ESMAP
ESP biannual meeting

Nov 07, 2023

Pretoria, South Africa

Index

1. Company

1. Company

A world class engineering firm specialized in high level & high value, basic and conceptual engineering for **energy storage** sector.

Headquarters in Spain (Seville), and offices in United Arab Emirates (Dubai) and United States (Houston).

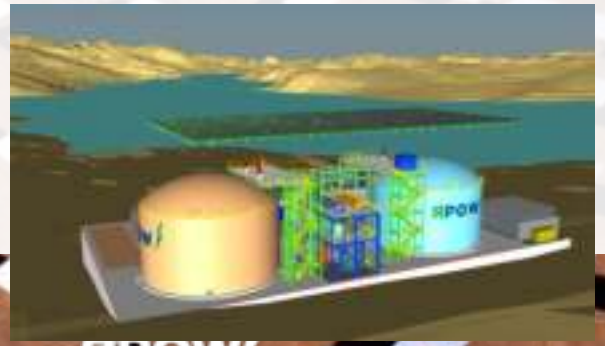
Our Senior Engineers stand for Experience and International Competence in Projects all over the world.

2. Solutions

2.1. Technical Solutions

01 PRODUCT DEVELOPMENT, TES FOR INDUSTRIAL APPLICATIONS

- Storage of thermal energy is one of the main R&D factors in continuous improvement for most of the players involved in the energy sector
- Our solutions suits to all those industries where the high temperature behavior is relevant to the productive line
- Active (based on molten salts) and passive storage (based on solids). Patents and brands protected developments

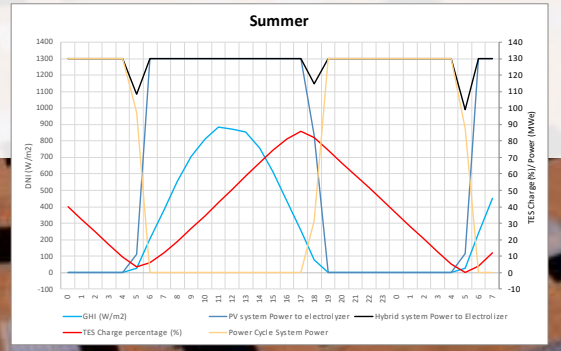


02 DESIGN AND TECHNICAL CONSULTANCY

- Key components design and specification
- Overall process in CSP and PV plants
- Technical Due Diligence
- Lender Technical Advisory
- Owners Engineering
- Failure diagnoses
- Expert Support for Arbitrations
- Specialized Training

03 OPERATION ASSESSMENT AND IMPROVEMENT

- Model and predict power plant thermodynamic performance and flexibility
- Identify plant performance improvements, optimize new power plant designs and assist feasibility studies
- Plant performance data evaluated online to monitor long-term trends and identify deviations and issues as early as possible
- Technical consultancy support to recommend improvements that deliver the required benefits



04 COMMISSIONING AND O&M SPECIALIZED SUPPORT

- Start-up and O&M team consists of experienced and knowledgeable professionals and cross-trained to provide management support to commissioning and O&M services
- All our team members possess extensive field experience in Solar (CSP+PV) and conventional power generation facilities

2.2. Innovation Projects

ISOP PROJECT

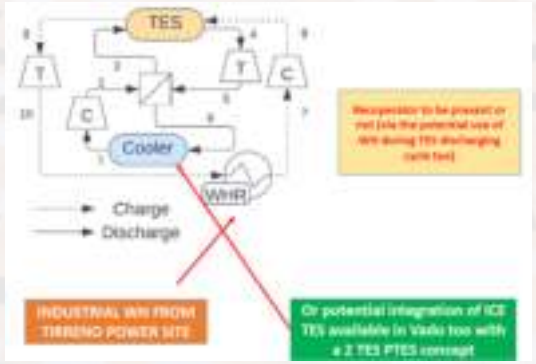
Innovation In Supercritical CO2 Power Generation Systems

Marie Sklodowska-Curie Actions

SCO2OP-TES PROJECT

sCO2 Operating Pumped Thermal Energy Storage for grid/industry cooperation

SCO2OP-TES



OTHER PROPOSALS ON GOING

- **FLUWS PROJECT**

Flexible Upcycled Waste Material based Sensible Thermal Energy Storage for CSP

- **I-UPS PROJECT**

Innovative High Temperature Heat Pump for Flexible Industrial Systems

INTELLECTUAL PROPERTY

- **4 Utility Models granted**
- **2 Patents applications under evaluation**

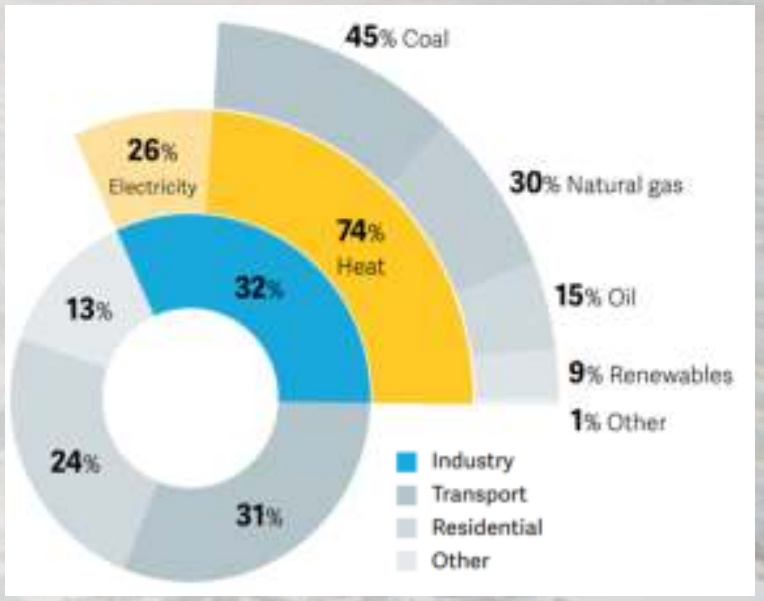
3. Industry and Grid Challenges

3.1. Industry Decarbonization

Great thermal power demand in industrial processes

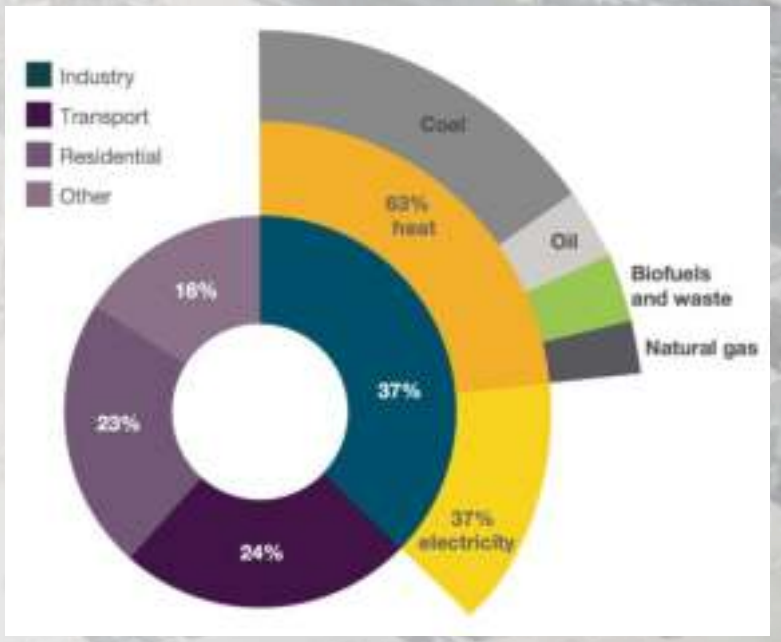
- Most produced by carbon driven sources (coal or gas fired boilers)
- Usually is a constant demand as most industrial processes work during all day long
  - It makes difficult of including renewables energies as their main energy source
- **Reduce carbon emissions in industry**

Global Heat Demand



Source: IEA/IRENA, chart of Solar Payback

Heat Demand in South Africa



Source: IEA Energy Balance of South Africa

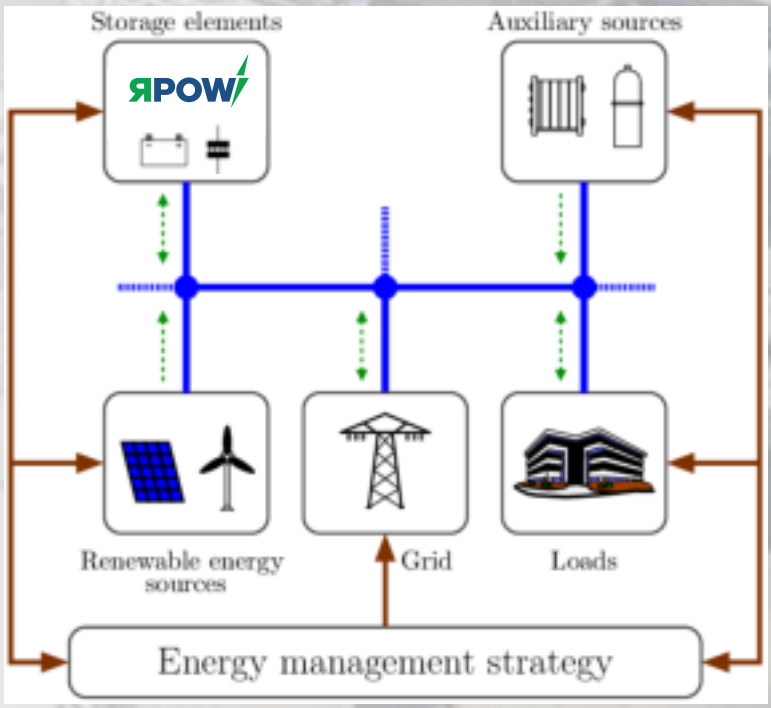
3.2. Electric Grid Stability

Necessity to match power generation and consumption in order to guarantee grid stability and electricity supply for every need

- Installed excess renewable power implies that there will be scenarios when production is much higher than power demand

- To guarantee grid stability such renewable power cannot be used therefore must be wasted

- By implementing **TES system** fed with electricity such excess production could be used and transferred to periods when there is not enough production to meet the demand



4. Molten Salt Thermal Energy Storage

4.1. TES Origin

Concentrated Solar Power (CSP)

Parabolic Trough

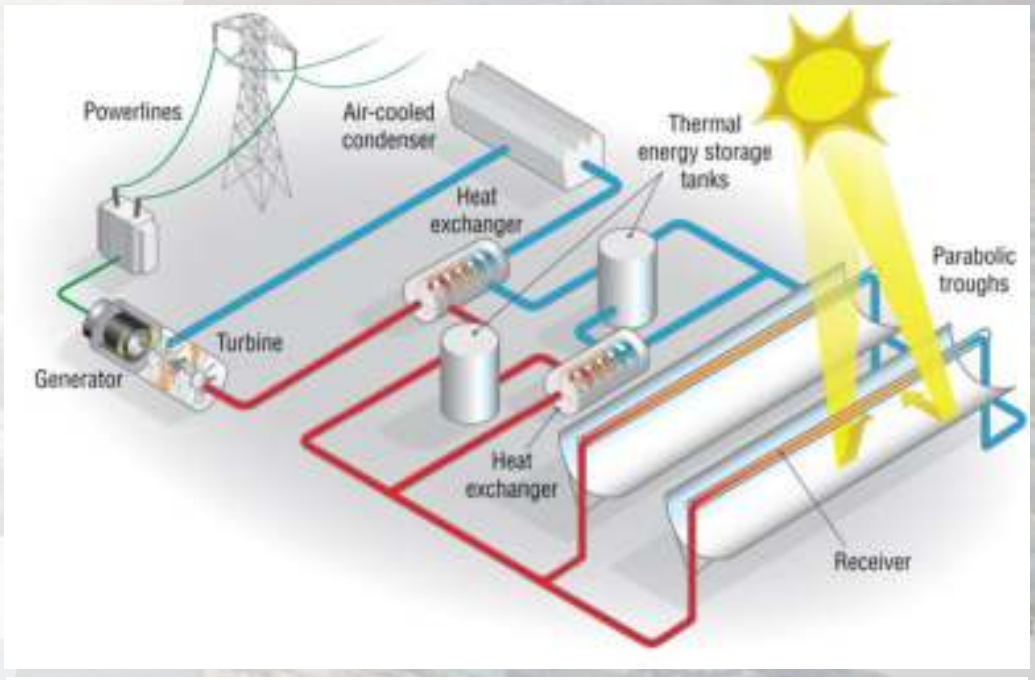
- Sun is reflected into linear receivers where the Heat Transfer Fluid (Thermal Oil) is heated up
- Thermal oil then heats up Molten Salts where thermal energy is stored. By means of a cold (290ºC) tank and a hot (400ºC) tank.

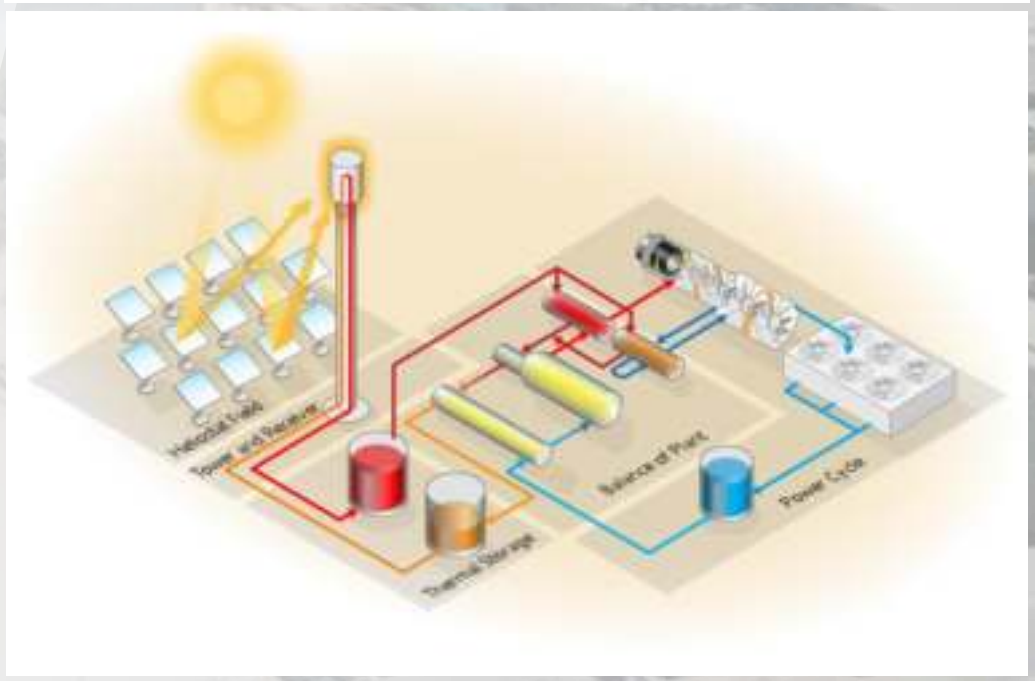
Central Tower

- Sun is reflected into a central receiver situated atop a tower where the Heat Transfer Fluid (Molten Salts) is heated up
- Hot MS are stored in the hot (565ºC) tank and the cold (290ºC) tank when discharged.

Power Cycle

- Electric power is generated by means of a Steam generator and Steam Turbine (discharge of MS)





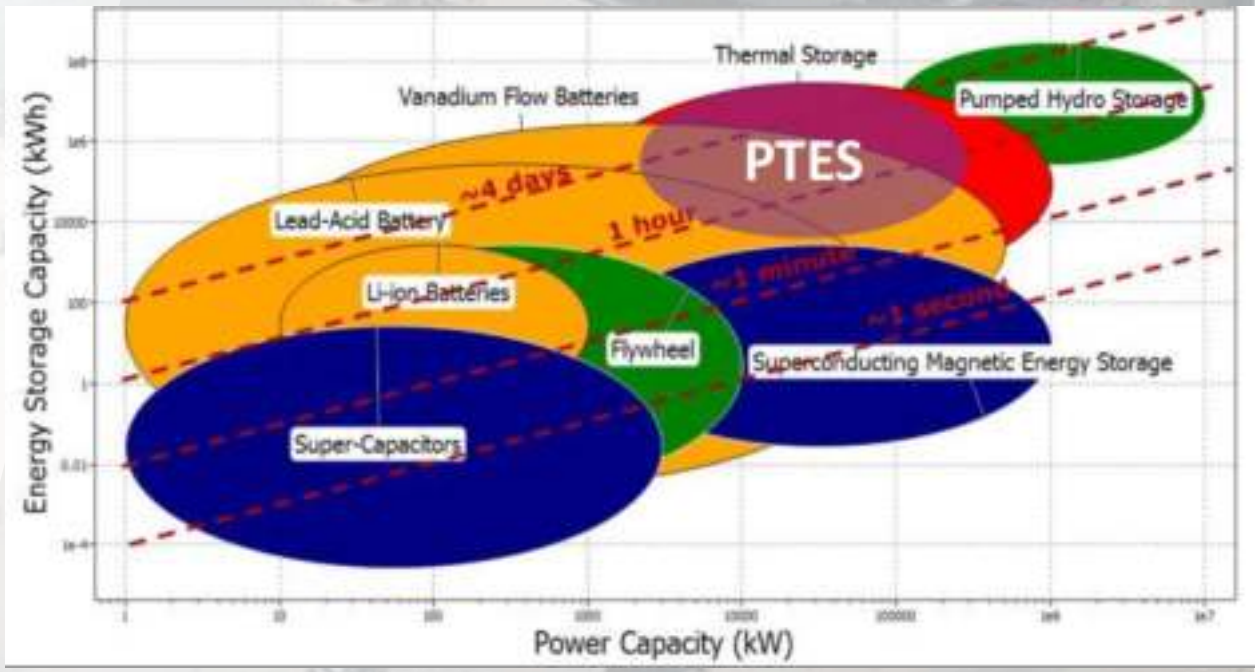
4.2. Molten Salt Thermal Energy Storage

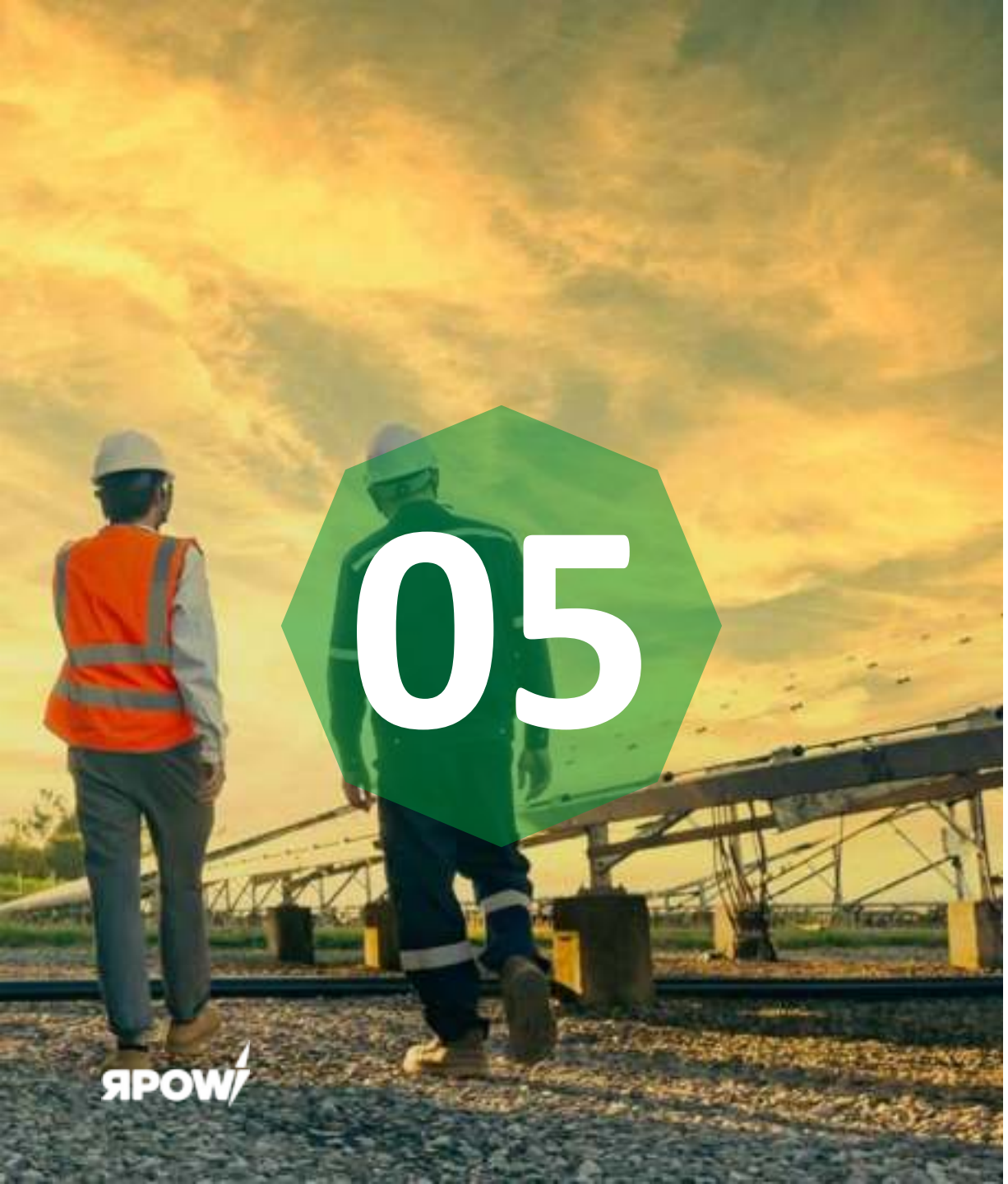
Background

- Origin: Concentrated Solar Power (CSP) plants with Molten Salt (MS) storage
- No Battery Degradation
- Common and available natural resources
- Extremally competitive above 100 MWth
- Commercial scale projects up to 6.500 MWth

Comparison with other Technologies

- MS batteries are able to Storage Heat from 200 to 565˚C
- Energy Storage Capacity from 5 MWh to 6.500 MWh
- High Round Trip Efficiency in P2H applications (>90%)

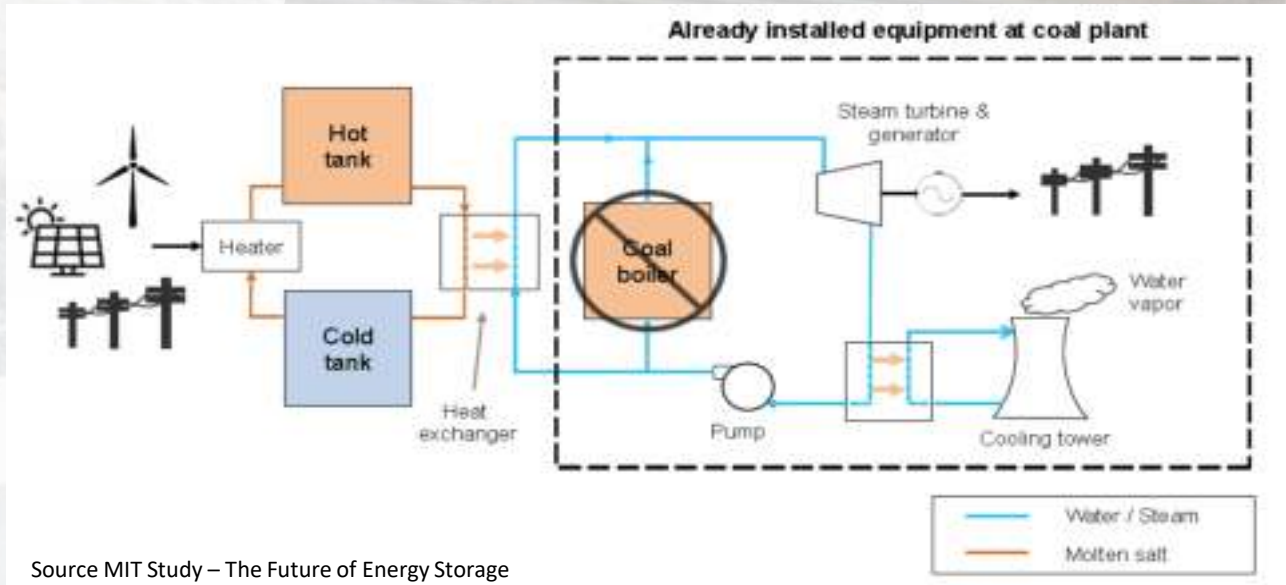




5. Real Applications

5.1. Steam Turbine retrofit with TES

- Substitution of carbon fuel fired boilers with a TES system
- Reuse of already installed equipment in power plants
- Service life extension and efficiency enhancement
- Advantages:
  - Clean generation
  - Maintaining assets with a new life
  - Availability to manage network with a short ramp up
  - Positive economic balance (OPEX)
  - Reduced CAPEX against possible dismantling
  - Trained personnel in the area of operation easily convertible
  - Maintenance of employment
- Optimal applicability in countries with a high energy production from coal fired power plants promoting the acceleration of decommissioning by 2040



Source MIT Study – The Future of Energy Storage

5.1. Steam Turbine retrofit with TES

- **CHILE:**
  - 28 coal plants (91% CO2 emissions)
  - In the next 5 years, 8 plants will stop after more than 50 y in operation
  - 1st goal by 2030: reduction of 30 MT CO2 retrofitting 3.600MW with renewables technologies with storage
  - By 2050, Chile will become a carbon-neutral country (with net greenhouse gas emissions equal to zero)
  - Operation cost reduction by >40%

- **SOUTH AFRICA:**
  - 19 coal plants produce 80% of the energy
  - 1st goal by 2030: increase renewables energy from 11% to 41%
  - Energy storage is crucial for South Africa to meet its energy demand and decarbonization targets

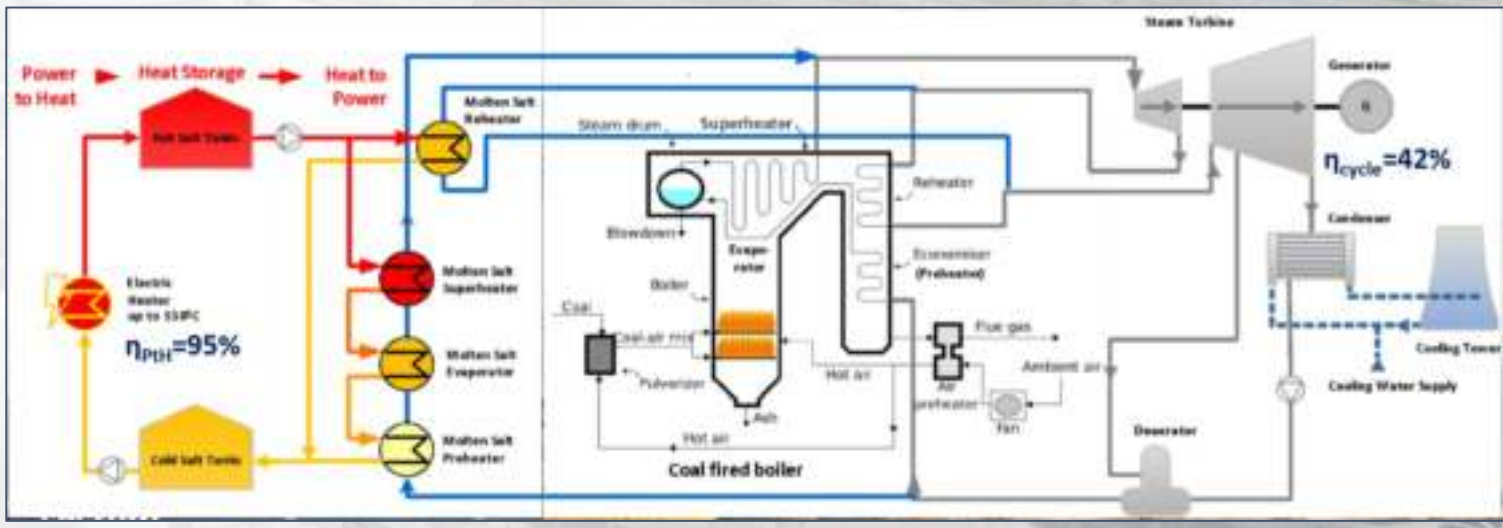

Eskom Power Plant in South Africa

Sources: Energy Minitry of Chile & Rystad Energy analysis

5.1. Steam Turbine retrofit with TES

P2H2P in Coal Fired Plant

- Location: Chile
- Net Power: 500 MW
- Electric Heater Power: 700 MW
- Storage time: 14 hours
- TES capacity: 7500 MWh
- Molten Salts inventory: 80.000 Tons approx.

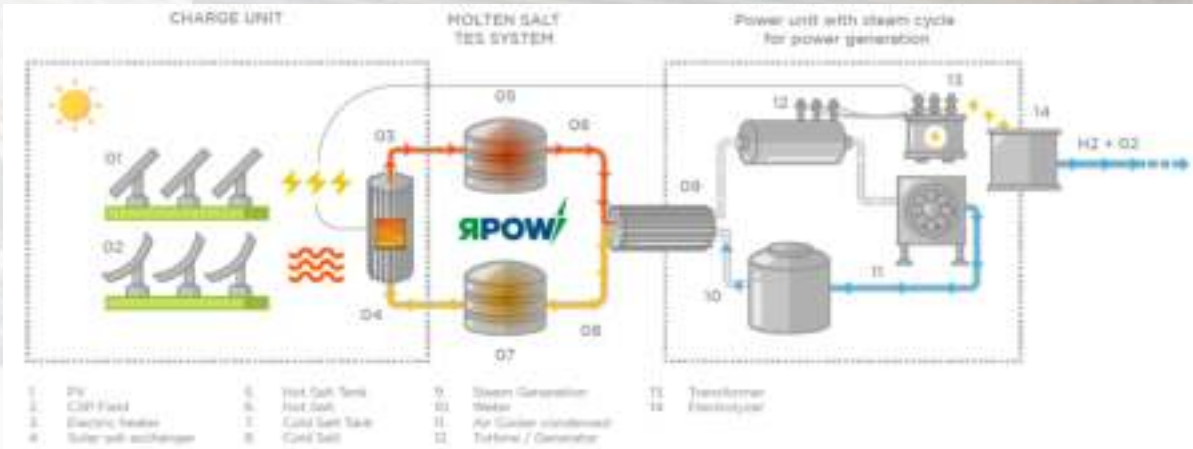


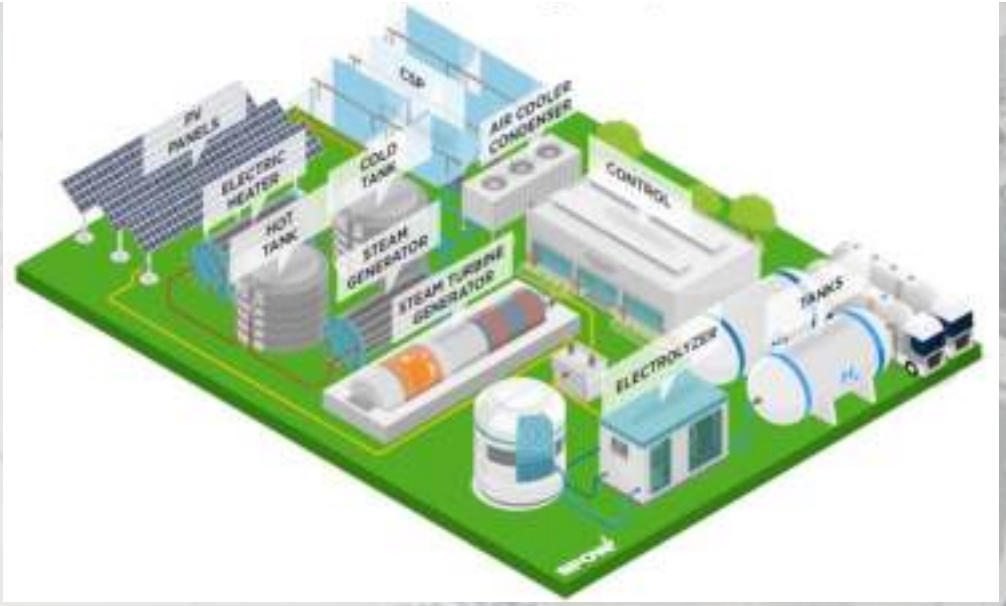
- Tasks performed:
  - Design Review of process configuration
  - Q&A of different topics
  - Schedule, Cost Estimation and Supply Chain support

REDUCTION OF >3.7 Mt/y OF CO2 EMMISIONS

5.2. Green H2 Production

- Renewable energy sources are intermittent making it impossible for green H2 to be produced around the clock
- The use of a Carnot Battery (TES) grants the ability to store excess renewable energy for long periods of time
- Therefore, being able to produce **Green H2 24/7**
- Advantages:
  - Electrolyzer performance improved, and payback reduced
  - Isolation of the system from the transmission network
  - Higher profitability than systems based on batteries, as long as the electrolyser is above 30MW
  - Standalone solution, with independence from the electrical grid and from energy price fluctuations
- Optimal applicability in countries with large capacity to produce energy from renewable sources and with strategies programs to **produce Green H2**



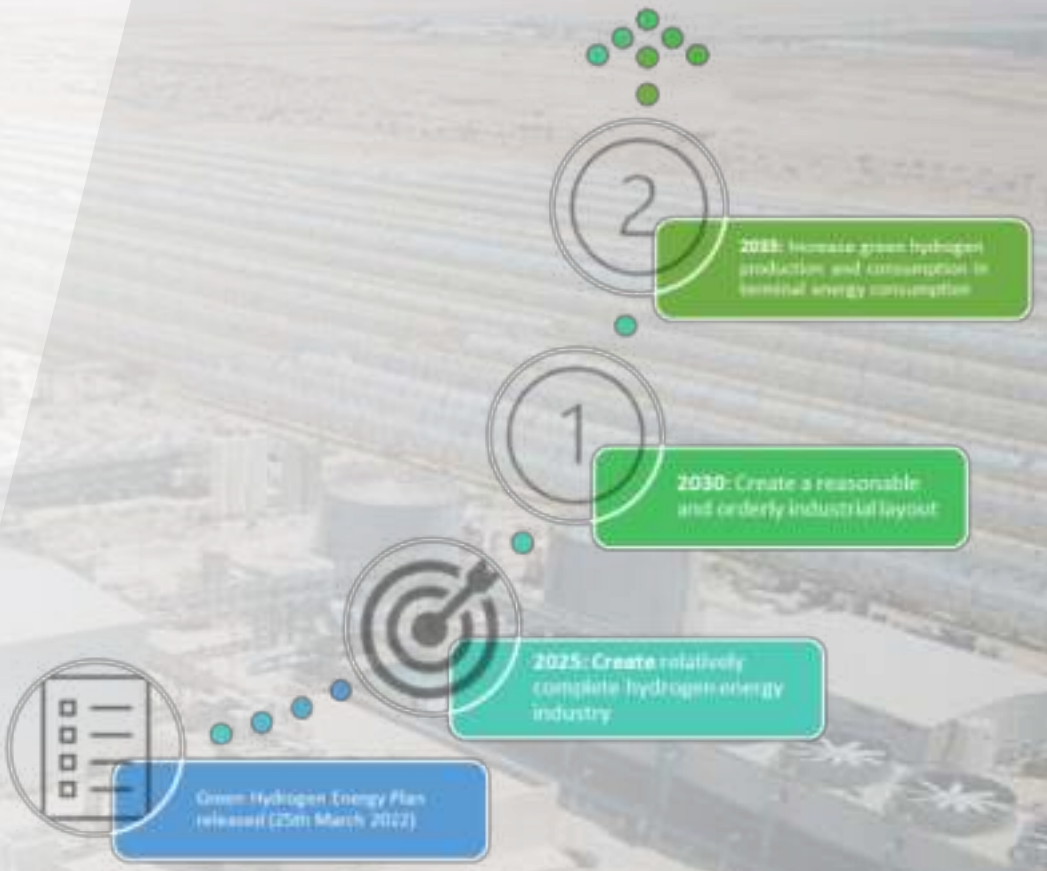


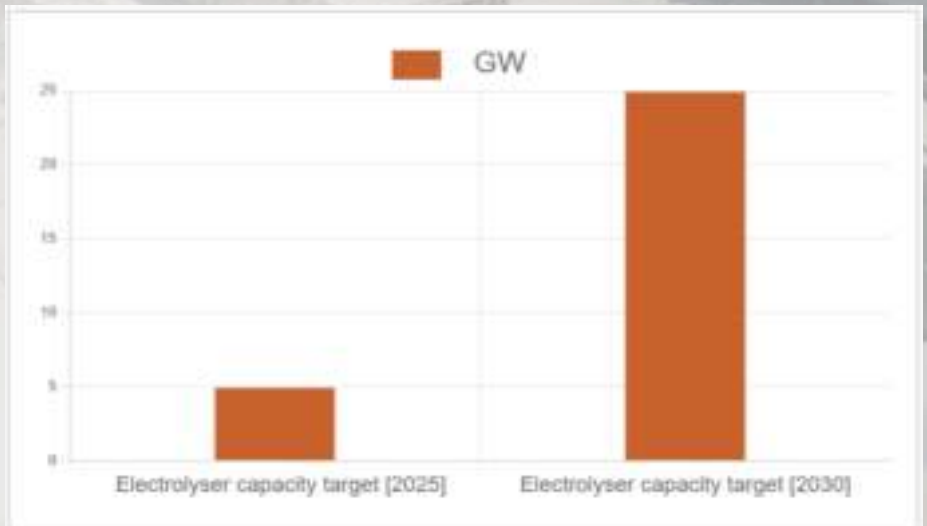
5.2. Green H2 Production

- **CHILE:**
  - Renewable energy export. Potential to produce 1800 GW
  - Decarbonizing economy
  - Job creation
  - Target: to produce the cheapest green H2, $1.5 per kg by 2030
  - World leader in the production and export of green H2 by 2040

- **SOUTH AFRICA:**
  - Create an export market for South African Green H2 and ammonia
  - Green the power generation sector
  - Decarbonize the transport and heavy industry sector
  - Locally manufacture green hydrogen supply chain components
  - Target: to produce 500.000 T/y by 2030

    10 GW of electrolysis capacity by 2030 and 15 GW by 2040





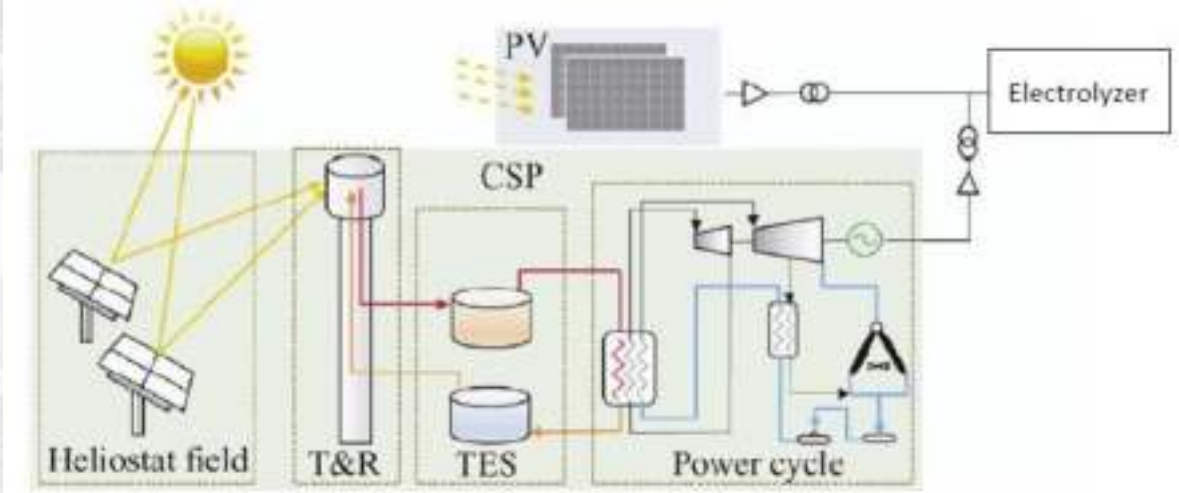
Source: Green Hydrogen Organization

5.2. Green H2 Production

CSP+PV hybrid evaluation for standalone Hydrogen production

- Location: California
- Net Power: 153 MWp PV + 113 MW CSP (Central Tower)
- Solar Field Size: 6212 Heliostats
- Storage time: 13 hours
- TES capacity: 3424 MWh
- Molten Salts inventory: 32.000 Tons approx.
- Utilization Rate Electrolyzer > 83%

- Tasks performed:
  - Prefeasibility and Profile Evaluation
  - Conceptual Design
  - Schedule, Cost Estimation and Supply Chain support



Month/Hour	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
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February	CT	CT	CT	CT	CT	CT	CT	CT	CT	PV	PV	PV	PV	PV	PV	PV	PV	CT	CT	CT	CT	CT	CT	CT
March	CT	CT	CT	CT	CT	CT	CT	CT	PV	PV	PV	PV	PV	PV	PV	PV	PV	PV	CT	CT	CT	CT	CT	CT
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December	CT	CT	CT	CT	CT	CT	CT	CT	CT	PV	PV	PV	PV	PV	PV	PV	CT	CT	CT	CT	CT	CT	CT	CT

REDUCTION OF >740 kt/y OF CO2 EMMISIONS

WITH THERMAL ENERGY STORAGE SYSTEMS

INDUSTRIAL DECARBONIZATION IS POSSIBLE

Contact: psantamaria@rpow.es

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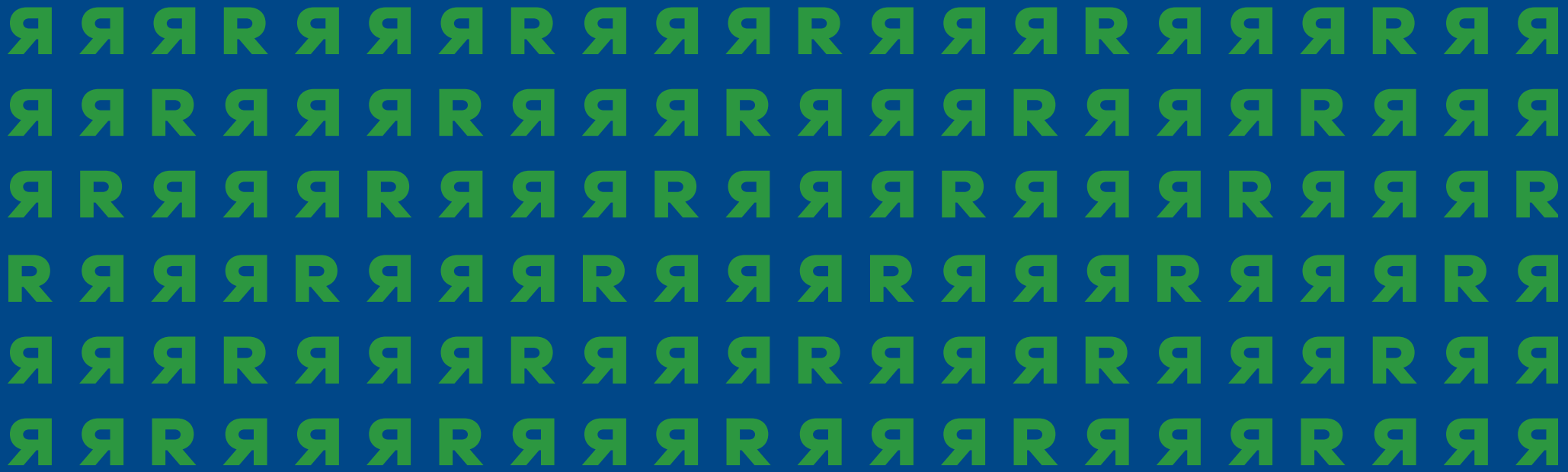

RPOW

+34 954 088 937 I rpow@rpow.es

Spain
Av. de Innovación 0,
Edificio Renta Sevilla 202. 41020.
Seville. SPAIN.

USA
1000 N. Post Oak Rd., Suite 220.
Houston TX 77055

United Arab Emirates
M08- Al Raffa, Al Raffa Area, Dubai. Dubai,
UAE