REACT Renewable Energy for Self-Sustainable Island Communities

REACT, small islands and their path towards green energy independence

SUSTAINABLE PLACES 2023

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Motivation of the REACT project

Energy cost overrun

- High dependency on the mainland energy market
- Losses during the transport and distribution of electrical energy (inefficient and costly energy transmission)

Fossil fuel consumption

- Lack of a strong generation/supply infrastructure
- High dependency on the energy import
- High GHG emissions

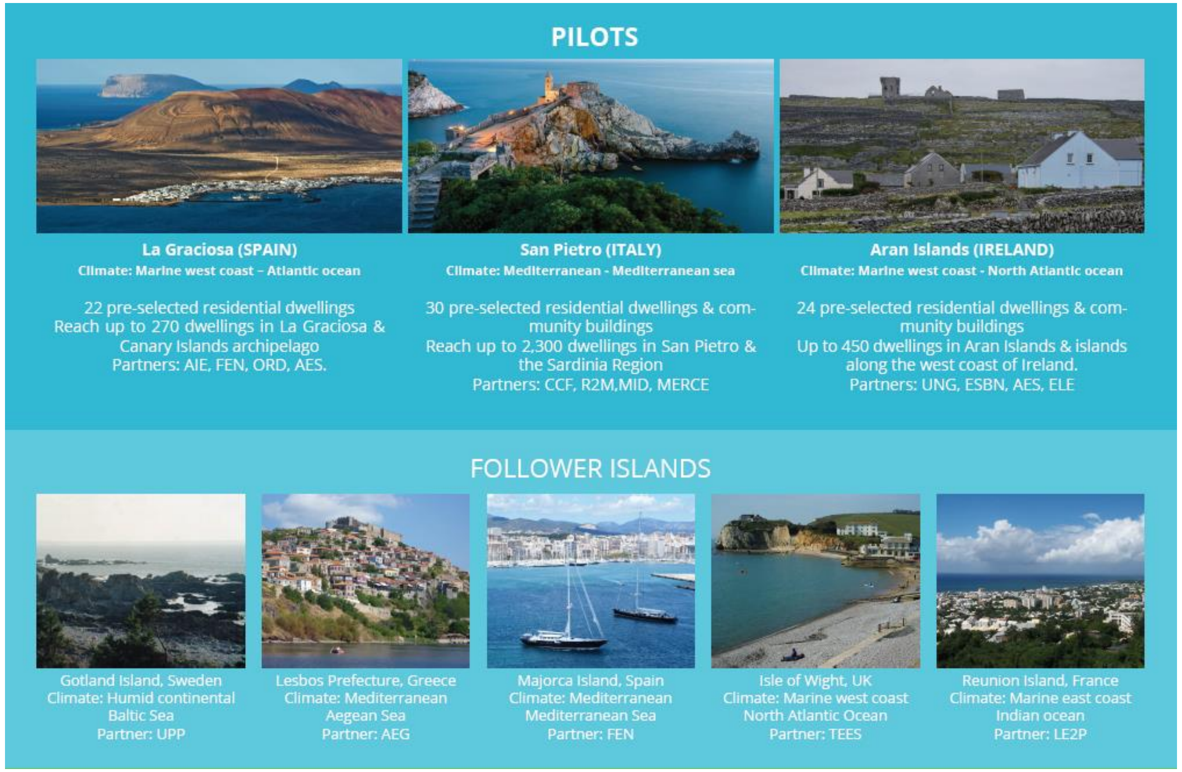
Variable load profiles

- Significant population fluctuations (tourist and non-tourist season)
- Different market contexts and climate conditions

There is a need to characterize and leverage islands' renewable energy resources (RES) to develop a more sustainable energy model

Aims and objectives of the REACT project

- REACT (*Renewable Energy for self-sustAinable island CommuniTies*) is a 4-year research project (01/01/2019 – 31/12/2022) funded by EU's Horizon 2020 programme that aims for island energy independency
- REACT will demonstrate the potential of large-scale deployment of RES and storage assets on geographical islands to bring economic benefits, contribute decarbonizing local energy systems and reduce GHG emissions
- REACT will deliver a scalable and adaptable cloud-based ICT platform for planning and management of RES/storage enabled infrastructure, supporting a holistic cooperative energy management strategy at the community level



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Energy Storage Technologies

The Rise of Battery Storage in Power Systems

- Energy storage systems have started to play a very significant role in our electric power systems, and battery is a key element to enable the energy transition.
- A great number of grid-scale battery systems have already been deployed throughout Europe, which contribute to the stabilization of the grid frequency.
- Germany installed 930 MWh home storage systems and 550 MWh large-scale storage systems by the end of 2018. (Ref: Clean Energy Wire)
- The tumbling cost of batteries is set to drive a boom in the installation of energy storage systems around the world (Ref: BloombergNEF)

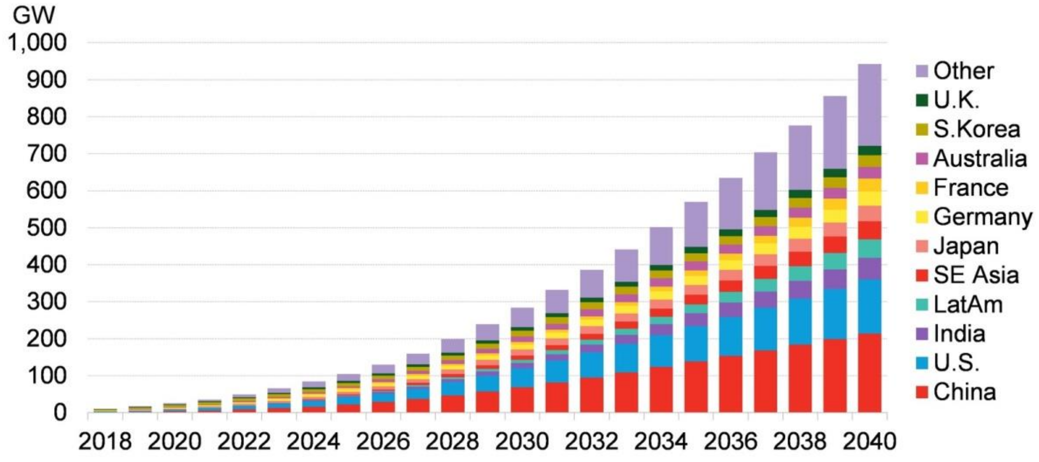


Figure: Global cumulative storage deployments (Source: BloombergNEF)

Energy Storage Technologies

The Energy Trilemma: PV – Battery Perspective

Energy Security:

1. Increased self sufficiency (30-40% vs. 60-70%)
2. Uninterrupted power supply in times of grid failures
3. Increased power system stability (Thanks to fast response and high-power capabilities)

Energy Equity:

1. Battery prices have fallen by over 85% since 2010
2. Self-consumption enables high private and communal participation (contributing to energy democracy)
3. Overall cost reduction, by optimizing grid operation (peak shaving, stress reduction, avoid grid expansion, etc.).

Environmental Sustainability:

1. Less Emission: Battery-50 g, PV 30 g, Waste (Biomass)-100 g, Gas firing plant-250 g, Coal Plant-350 g ($CO_{2,eq}$ per kWh).
2. Higher flexibility enabling provision of high share of renewables

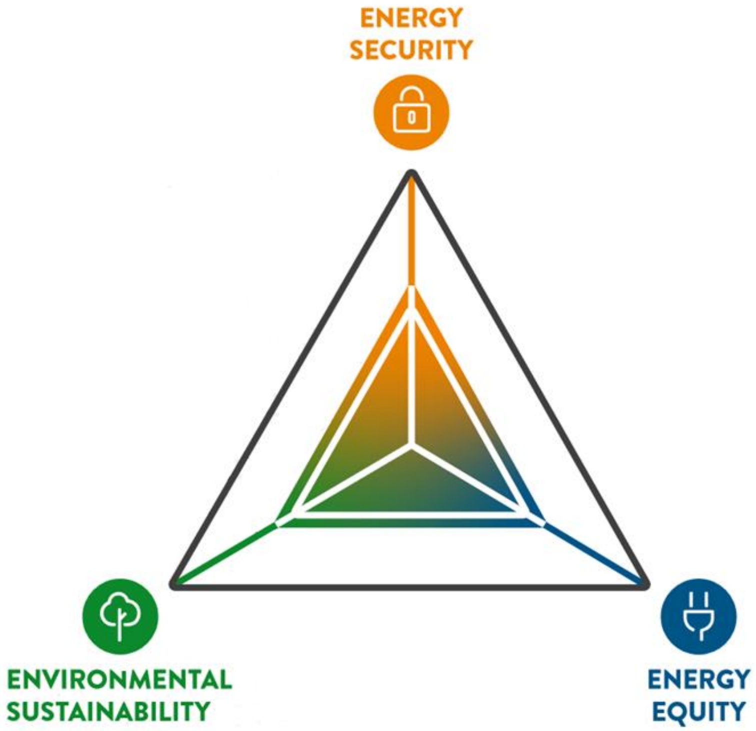


Figure: The Energy Trilemma
(Image Adapted from World Energy Council)

Energy Storage Technologies

The Role of Battery Storage in the REACT Project

- The main innovation relies on the integration of batteries within a central ICT platform (REACT Platform) allowing the batteries take part in demand response in demo sites.
- The battery integration to the REACT platform is based on open-source energy management framework OpenMUC, and on existing product APIs (e.g., MIDAC API), and will provide state-of-the-art control capabilities
- Forecasting (weather, generation, consumption) information will aid optimized battery scheduling, leading to manifold benefits in terms of cost and resource utilization.

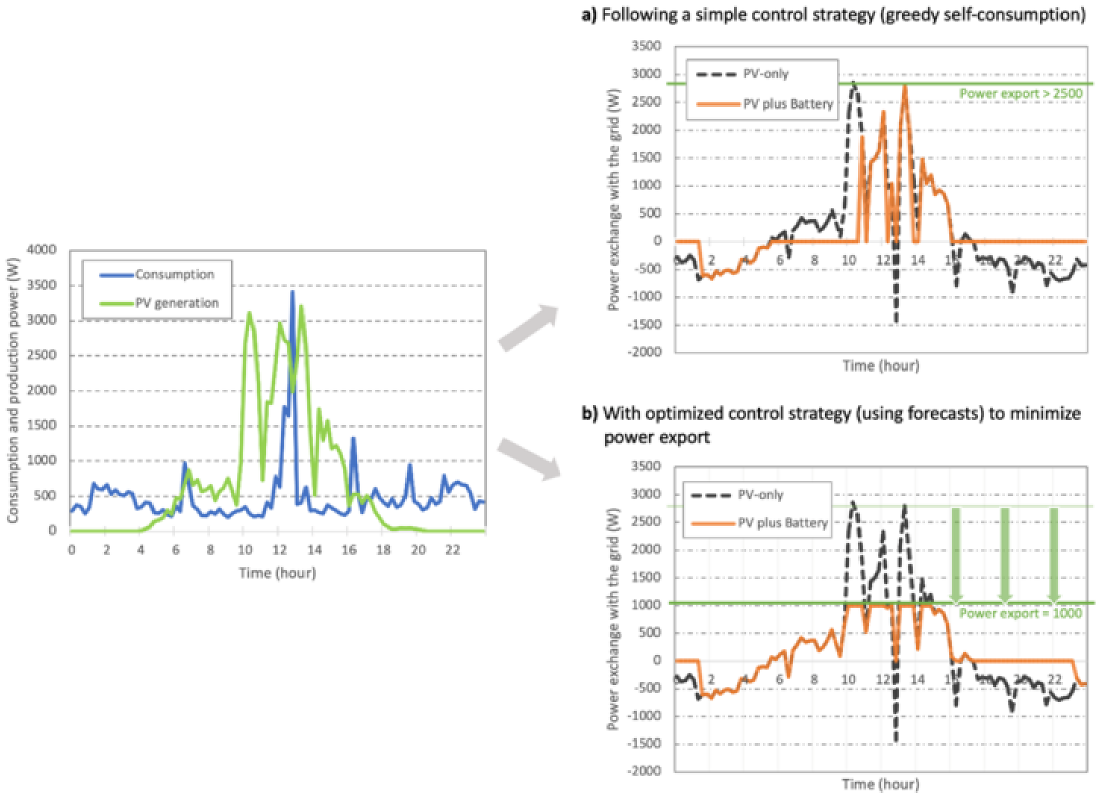
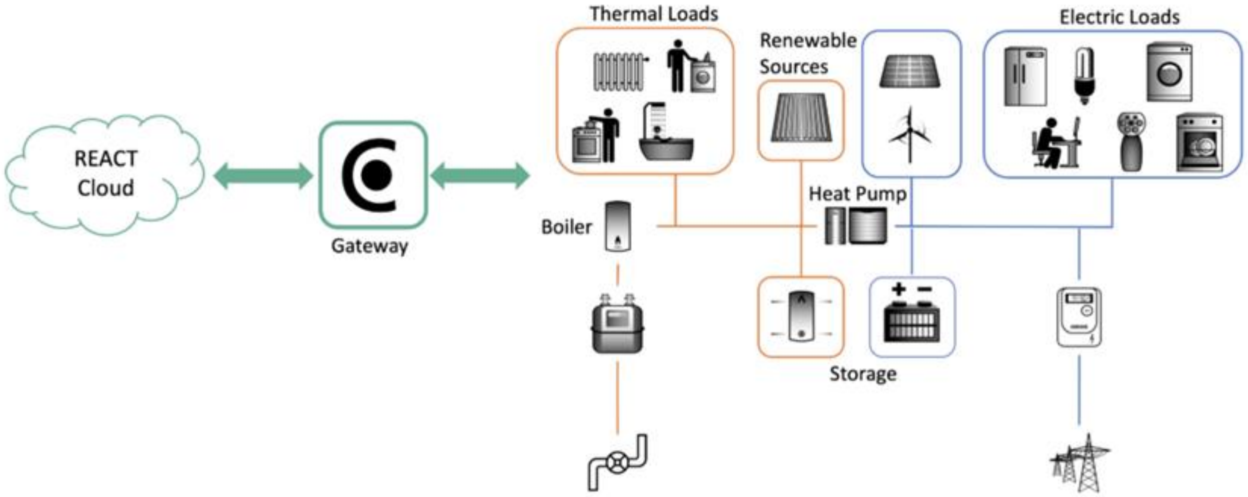


Figure: Supply-Demand Balance. Left: Energy Demand and PV Supply. Right (Upper): Simple Control. Right (Lower): Optimized Control

Energy Storage Technologies

The Role of Battery Storage in the REACT Project (Contd.)



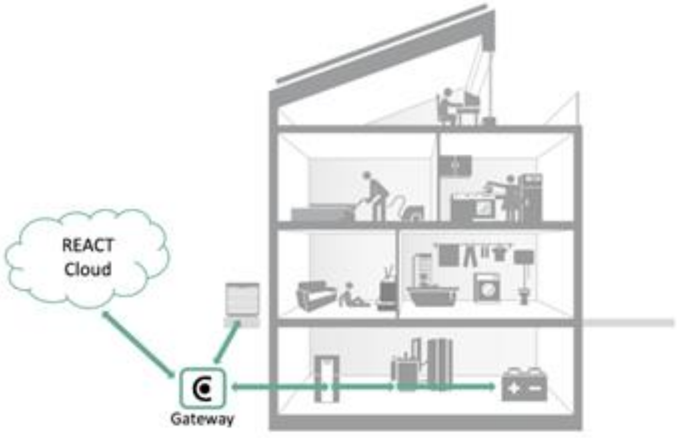


Figure: ICT integration of household equipment to the REACT platform. A communication gateway connected to the internet enables information exchange between the assets and the cloud platform. This platform offers analytic and optimization services to all customers.

Energy Storage Technologies

Hydrogen Storage: Market Perspective

- Hydrogen Europe and other European and worldwide agencies involved in the hydrogen markets consider them (and particularly green hydrogen market) as strategic and promising
- Hydrogen is not a primary energy source itself, but a storable and transportable energy vector.
- It has a high energy value per mass unit (energy density) reaching up to 120 MJ/kg, much more than traditional fuels but being much light weighted, with a density of 0.089 kg/m^3 at 0 °C and 1 bar (1/10th of CH_4). This allows storing a relevant amount of energy mass within a reasonable volume
- Hydrogen offers a big energy density in terms of mass and a low energy density in terms of volume (up to 10,8 MJ/m^3), which means approximately 3 kWh/Nm^3

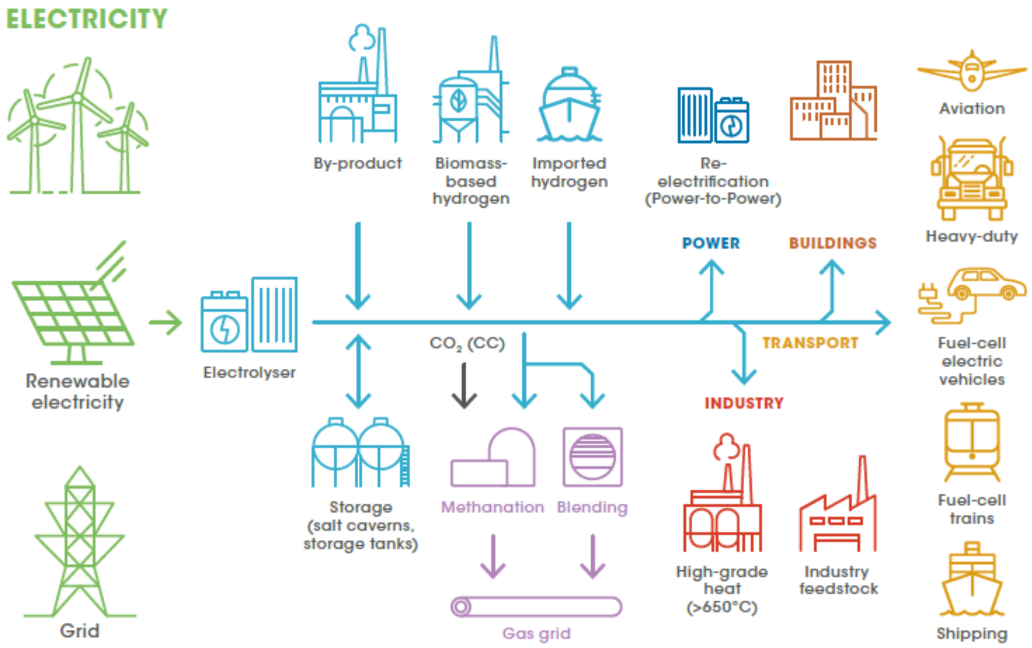


Figure: Concept of P2H$_2$ and the end-use applications of hydrogen (Source: "Hydrogen from renewable power", International Renewable Energy Agency (IRENA))

Energy Storage Technologies

The Role of Hydrogen Storage in the REACT Project

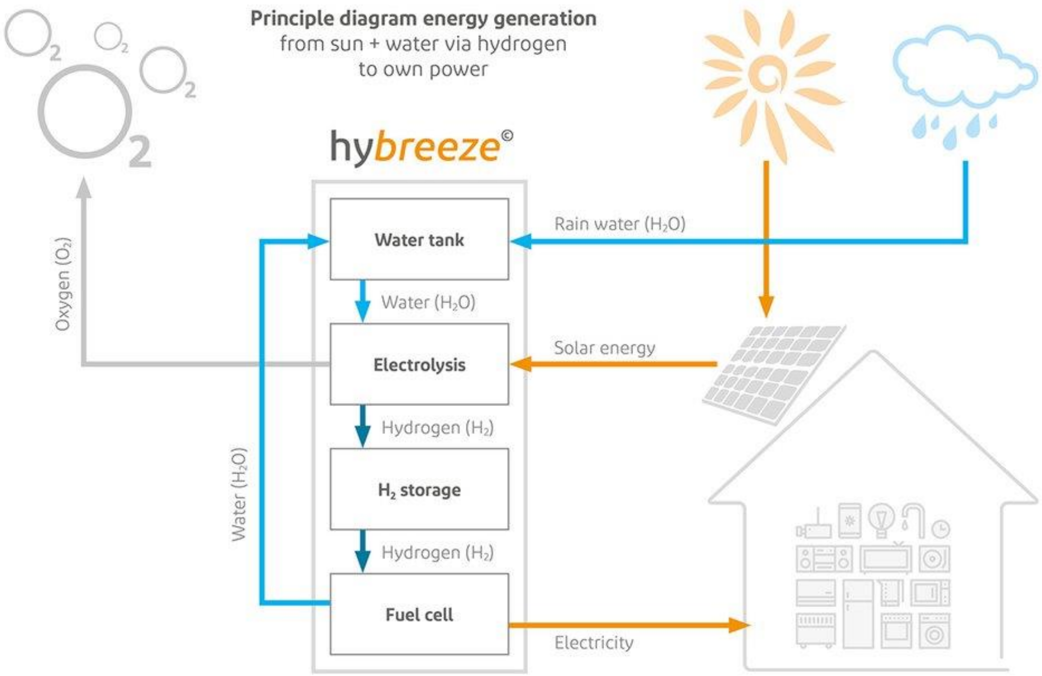


Figure: Principle diagram of a domestic P2H system by Innov Energy. The actual P2H system being deployed within the REACT project follows that principle, focusing on the re-electrification pathway (electricity storage and regeneration)

- As stated in IRENA's report *Innovation landscape brief: Renewable Power-to-Hydrogen* (2019): *"Hydrogen produced with excess solar PV and wind power through water electrolysis can be stored for later use – as a fuel for transport, industry and other sectors. Hydrogen production can be used as a 'smart' load to increase power system flexibility and help to decarbonise the overall economy"*
- The P2H system will contribute to the REACT project's innovation goals and objectives as a new integrative and interoperable energy storage asset. Moreover, the P2H system will be customized to keep a complete set of contributions in terms of grid support, power balance and reduce curtailment of excess VRE generation

Energy Storage Technologies

Power-to-Hydrogen System for the REACT Project

- Contacts with many small-scale P2H system providers/suppliers: Toshiba, GKN Hydrogen, Home Power Solution (HPS), Pure Energy Centre (PEC), Logan Energy and Clean Technology System Hybrid & Hydrogen (CTS H2);
- Chosen supplier after pre-feasibility & technical-economic assessment: **CTS H2**
    - Features of H2 Home system (featured equipment in the container unit):
        - Hydrogen generator (electrolyser): 2 x AEM providing 1 Nm^3/h at 35 bar with STD power supply of 100 – 240 V_{AC} and 4,8 kW of nominal power consumption (6 kW_p)
        - Hydrogen storage tank: 800 L (28,5 Nm^3 of H_2 at 35 bar, approximately 31 kWh of energy storage)
        - Fuel cell unit: 2 x module providing 5 kW_p output power (43,2 – 57,6 V and 0 – 94 A @54V), 24 V of input voltage and external temperature between 5 and 45 °C
        - EMS Monitoring and control system: Industrial PLC (Siemens) for monitoring the system and other supported devices/sensors with data collecting and remote control
    - Customization of H2 Home system included (PLC software for reading/writing through OpenMUC's Energy Gateway, rain water collection tank + purification and circulation system, etc.)
    - Transport, installation & commissioning at one of the Irish pilot site's buildings
    - Warranties, O&M tasks and local technician training (maintenance and safety) included

Figure: 3D perspective of the proposed hydrogen storage system and its components, customized to fit inside a metal container (Source: CTS H2)

Energy Storage Technologies

Energy Storage Benchmarking

Benchmark Criteria / Energy Storage	Lead-carbon	Li-ion (LTO)	Li-ion (NMC)	Vanadium Redox Flow	Sodium-ion	Hydrogen
Communication, integration and interoperability	+++	+++	+++	+	++	+
Technical innovation degree	+	++	+	+++	+++	+++
Technology and market readiness	+++	++	+++	++	++	++
Environmental impact (LCA) and footprint	+	++	++	+++	+++	++
Technical performance	++	+++	+++	++	++	++
Costs	+++	+	++	++	++	++

Benchmark Criteria / Energy Storage	Weight	Lead-carbon	Li-ion (LTO)	Li-ion (NMC)	Vanadium Redox Flow	Sodium-ion	Hydrogen
Communication, integration and interoperability	3	3	3	3	1	2	1
Technical innovation degree	3	1	2	1	3	3	3
Technology and market readiness	2	3	2	3	2	2	2
Environmental impact (LCA) and footprint	2	1	2	2	3	3	2
Technical performance	1	2	3	3	2	2	2
Costs	1	3	1	2	2	2	2
Sum		**25**	**27**	**27**	**26**	**29**	**24**

Figure: Benchmarking of energy storage technologies being deployed within the REACT project

- Benchmarking shows that Sodium-ion and Lithium-ion batteries (Titanate Oxide and Nickel-Manganese-Cobalt Oxide) are the most suitable options to be deployed at the pilot sites under the main REACT project's aims and objectives
- The REACT project will also deploy a P2H storage solution based on a patented plug-and-play hydrogen generation, storage and power reconversion unit to serve as a test bed for communication & interoperability, integration, grid interaction and other research purposes via on-site demonstration activities

Grid Stability Issues

How the REACT Project Aims to Tackle Geographical Islands' Grid Stability Issues

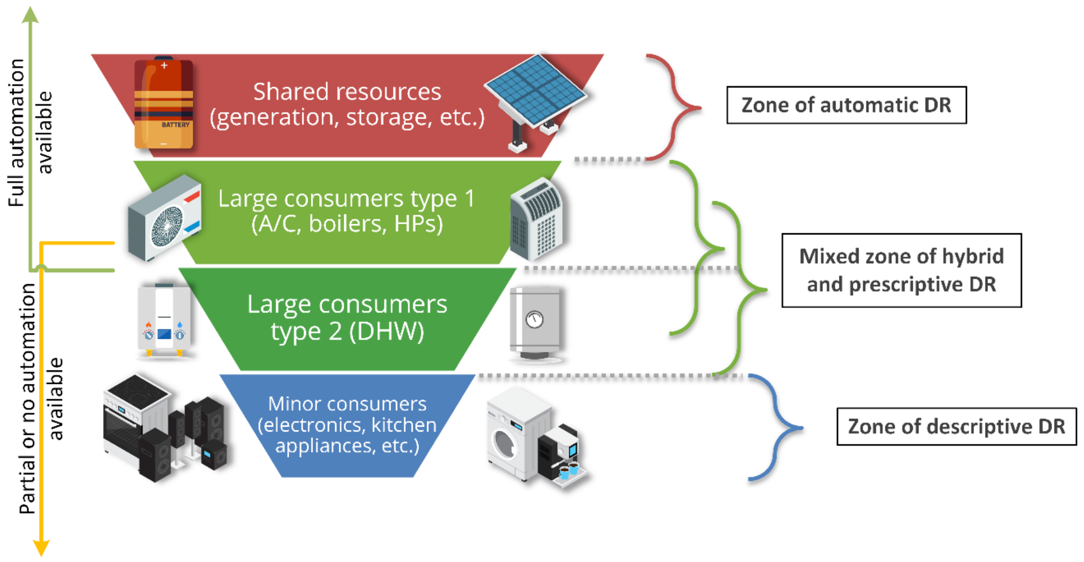
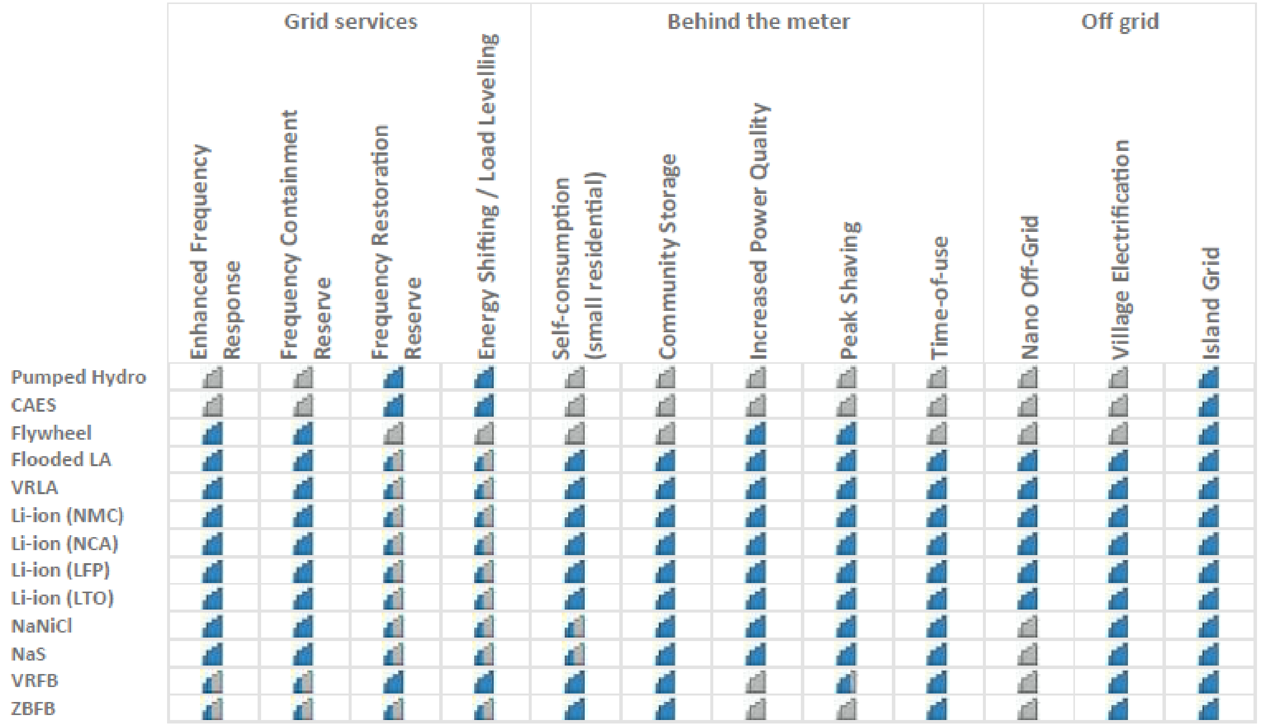


Figure: Different types of controls foreseen within the REACT Project (Source: Jelic et al. (2021))



Source: International Renewable Energy Agency.
Note: CAES = compressed air energy storage; LA = lead-acid; VRLA = valve-regulated lead-acid; NMC = nickel manganese cobalt oxide; NCA = nickel cobalt aluminium oxide; LFP = lithium iron phosphate; LTO = lithium titanate; NaNiCl = sodium nickel chloride; NaS = sodium sulphur; VRFB = vanadium redox flow battery; ZBFB = zinc bromine flow battery.

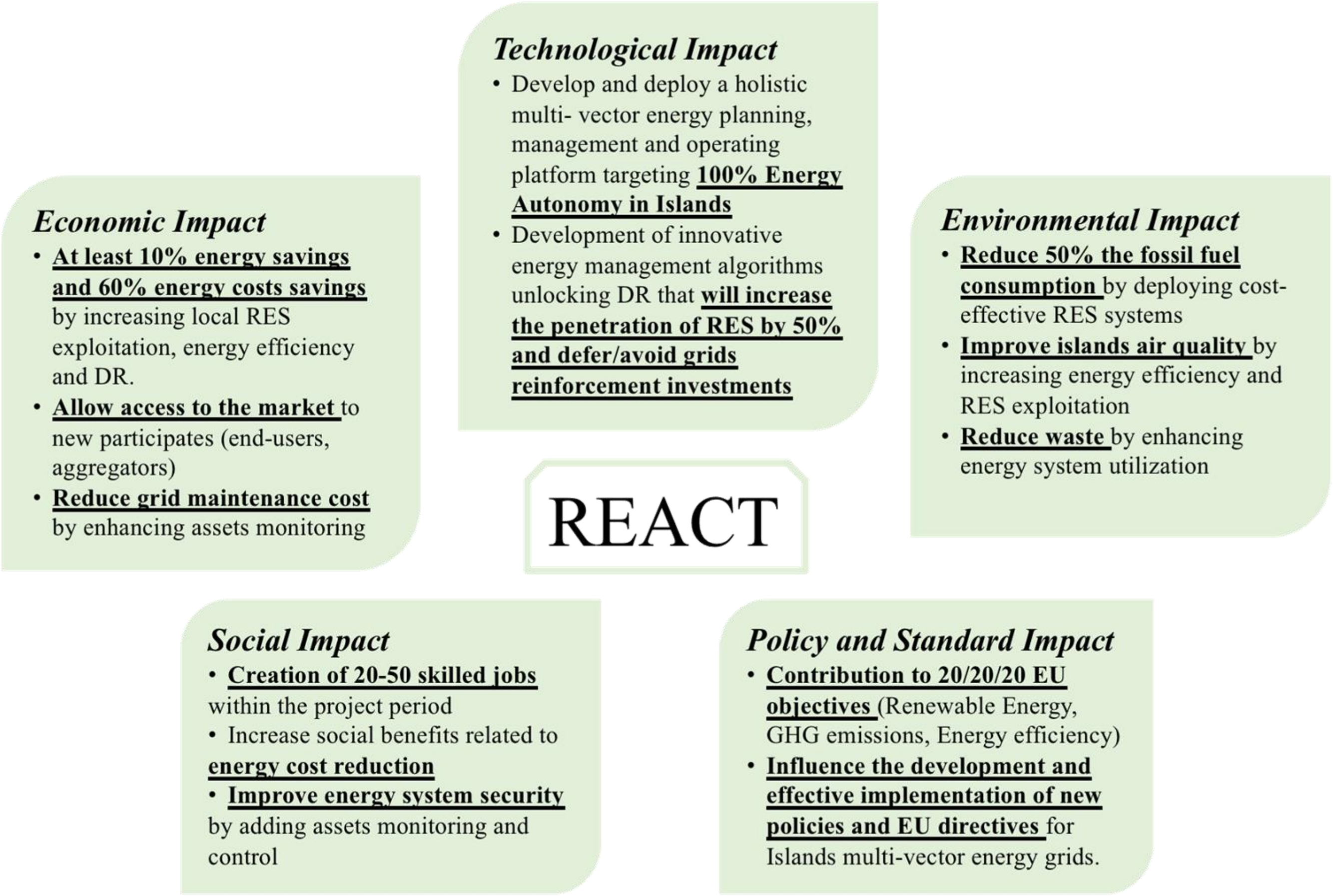
Figure: Suitability of storage technologies for different applications (Source: "Electricity Storage and Renewables: Costs and Markets to 2030", International Renewable Energy Agency (IRENA)

Future Activities to Pursue REACT's Aims and Objectives regarding Renewables and Storage Technologies

- Completion of all installation & commissioning works of the RES and storage enabled infrastructure
- Test and validate REACT's ICT platform features
- Accomplish & track REACT's progress towards the achievement of the overall project's Scientific & Technical Objectives (STOs):
  - Increase RES hosting capacity coupled to large-scale energy storage deployment
  - Unlock DR potential + optimize distribution grid's flexibility
  - Perform lifecycle assessment and long-term plan of RES and storage enabled infrastructure
  - Engage end consumers to take an active part in the energy control loop
  - Develop effective business models ready for large-scale replication

Expected Outcomes and Impacts of the REACT Project

- Address Impacts From the Call through the REACT's Key Impacts (KIs):
  - Achieve at least 10% energy savings and 60% energy price drop in islands
  - Enable higher penetration (min. 50%) of RES in islands grids and reduce 50% of island's fossil fuel consumption
  - Unlock full potential of DR strategy in residential and tertiary buildings, enhancing grid balancing and other ancillary services
  - Reduce/defer max. 30% the DSOs required investments in grid reinforcements and grid balancing
  - Provide a high degree of interoperability with current systems
  - Unlock new services for the entire energy value chain



Sum-up

	Island 1 (La Graciosa)	Island 2 (San Pietro)	Island 3 (Inis Mor)
Renewable energy sources	• **New PV systems**: 22 x between 1.1 – 7.8kWp (total 60.1kWp) • **Existing PV systems**: 1 x 4.5kWp and 1 x 29.6kWp (total 34.1kWp) • **Existing ST systems**: many small ST systems mainly for DHW use	• **New PV systems**: 15 x between 3.0 – 19.9kWp (total 80.0kWp) • **Existing PV systems**: 16 x between 1.0 – 19.8kWp (total 119.7kWp) • **Existing ST systems**: many small ST systems mainly for DHW use	• **New PV systems**: 19 x between 2.2 – 11.1kWp (total 81.2kWp) • **Existing ST systems**: many small ST systems for both heating and DHW use
Type of energy storage technologies used	• **Li-ion LFP**: 11 x 6.4kWh (total 110.80kWh) • **Li-Ion NMC**: 1 x 3kWh • **PLH-C**: 4 x between 4.19 – 8.16kWh (total 22.90kWh) • **$NaNiCl_2$**: 1 x 7.70kWh • **VLA/VRLA**: 3 x between 4.9 – 9.0kWh (total 18.80kWh)	• **New ESS – Li-ion LFP**: 30 x between 4.2 – 16.8kWh (total 210.0kWh) • **Existing ESS - Pb**: 1 x 16.8kWh	• **Li-ion LFP**: 14 x between 6.0 – 16.0kWh (total 134.0kWh) • **$NaNiCl_2$**: 4 x 6.0kWh (total 24.0kWh) • **P2H**: 1 x 31kWh
Grid stability issues and improvement	• **Issues**: Grid safety, power quality, power fluctuation, new disruptive DG/ESS technologies integration, etc. • **Improvement**: Establish RECs, provide grid supportive & ancillary services, enhance grid flexibility…	• **Issues**: Grid safety, power quality, power fluctuation, new disruptive DG/ESS technologies integration… • **Improvement**: Establish RECs, promote VPP & aggregator services, stimulate penetration of new RES technologies…	• **Issues**: Grid safety, power quality, power fluctuation, new disruptive DG/ESS technologies integration… • **Improvement**: Establish RECs, increase grid synergies, provide grid supportive & ancillary services, enhance grid flexibility…
End users/consumers involved	• Buildings (Residential, Commercial, Tertiary & Public/Institutional)	• Buildings (Residential, Commercial, Tertiary & Public/Institutional)	• Industry, Transport and Buildings (Residential, Commercial, Tertiary & Public/Institutional)
Lesson learnt	• Poor RES knowledge, challenging user engagement, local (mainly urban planning) RES framework limitations for RES/storage deployment	• Poor RES knowledge, state-wide and local RES framework limitations for RES/storage deployment, VPP as key enabler	• Poor RES knowledge, clear & updated state-wide and local RES framework, promising grid synergies potential
Future results	• Energy supply and demand side optimisation, distribution grid estimation and fault detection, renewable energy supply & demand forecasting, improved smart grids integration & interoperability, holistic demand response strategy at community level, innovative business models for sustainable grids in geographical islands		

Conclusions

How To Achieve Island Energy Independency & Self-Sufficiency

- REACT takes promising background from previous smart grid and R&D activities to work around four Innovation Levels (ILs):
    1. Advanced innovative technologies
    2. Technology integration
    3. New synergies
    4. User engagement & Business models
- REACT's work flow to decarbonizing energy systems of geographical islands runs through several paths:
    - Optimization of multi-carrier energy dispatching (electricity, gas, transport)
    - Holistic cooperative demand response (DR) strategy at community level
    - Integration and testing of innovative energy storage technologies
    - Establish synergies between different energy grids of the islands
    - Deployment of advanced decision support tools
    - User engagement to take an active part in the control loop

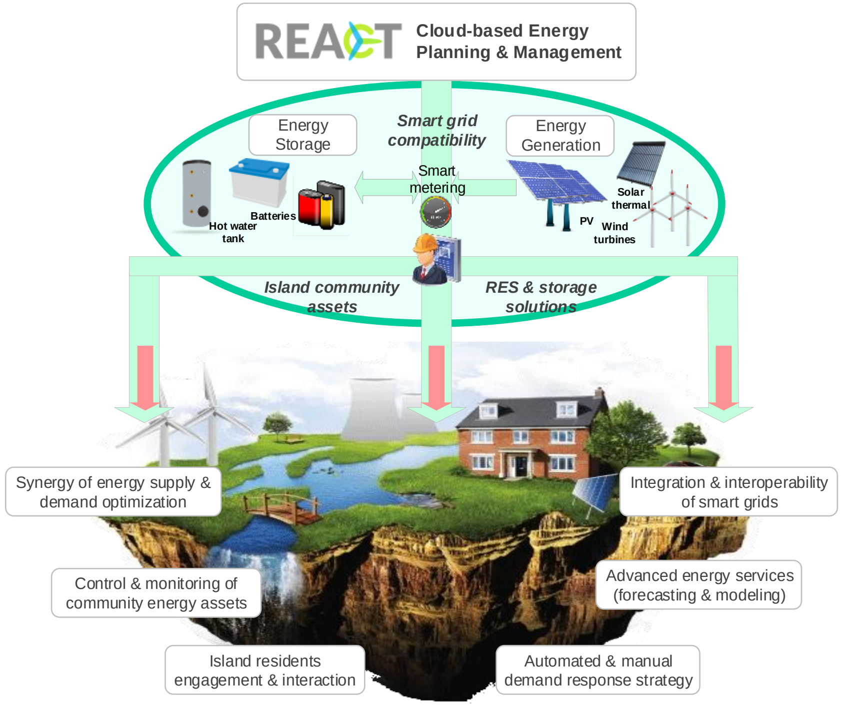


Figure: Schematic of the main contributions & innovations of the REACT project towards the achievement of geographical island's energy independency & self-sufficiency

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https://www.linkedin.com/company/react-2020-project/

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YouTube channel
https://www.youtube.com/channel/UCDPj1ebKXQyskcTPY5nB7BA

Facebook groups (Irish pilot in progress)
https://www.facebook.com/LaGraciosaREACT/
https://www.facebook.com/SanPietroREACT

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These projects have received funding from the European Union’s Horizon 2020 research and innovation programme