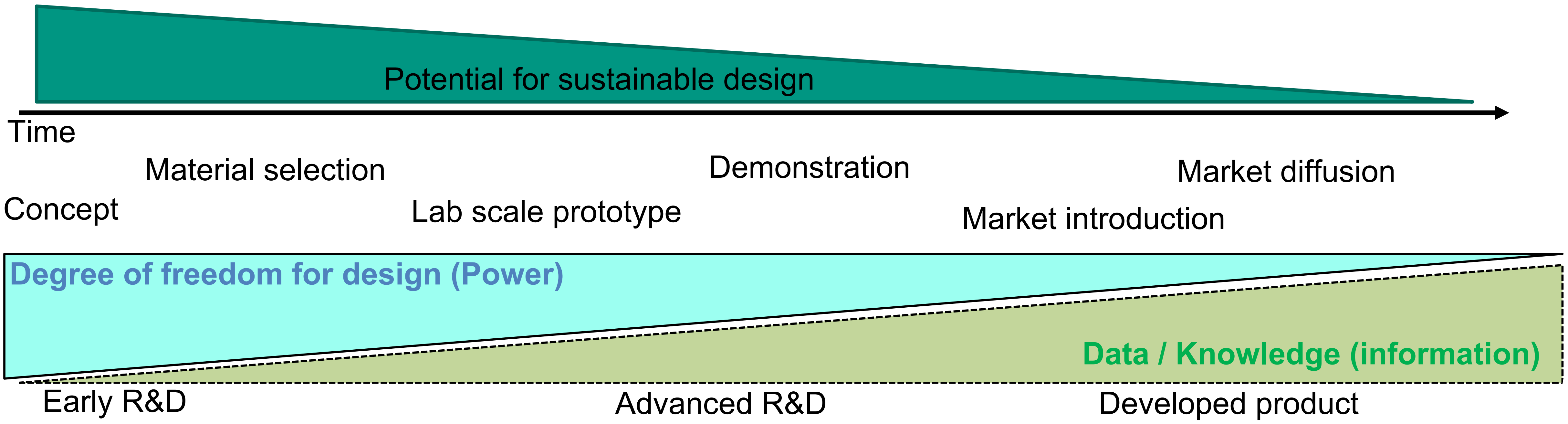
Sustainability Challenges

- Sustainability assessment - in early technology development stages opportunities to steer are plentiful, but hard to choose from, while at later stages this is reversed



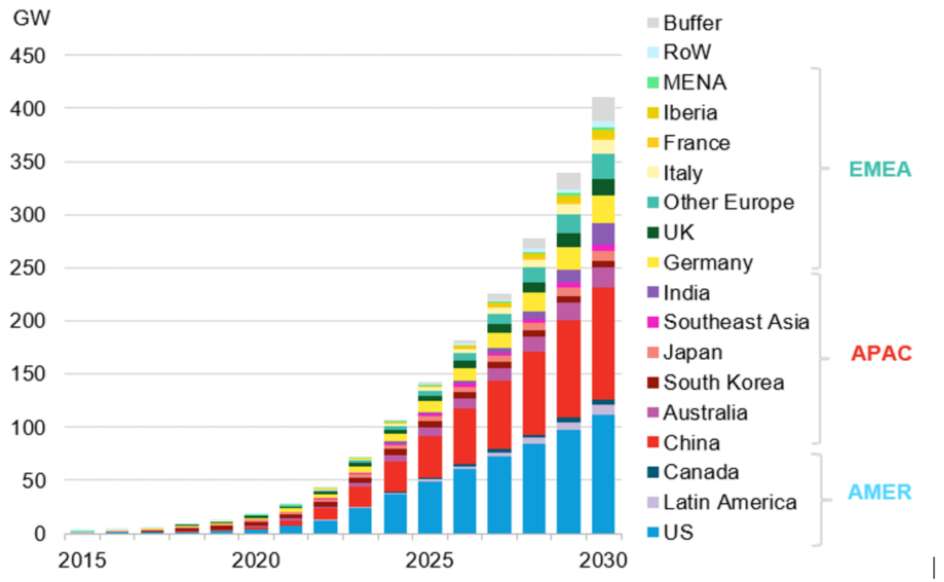
D. Collingridge, *The social control of technology*. New York: St. Martin's Press, 1980.

Energy Storage

- Energy transition → Renewables
- +387GW / 1,143GWh 2022 to 2030
- Significant ramp-up in capacity fueled by the current energy crisis
- Scaling up for a market expected to add almost 11 times more gigawatt-hours in 2030 than 2021
- Evolving battery technology is driving the energy storage market
- **Supply chain constraints could slow additions → Raw material criticality**

https://about.bnef.com/blog/global-energy-storage-market-to-grow-15-fold-by-2030/

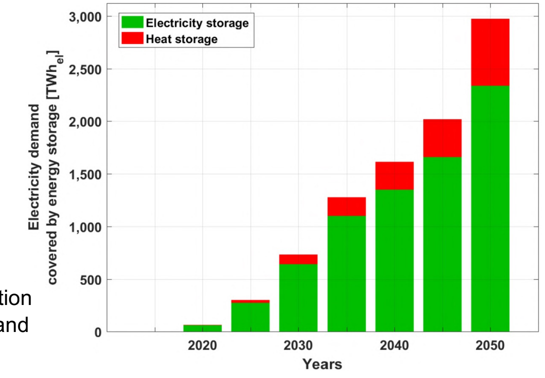
Figure 1: Global cumulative energy storage installations, 2015-2030



Source: BloombergNEF. Note: "MENA" refers to the Middle East and North Africa; "RoW" refers to the rest of the world. "Buffer" represents markets and use cases that BNEF is unable to forecast due to lack of visibility.

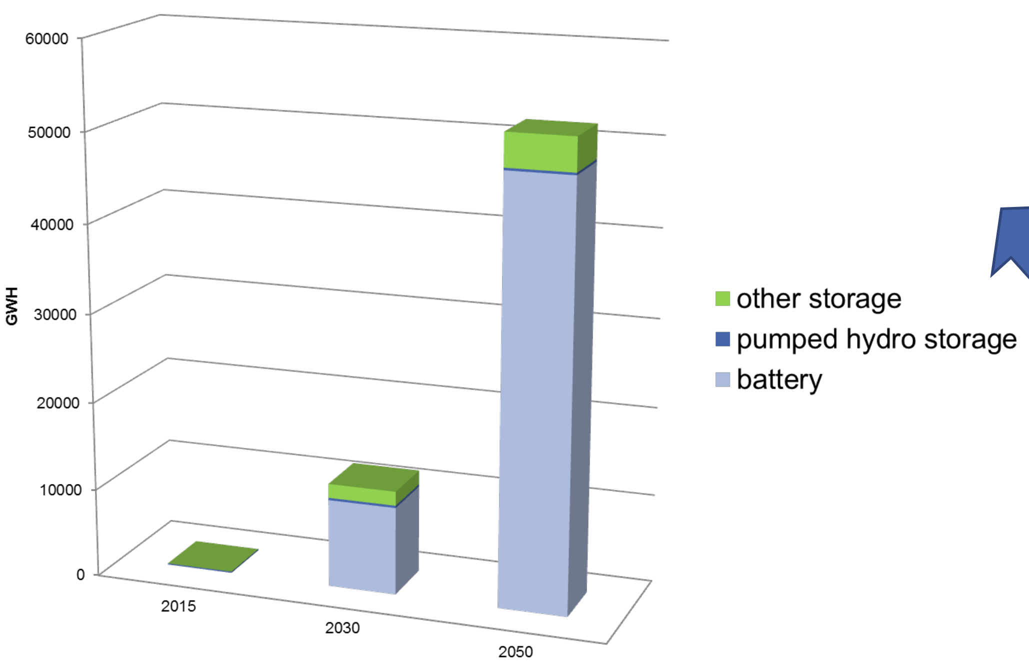
Several studies point at same direction

Ram M., et al. C. Global Energy System based on 100% Renewable Energy – Power, Heat, Transport and Desalination Sectors. Study by Lappeenranta University of Technology and Energy Watch Group, Lappeenranta, Berlin, March 2019

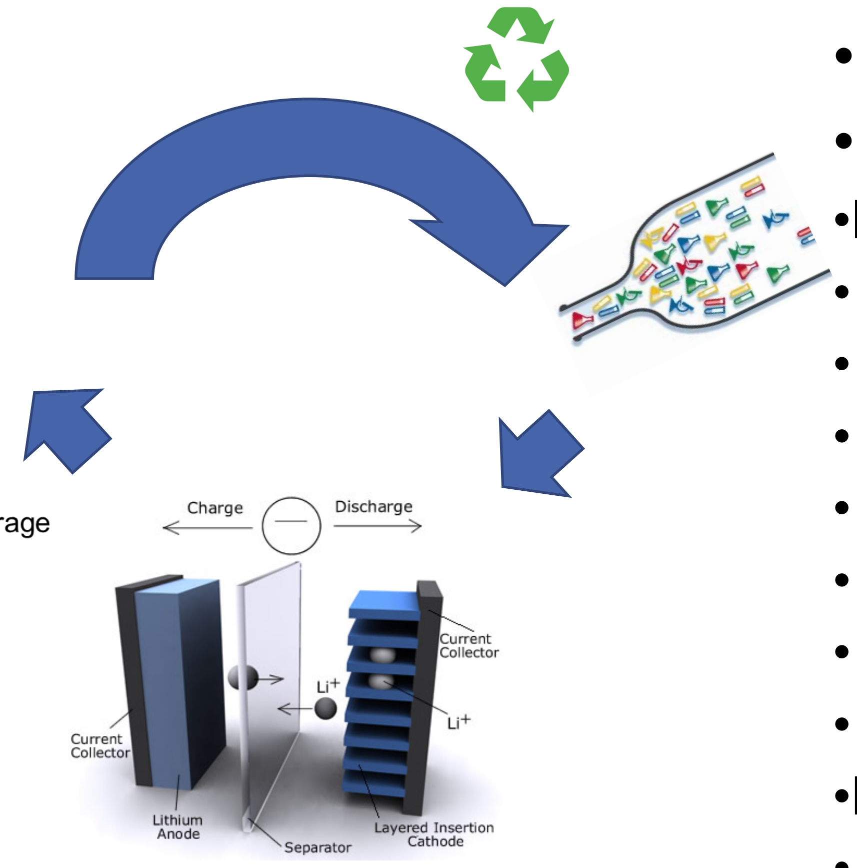


Demand for raw materials

Global Storage Capacity until 2050

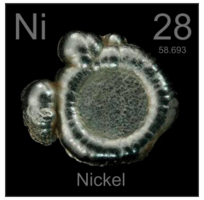


[Based on EnergyWatchGroup 2017]



[https://enerdel.com]

- **Co**
- **Li**
- **Ni**
- Mn
- **Cu**
- **V**
- **C**
- La
- Ge
- Gr
- **P**
- ...



Need for new technologies

Raw material criticality

- No common standard for raw material criticality assessment but rather several methods and indicators to analyze raw material criticality with varying spatial and technological and socio-economic scopes

- Supply Risk (SR) → composite index characterizing the risk of a disruption in supply of a specific material[1]

e.g. global supply and sourcing countries mixes (described by the Herfindahl-Hirschman Index HHI), import reliance, supplier countries' governance performance (World Governance Index (WGI) [53]), trade restrictions and agreements, availability and criticality of substitutes as well as end-of-life recycling input rate (EOL RIR).

Example: Lithium & Sodium-Ion Batteries

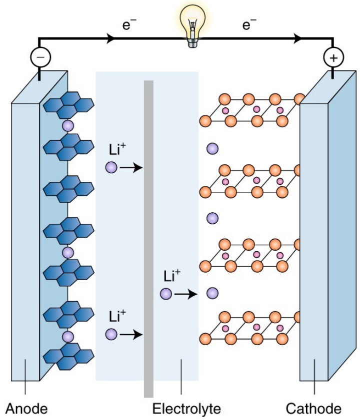
- SIB are based on essentially the same principle like LIB
- **Sodium** instead of **lithium** in the cathode active material and electrolyte salt
- **Aluminium** instead of **copper** for the current collector
- Use of several cathode materials

Li-Ion Batteries

„Same, same but different „

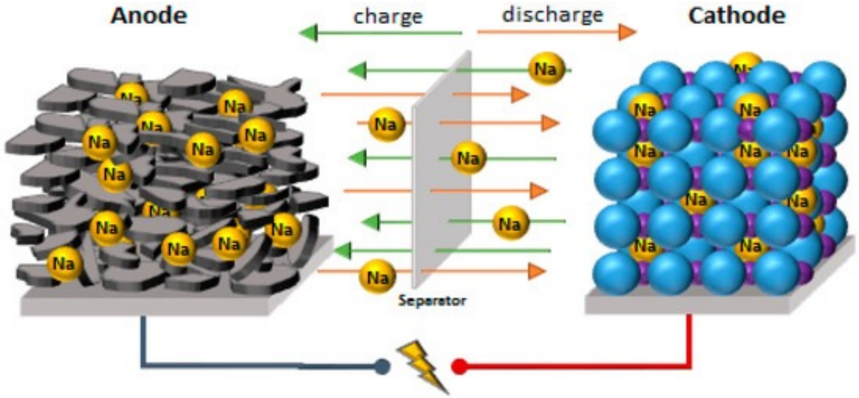
Na-Ion Batteries

Anode Materials:
Graphite
Metallic Li



Li-Cathode Materials:
Ni
Co
Mn
FePO4
Al
…

Anode Materials:
Hard Cabon
Metallic Na



Na-Cath. Materials:
Ni
Mn
FePO4
Ti
Al
…

Goodenough, J.B. How we made the Li-ion rechargeable battery. Nat Electron 1, 204 (2018). https://doi.org/10.1038/s41928-018-0048-6

J. F. Peters, A. Peña Cruz, und M. Weil, „Exploring the Economic Potential of Sodium-Ion Batteries“, *Batteries*, Bd. 5, Nr. 1, S. 10, März 2019, doi: 10.3390/batteries5010010.

Example: Lithium & Sodium-Ion Batteries Raw Material Criticality

Karlsruhe Institute of Technology

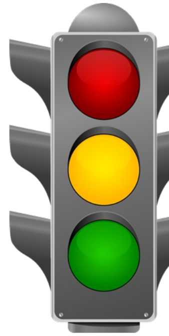
Element	EU Supply Risk (SR^{EU})	Economic importance	EOL RIR [%]	Import reliability [%]	Nasser et al. Supply Risk	British geological survey Risk Index	Hayes et al - USGS Review	Static range [y]	Resources - qualitative scale	CRI	HHI	Three main suppliers (int. Country codes) by global share	Level
Scope	Europe				US	N/A	Global	Global	Global	Global			
Al	**0.6**	5.4	12	59	0.6	4.8	33	153	3	0.00	3,456	CN 55%, RU 5.7%, IND 4,6%	Processing
Co	**2.5**	5.9	22	86	0.6	8.1	73	49	1	-1.50	5,316	CD 72.4 %, AU 3.7 %, RU 3.5 %	Mining
F	**1.2**	3.3	1	66	0.3	6.7	57	44	3	-0.35	3,678	CN 52,7% , MX 29.5 %, VN 3.6%	Mining
Fe	**0.5**	6.8	31	72	0.1	5.2	25	64	3	0.50	2,030	AU 36.8%, BR 19.3%, CN 13.8%	Mining
Li	**1.6**	3.1	0	100	0.35	7.6	40	240	2	1.16	4,184	AU 60.9%, CL 19%, CN 7.5%	Mining
Mg	**3.9**	6.6	13	100	0.4	7.6	75	954	3	-0.25	8,291	CN 90.9%, USA 3.2%, IL 2.2%	Processing
Mn	**0.9**	6.7	8	90	0.35	5.7	40	68	3	0.08	1,487	ZA 28%, AU 16.9%, GA 13.6%	Mining
Na	**0**	0	0	0	0	0	0	1000	3	N/A	N/A	N/A	N/A
Ni	**0.5**	4.9	17	28	0.4	5.7	19	38	2	0.26	1,420	CN 31.3%, ID 13.2%, JP 8.5%	Processing
P	**1.1**	5.6	17	84	0.25	0	40	282	3	-0.13	2,147	CN 41.1%, MA 15.6%, USA 10.3%	Processing
S	**0.3**	4.1	5	0	0	0	0	1000	3	N/A	N/A	N/A	N/A
Si	**1.2**	4.2	0	63	0	0	20	1000	3	0.16	4,148	CN 61.9%, USA 14.8%, BR 6.5%	Processing
Ti	**1.3**	4.7	19	100	0.4	4.8	25	50	2	0.25	856	ZA 14.8%, MZ 12.8%, AU 11.6%	Mining
V	**1.7**	4.4	2	n/a	0.45	8.6	67	271	2	-0.30	4,104	CN 58.7%, RU 18.8%, ZA 16.4%	Mining
Zr	**0.8**	3.2	12	100	0.2	6.4	57	45	2	0.52	2,078	AU 32.3%, ZA 29.5%, USA 8.0%	Mining
min	0	0	0	0	0	1	0	12	1	-2.50	0		
max	7	9	100	100	1	10	100	1000	3	2.50	10,000		
Treshhold	1	2.75	N/A	N/A	N/A	N/A	N/A	N/A		A	B		

A) CRI= interval of -2,5 to 2,5. Values below -0.5 indicate a high risk, whilst values over 0.5 indicate a low country risk.

B) HHI=interval 0-10,000 where 1,500 to 2,500 represent a moderate concentration, over 2,500 represents a very high concentration, 10,000 a monopoly

Resources=qualitatively derived from USGS

Li-Ion



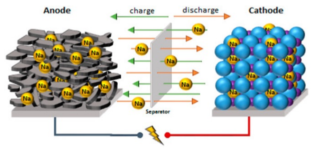
Lower performance

Moderate performance

Good performance

Indicative Traffic light system

Na-Ion



M. Baumann, M. Häringer, M. Schmidt, L. Schneider, J. Peters, W.Bauer, J. R. Binder, and M. Weil, „Prospective Sustainability Screening of Sodium-Ion Battery Cathode Materials, Advanced Energy Materials, 2022, doi: 10.1002/aenm.202202636

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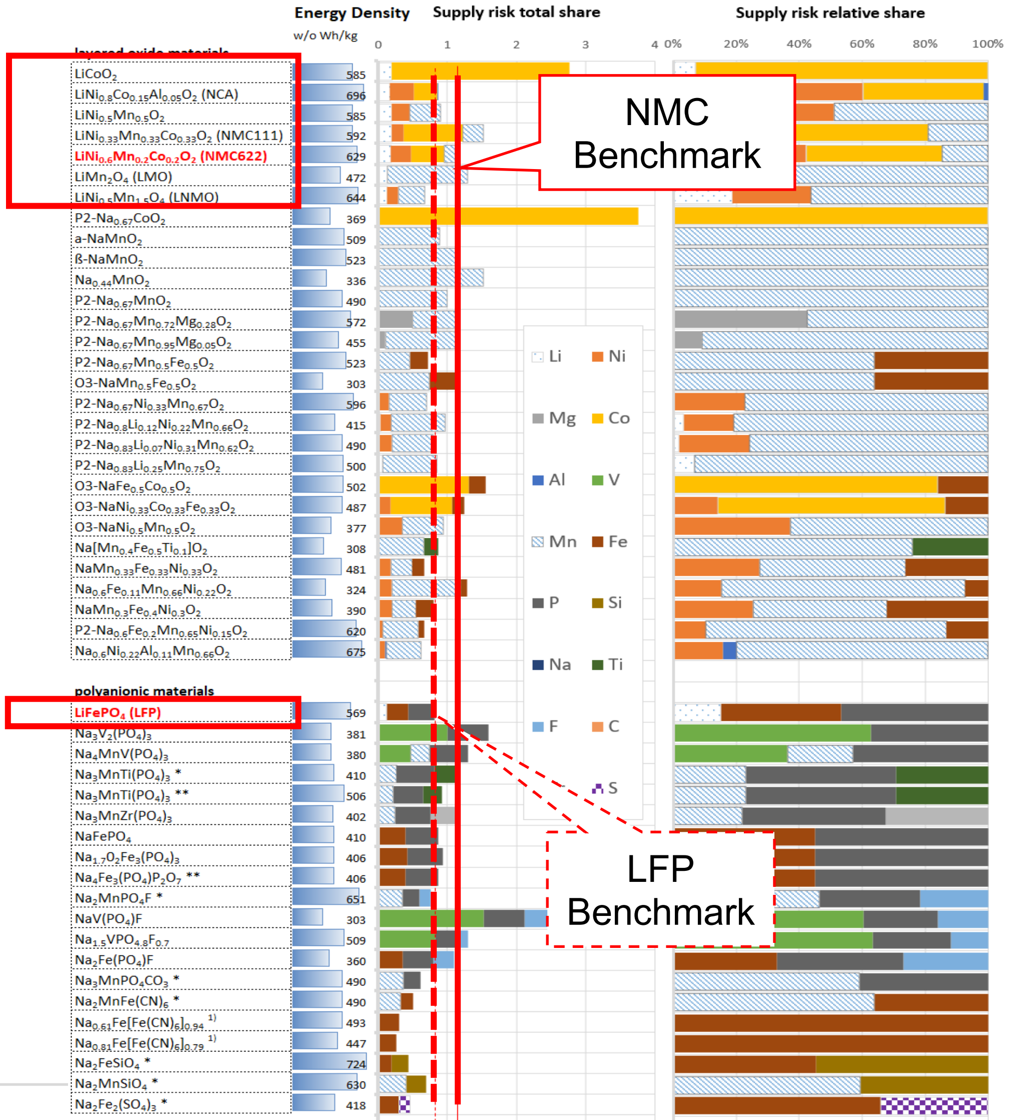
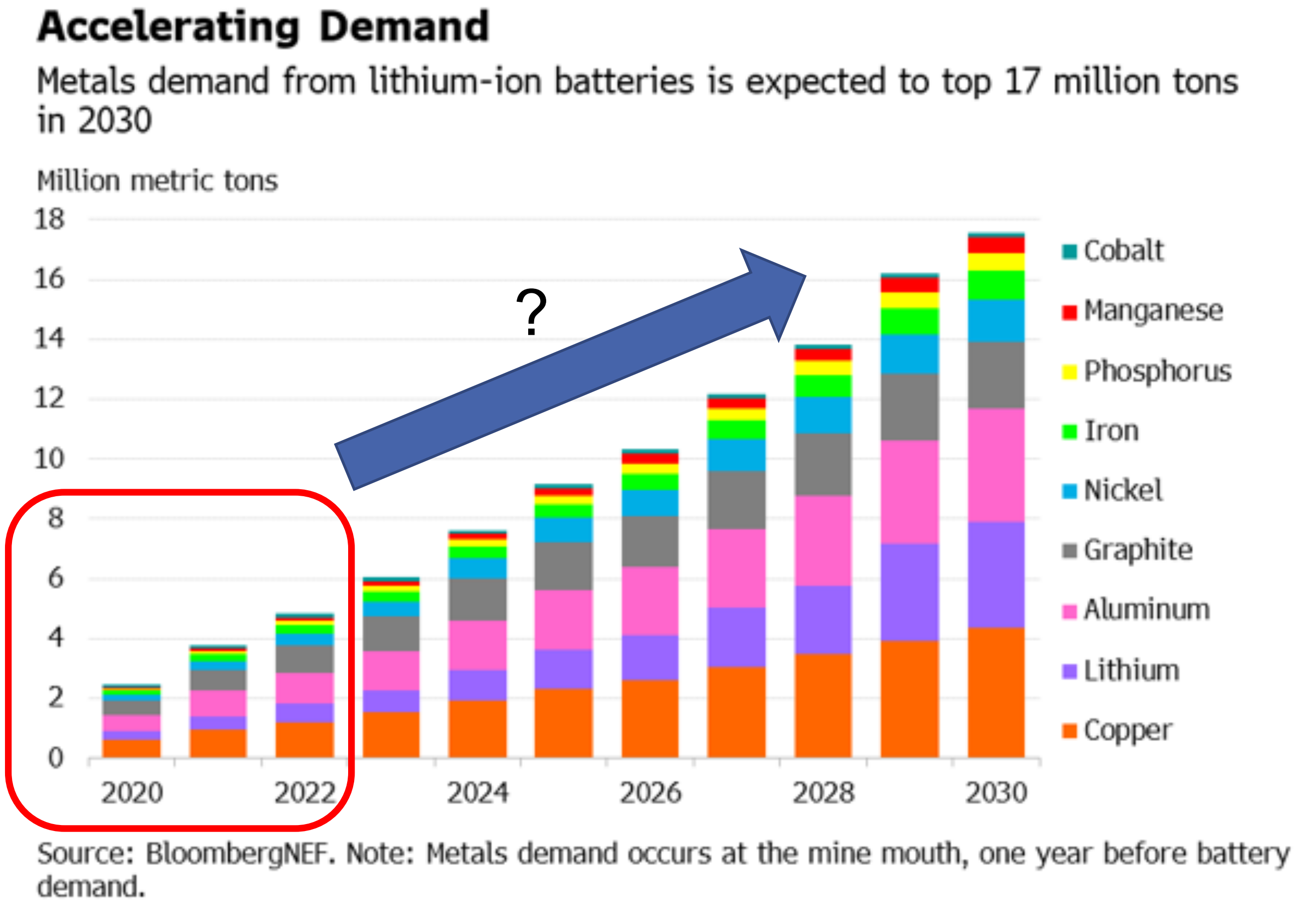
Example: Sodium-Ion Batteries
Raw Material Criticality



Only status quo, criticality can change



https://about.bnef.com/blog/race-to-net-zero-the-pressures-of-the-battery-boom-in-five-charts/

M. Baumann, M. Häringer, M. Schmidt, L. Schneider, J. Peters, W.Bauer, J. R. Binder, and M. Weil, „Prospective Sustainability Screening of Sodium-Ion Battery Cathode Materials, Advanced Energy Materials, 2022, doi: 10.1002/aenm.202202636

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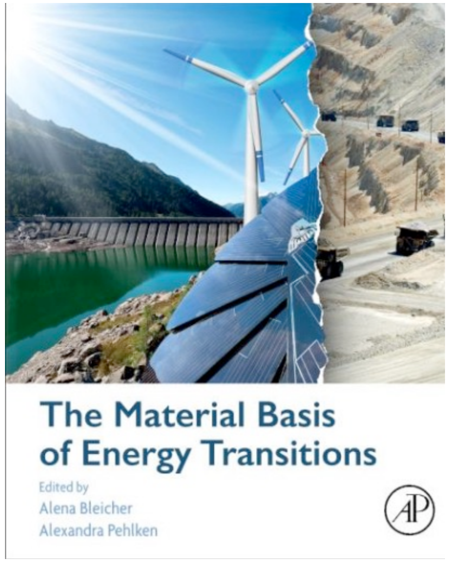
Potential scenarios (simplified)

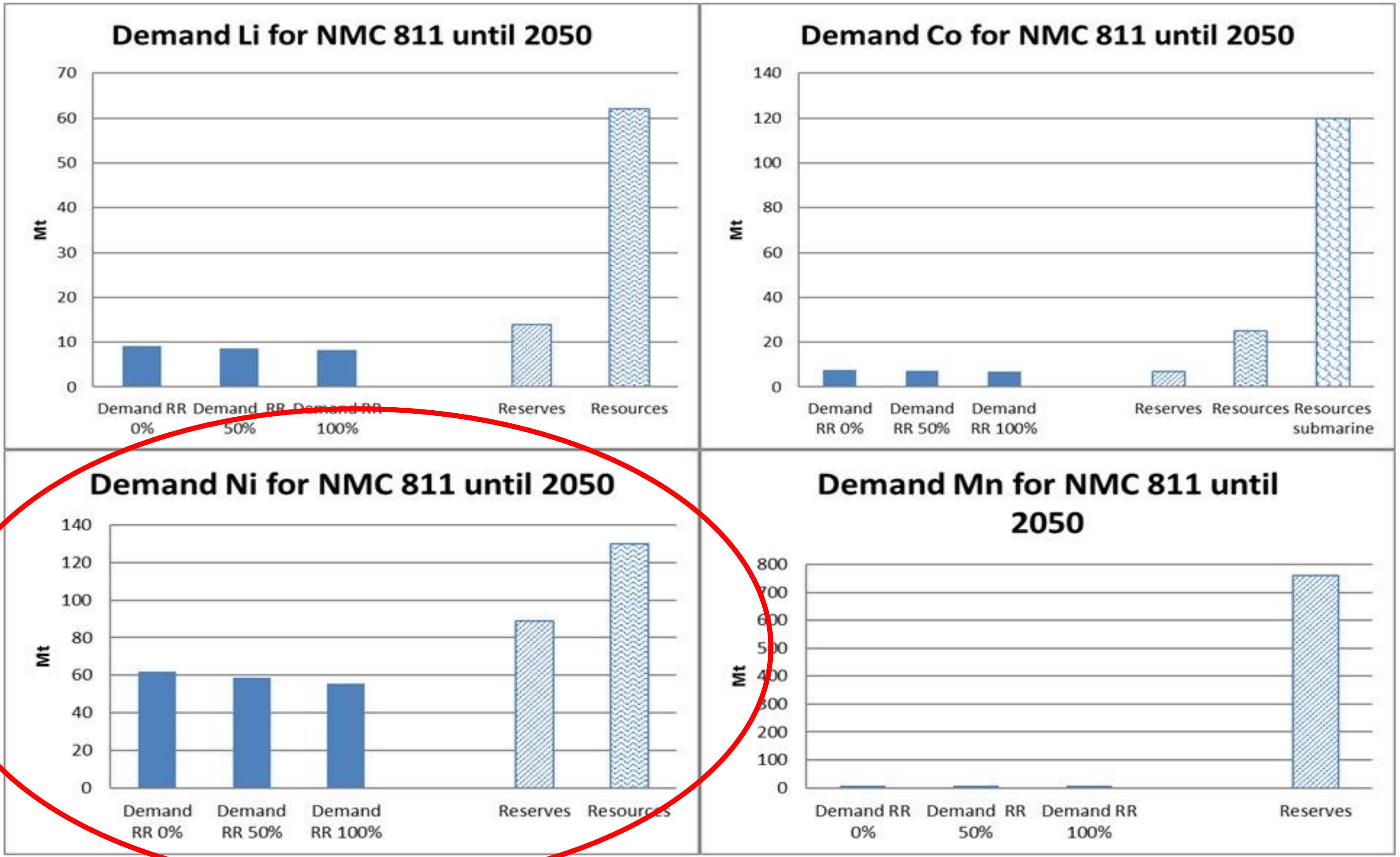


ENERGYWATCHGROUP

Marcel Weil, Jens Peters, Manuel Baumann

Chapter 5: Stationary battery systems: Future challenges regarding Resources, Recycling and Sustainability, 2020

- LFP
- NMC11, 622 and 811
- NCA



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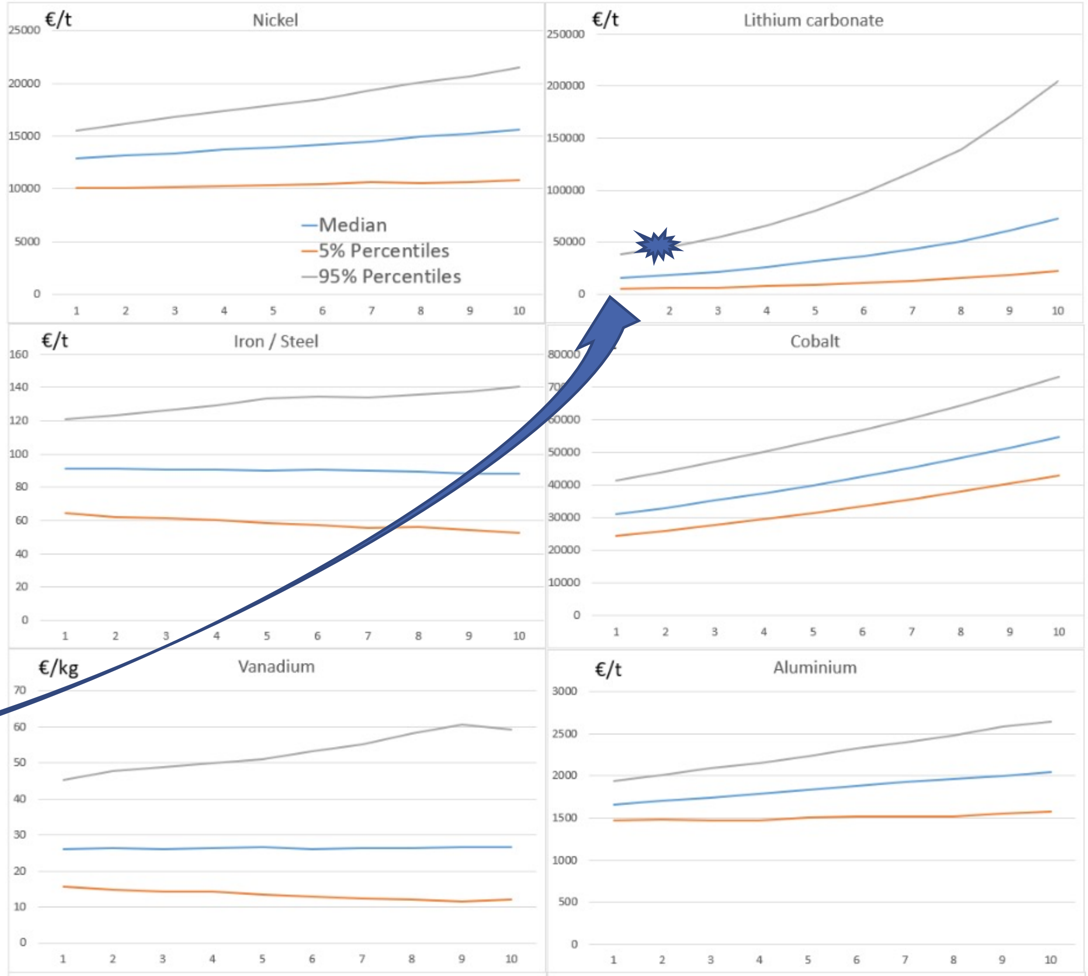
Raw Material Cost

Geometric Brownian motion model price development until 2031

Karlsruhe Institute of Technology

Amid rising raw material and component costs, battery prices could increase for the first time since at least 2010. [BNEF]

Lithium Carbonate (99.5% Battery Grade) price Charts



M. Baumann, M. Häringer, M. Schmidt, L. Schneider, J. Peters, W.Bauer, J. R. Binder, and M. Weil, „Prospective Sustainability Screening of Sodium-Ion Battery Cathode Materials, Advanced Energy Materials, 2022, doi: 10.1002/aenm.202202636

https://about.bnef.com/blog/race-to-net-zero-the-pressures-of-the-battery-boom-in-five-charts/

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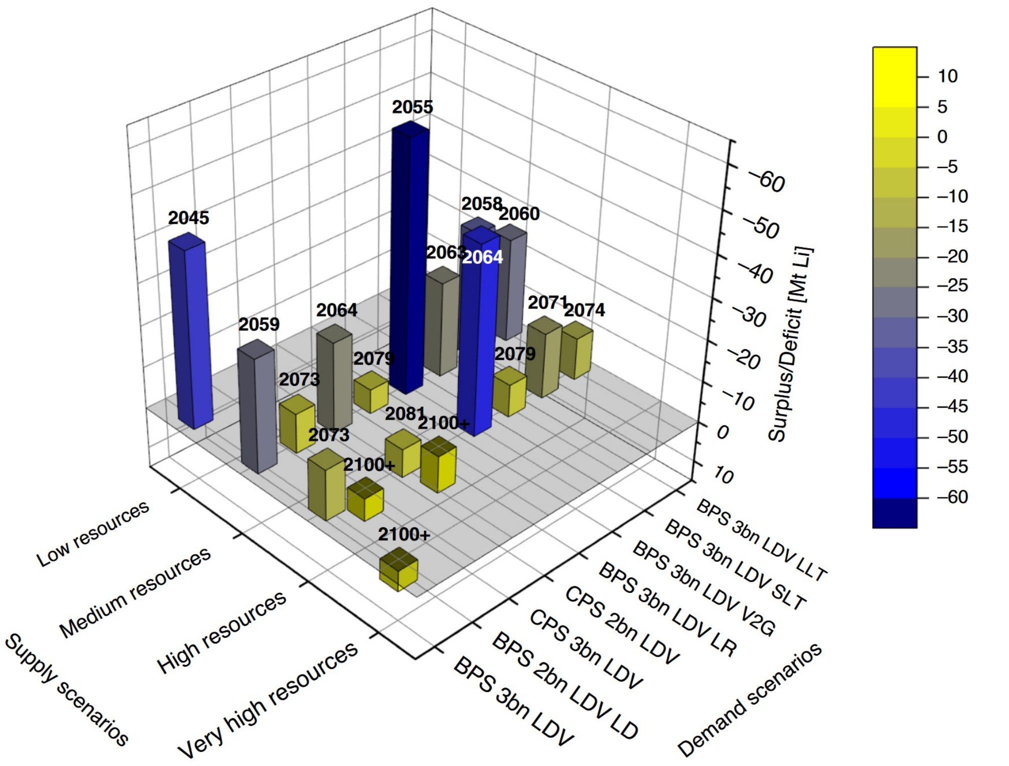
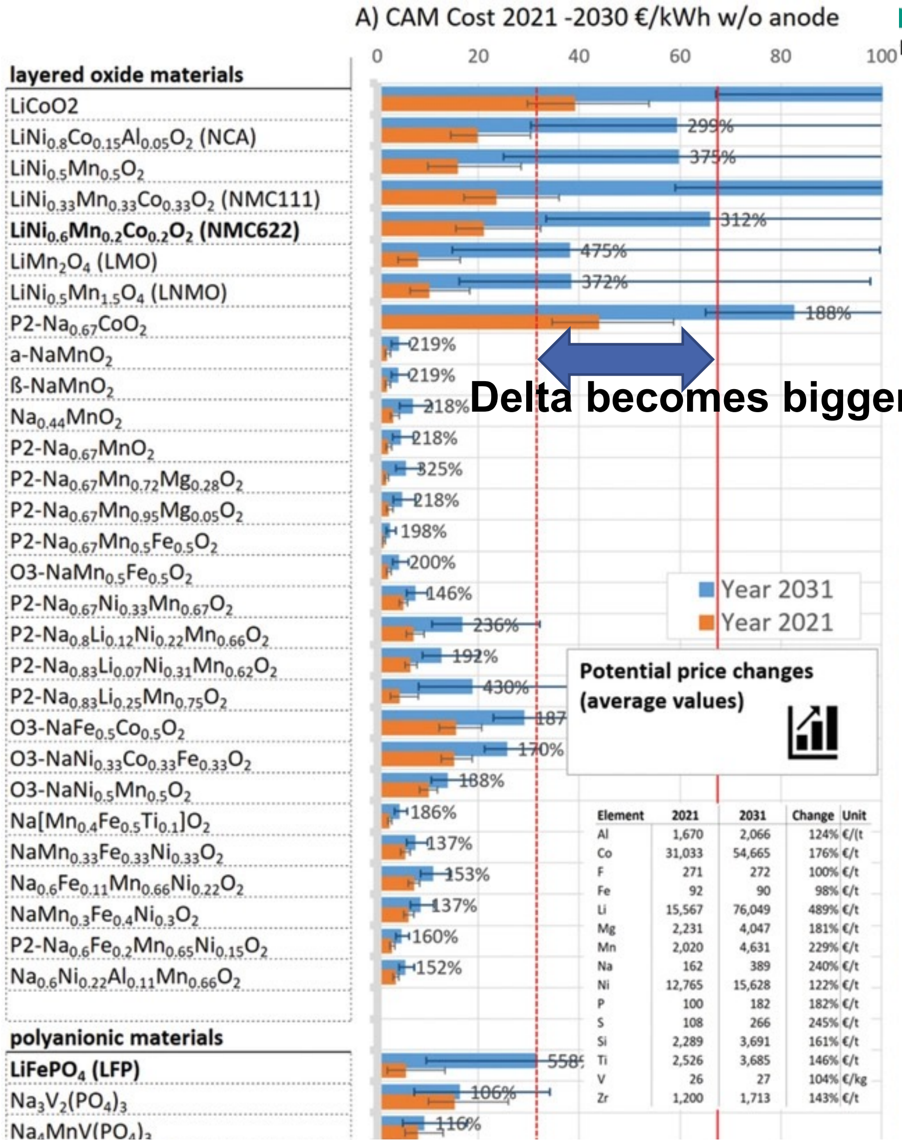
Raw Material Cost

- Demand and raw material price development



Greim, P., Solomon, A.A. & Breyer, C. Assessment of lithium criticality in the global energy transition and addressing policy gaps in transportation. Nat Commun 11, 4570 (2020). https://doi.org/10.1038/s41467-020-18402-y

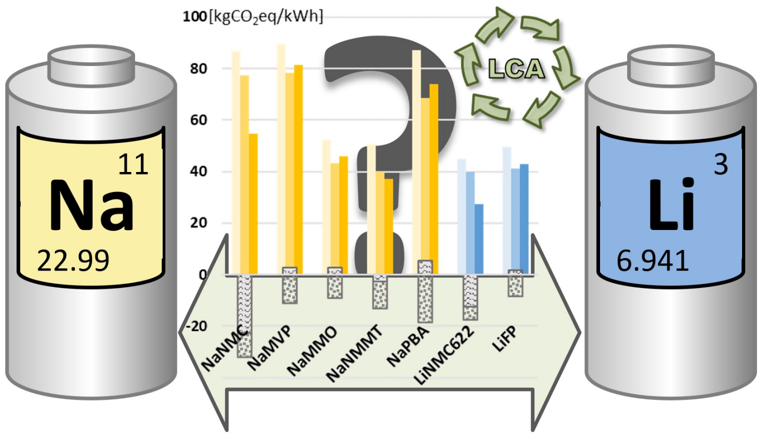
Geometric Brownian motion model
price development until 2031

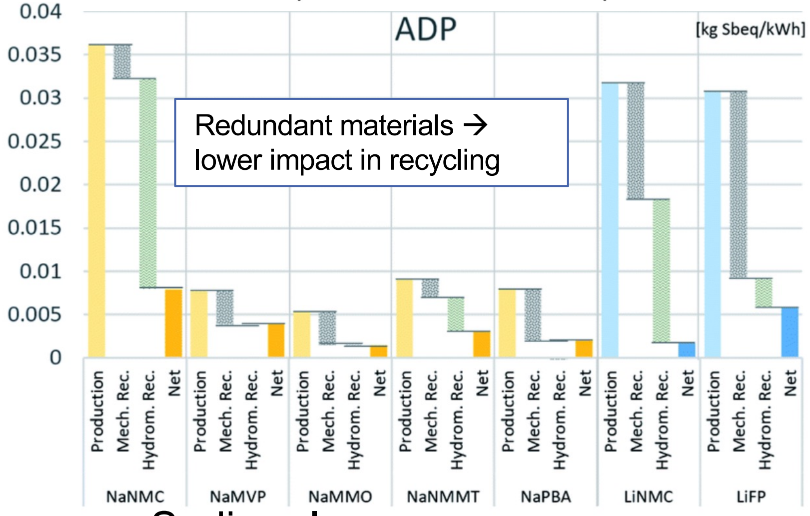


Element	2021	2031	Change	Unit
Al	1,670	2,066	124%	€/(t
Co	31,033	54,665	176%	€/t
F	271	272	100%	€/t
Fe	92	90	98%	€/t
Li	15,567	76,049	489%	€/t
Mg	2,231	4,047	181%	€/t
Mn	2,020	4,631	229%	€/t
Na	162	389	240%	€/t
Ni	12,765	15,628	122%	€/t
P	100	182	182%	€/t
S	108	266	245%	€/t
Si	2,289	3,691	161%	€/t
Ti	2,526	3,685	146%	€/t
V	26	27	104%	€/kg
Zr	1,200	1,713	143%	€/t

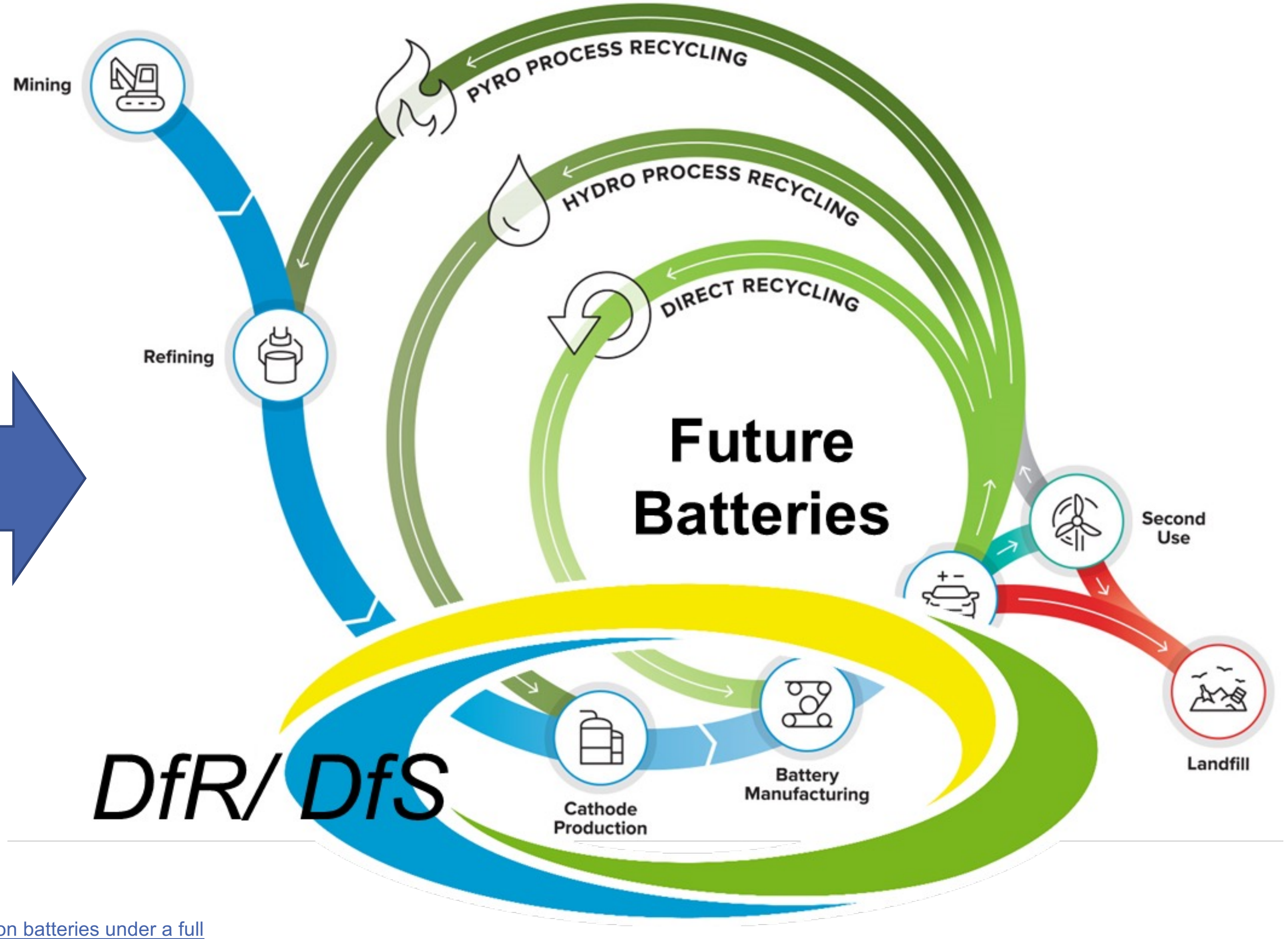
M. Baumann, M. Häringer, M. Schmidt, L. Schneider, J. Peters, W.Bauer, J. R. Binder, and M. Weil, „Prospective Sustainability Screening of Sodium-Ion Battery Cathode Materials, Advanced Energy Materials, 2022, doi: 10.1002/aenm.202202636

Impact of recycling





Sodium-Ion Lithium-Ion



Peters, J. F.; Baumann, M.; Binder, J. R.; Weil, M. On the environmental competitiveness of sodium-ion batteries under a full life cycle perspective – a cell-chemistry specific modelling approach 2021. Sustainable energy & fuels. doi:10.1039/d1se01292d

Conclusion and Questions

- Sustainability assessment in early TRL research
- Supply chains are crucial & criticality can change
- Recycling alone not be enough to avoid potential resource limitations
- Technologies based on abundant materials are part of the solution (e.g. Na, Mg)
- A combination of storage technologies (as well as other flexibility options for grid applications)

StoRIES
Storage Research Infrastructure Eco-System

Follow our work!
https://www.storiesproject.eu/

Questions:

- Do you consider Sustainability aspects as raw materials criticality relevant in the development of (your) technology and if yes, why?
- Is the topic being addressed sufficiently in science and industry?

Thank you for your attention!

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http://www.itas.kit.edu/

Research for Sustainable Energy Technologies (RESET)

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Literature

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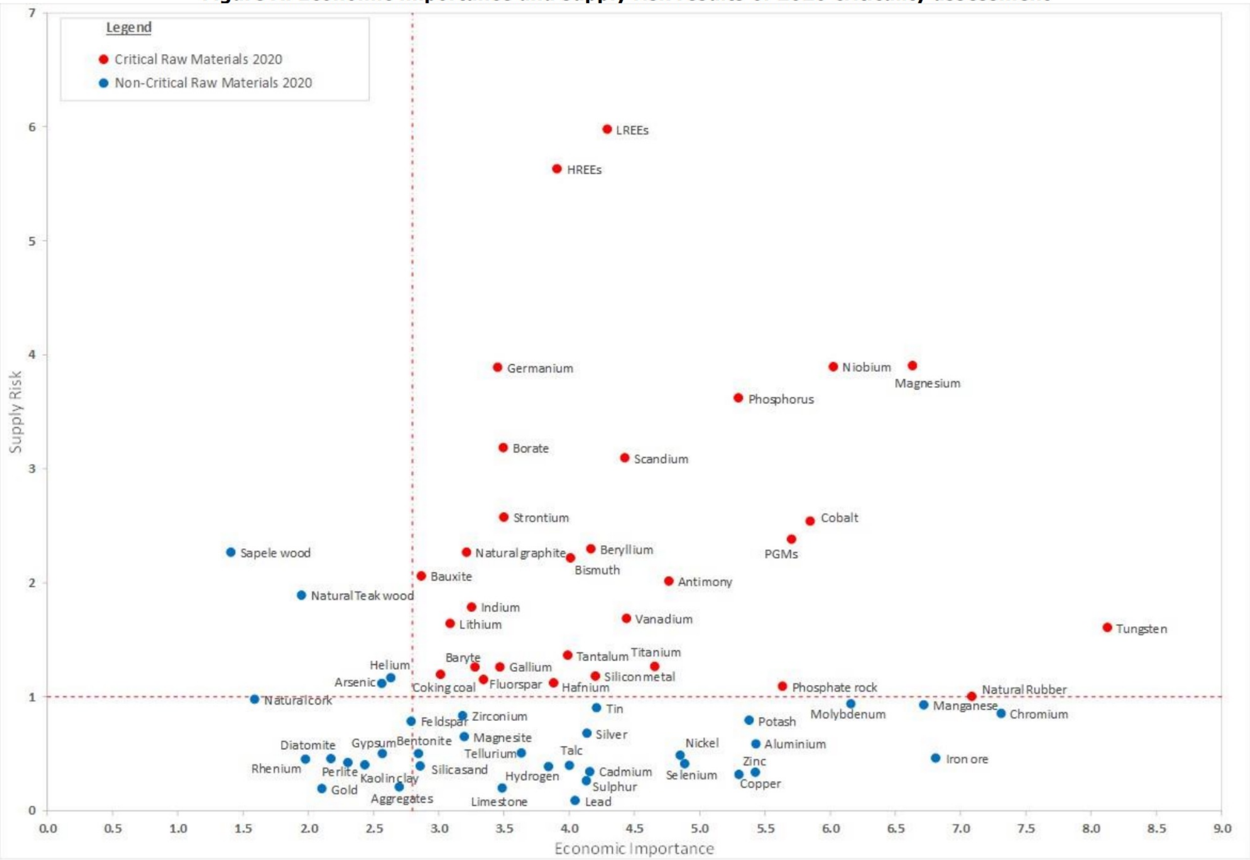
- SR^{EU} considers several factors characterizing the risk of a disruption in the supply of a specific material, including supply country mixes, import reliance, supplier countries' g
and agreements, availability a
recycling input rate.

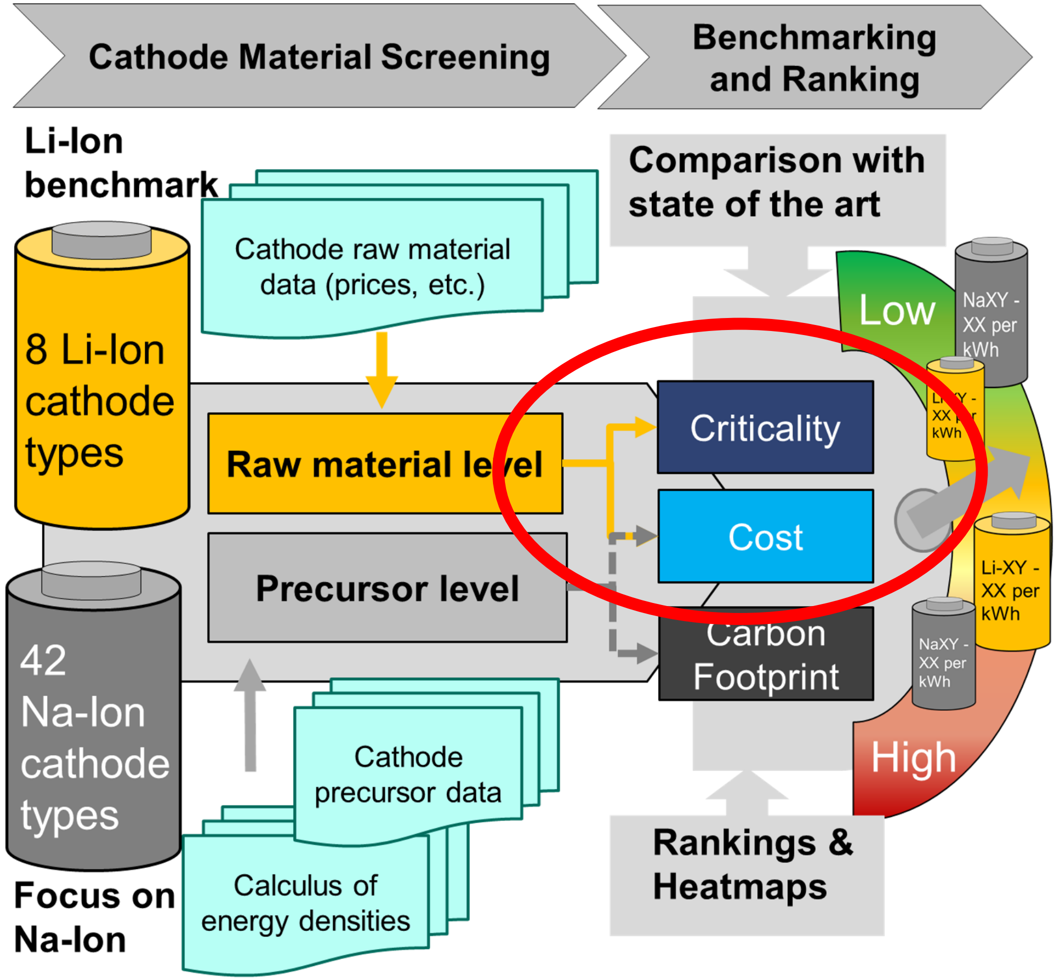


Example: Sodium-Ion Batteries

- **What:** Cathode materials benchmarking
- **How:** Screening of 49 cathodes
- **Data:** Theoretical data
- **Level:** Early R&D, Lab-scale
- **Target group:** Developers…

Separation of cathode materials into:

- Oxidic Materials (NMC622 Benchmark)
- Polyanionic Materials (LFP Benchmark)



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