

## Main circularity projects

We are developing several projects mainly related to new assets (wind, solar, BESS, and grid development) and upcoming products/services for end customers, with the aim of reducing the consumption of raw materials, especially critical ones.

The initiatives focus on three of the five pillars of the model:

- **Circular design – use of circular inputs**

Several solutions to reduce raw material consumption use circular inputs i.e., from previous life cycles (use of recycled plastic for smart meters and charging infrastructure for electric vehicles or recycled aluminum for street lighting systems) or by identifying new solutions that use alternative and more sustainable materials (wooden towers for wind turbines, innovative wind blades made of fabric, or hybrid towers in which the base and first sections are replaced by a concrete pedestal that will be made directly on site, significantly reducing the use of steel). Another project in this sense is the partnership with Vulcan Energy to develop projects for geothermal lithium extraction.

- **Circular use – useful life extension**






Reducing the need for new assets also reduces the associated material requirements. Among the various initiatives implemented are the application of machine learning techniques for predictive maintenance in power

generation and distribution plants or advanced repair technologies such as additive manufacturing.

- **Value recovery – identification of new life cycles**

When an asset reaches the end of its useful life, the objective is to identify new life cycles through solutions that maximize the amount of recoverable materials in order to reinsert them into the production cycle. All the Group’s different Business Lines are actively involved in major asset recycling projects: from PV with the Photorama project, which aims to recycle 95% of materials, to sale for scrap metal recovery, to the recycling of power line poles, reusing the recovered material for new poles, to the construction in Spain of a battery recycling plant with a target capacity of 8.000 tons/year, up to a circular management of the Group’s decommissioned IT assets by giving them to employees, selling them to third parties or donating them for social purposes (see the chapter “Digitalization”). In addition, we are evaluating new models for the enhancement of secondary raw materials: for example, in Spain we are testing collaboration with plants authorized to process and recover scrap metal, in order to obtain secondary raw materials to be fed into new production cycles.

Here are some examples of projects implemented:

	 <b>Storage</b>	 <b>Wind</b>	 <b>Solar</b>	 <b>Grid</b>	 <b>Customer solutions</b>	<b>Cross</b>	
<b>CIRCULAR DESIGN</b>	<b>Circular inputs</b>	Geothermal lithium (Vulcan Energy)	Wind tower with wooden materials (3SUN)	Solar panels with recycled plastic	Circular Smart Meter with recycled plastic	Recycled plastic for EV charging stations	Materials passport
		BESS – New technologies for storage Thermal Energy Storage	Textile materials for wind turbine blades	Cell with copper replacing the silver (3SUN)		Recycled aluminum for public lighting systems	Sustainability K for procurement
		New storage technologies for storage: gravitational storage	Hybrid wind towers		Redesign of grid asset		
<b>CIRCULAR USE</b>	<b>Useful life extension</b>	2 <sup>nd</sup> life Battery Melilla (Spain)					Predictive maintenance
		Project PIONEER (Italy)					Repair through additive manufacturing
		Predicting failures software (IPCEI)					
<b>VALUE RECOVERY</b>	<b>New life cycles</b>	EV batteries recycling	Wind turbine blades recycling (Wind New Life)	Solar panel recycling (Photorama)	Grid mining		Sale of natural gas
							New models for the enhancement of secondary raw materials from scrap metal

Enel's Circular Procurement strategy aims to improve the circularity of purchased products and services through the definition of metrics (such as the EPD system, Environmental Product Declaration) to assess the whole-life environmental impacts related to the material and energy flows of the strategic product categories purchased, co-innovation with suppliers, and the use of tender requirements and rewarding factors to incentivize suppliers to offer in-

creasingly circular products. In addition, the Enel Group is developing tools and strategies to improve the tracking of materials along the value chain and to push suppliers to make efficient use of materials by focusing on recycling and recovery at the end of life and to increase transparency. See the chapter "Sustainable supply chain" for more details.

## Technological innovation in solar panel production (3SUN)

The new HJT (Hetero Junction Technology) solar module that will be produced in 2024 in the 3SUN Gigafactory in Catania, Italy, is a latest-generation double-sided photovoltaic module that guarantees less degradation of photovoltaic modules and extends their service life to more than 30 years. Due to its high efficiency (around 24%) resulting from the possibility of using larger and thinner wafers, it will already use a reduced amount of silicon for peak power. In addition, as a further evolution, a new HJT Tandem panel is being developed that will significantly exceed the state of the art in photovoltaic cells in terms of efficiency, reaching more than 30%; this will increase the efficiency of a conventional module by 15-20% and allow more energy to be generated, with the same number of modules installed, thus requiring less material such as polysilicon. In addition, technologies are being developed to introduce recycled materials into the production process (such as replacing panel glass with recycled plastic) and the possibility of replacing the silver (a material with a high environmental impact used in the metallization process of the cell) with copper is being evaluated.



### Andrea Tecci

Ecosystem and Circular Economy CC - EGP&TGx

*"At 3SUN we are working to increasingly improve the circularity of the PV module and minimize the consumption of raw materials, working on its entire life cycle: using circular materials, improving its productivity, extending its service life and finally maximizing the quantity of material that can be recovered at the end of its service life. The aim of all of this is to make this technology increasingly sustainable and competitive."*

## BESS – New technologies for storage



Again with the aim of promoting the development of new, more sustainable materials and processes, a first innovative commercial alternative to chemical storage based on gravity technology will be installed. The plant will be commissioned in the United States in 2024. Specifically, the storage system will use excess electricity from the grid to move large blocks of cement material.

Another alternative solution that Enel installed in Italy at the end of 2022 is **Thermal Energy Storage (TES)** based on solid material and using rocks with high thermal capacity to retain thermal energy from the process fluid. Using common fragmented rocks, the TES system has the capacity to store up to 24 MWh of clean heat at a temperature of around 500 °C for at least 5 hours.

All materials used (rocks, pipes and casings) are to be considered environmentally sustainable as there are no chemical compounds or critical or flammable materials.



## Redesign of grid asset



Several initiatives are underway within Enel Grids, which also leverage an innovation ecosystem to improve the circularity of different assets through design and the use of new materials.

The search for solutions with a lower environmental impact for distribution poles has also led Enel Grids to explore alternative materials to conventional ones; in addition to the use of recycled aggregates for the manufacture of new poles, an analysis is underway for the use of wood poles free of toxic impregnating agents with a design oriented towards total recyclability at the end of their life. Alternative solutions to conventional construction methods are also being tested, with 3D printing and for pile foundations, in order to reduce installation times and material consumption (see the chapter "Innovation").

Also thanks to the Open Innovability® platform, challenges

were launched in 2022 to gather a new concept for the design of primary and secondary substations to promote their harmonious landscaping, the adoption of circular solutions in terms of both the materials used and the sharing of space with the community.

### Circular Smart Meter – Closed loop recycling

From 2020, production of the new Circular Smart Meter began through a circular model and a pathway to redesign the value chain of the electronic meter, using material from discarded meters to make the new ones. About 2 million circular meters were produced in 2022. 48% by weight of the new meters are reclaimed materials: end-of-life recyclability (plastic, steel and other metals) is estimated at 79% by weight. Over its lifetime (15 years), each circular smart meter saves 7 kg of CO<sub>2</sub> and 1.1 kg of virgin material.

## Circular EV charging stations



We have been working for several years on the products in the Enel X Way portfolio by revising their design to improve their circularity. In fact, our main AC (alternating current) charging products use recycled polycarbonate as their main structural material (100% for JuiceBoxes and 75% for JuicePoles). For the JuicePole, AC public charging stations

installed in 2022 alone amounted to 3,000 new points. The use of materials was also optimized, reducing the overall weight of the product by around 32%. Another example of a circular solution we have implemented is the recovery through remanufacturing of end-of-life components to be reused as spare parts.

## Useful life extension of batteries



Enel is developing several solutions to extend the life of batteries, including the development by Enel X Enel X in the framework of an IPCEI project for artificial intelligence tools for predicting failures, anomalies and for modelling the degradation of lithium-ion batteries in order to extend their life and increase their reliability, optimizing operating and maintenance activity (project completion expected by 2023). A further strategy to extend the life of batter-

ies from the automotive sector is to reuse them "second life" solutions such as stationary storage systems.. Enel has developed a first solution of this type in Melilla (4 MW/1.7 MWh storage plant), realized through the reuse of about 90 batteries, and is completing another one with a nominal capacity of 2.5/10 MWh as part of the PIONEER (airPort sustainability secONd lifE battEry stoRage) project with Aeroporti di Roma.

## "Wind New Life" project



The project proposes to develop a circular value chain to manage the end-of-life of wind turbine blades, through the development of two plants in Italy and Spain that will provide for the collection of the blades, their processing for production of second raw material and the reuse of the same for the production of high value-added components (building materials, sanitary and furnishing products, flooring, cabinets and electrical conduits). The Spanish plant, operational from 2025, will handle around 8,000 tons of material per year. In Italy, the aim is to manage around 3,000 of them by the second half of 2025.



## Grid Mining



With the aim of maximizing the contribution to decarbonization along the entire value chain, a **Grid Mining & Zero Waste** model has also been defined, which, by considering grid assets as a mine to be drawn from at the end of life, allows the recovery and market leveraging of precious metals and other materials and devices from obsolete distribution infrastructures. In this regard, to ensure a complete tracking of the materials contained in the network assets from the input phase of the value chain, we have developed and digitalized in our systems the "Digital Product Passport" (DPP) that allows us to have a clear and detailed picture of the different types and quantities of materials in use. The DPP allows not only for monitoring any materials considered critical, for which it might be useful to evaluate an alternative, but also for defining *ex ante* end-of-life reuse assumptions. In this regard, the End of Life Dashboard was developed as part of the Grid Mining strategy. Starting with reverse logistics information on the type and number of decommissioned grid assets, in close connection with the DPP, it gives us information on the decommissioned materials, their quantity and type, and the possible CO<sub>2</sub> savings related to their reuse as "second raw mate-

rial". Having an integrated and digitalized tracking system along the entire value chain is the driving force toward the ambition to open our "mine" to the outside world as well, making it available to other companies or different sectors in order to involve their respective production chains and feed new markets for raw and secondary materials, promoting the development of the area and the saving of virgin materials, and creating new job opportunities related to waste material recovery initiatives while minimizing environmental impacts.

### The recycling of photovoltaic panels (PV Recycling)

As far as the end-of-life recovery of photovoltaic panels is concerned, Enel is collaborating in the Photorama project (European Horizon 2020 program), which aims to automate the process of dismantling solar panels and to identify a handling process suitable for the recovery of valuable materials (purity greater than 99.9%), reaching a recycling rate of 95%. This solution will improve the recovery process in terms of both recoverable quantity and quality of the recovered material.