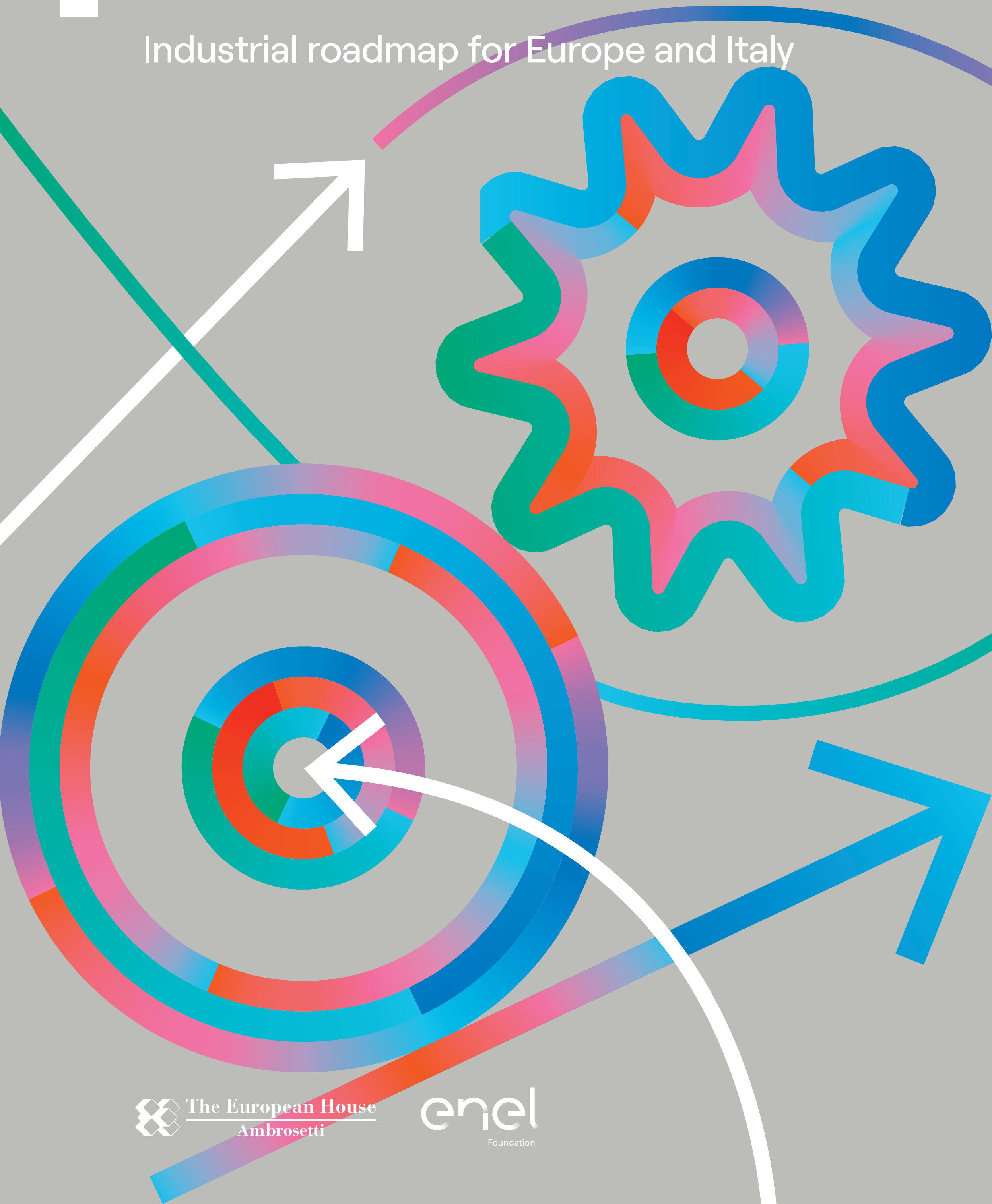
Energy transition strategic supply chains

Industrial roadmap for Europe and Italy



The European House Ambrosetti

enel Foundation

Energy transition strategic supply chains

Industrial roadmap for Europe and Italy

Table of contents

Preface 8
Remarks by the Scientific Committee 13
Key messages of the Study 18

Part 1
The reference context of decarbonization pathways in Europe and in Italy **36**

1.1 The state of the art of energy transition in Europe and in Italy 42
1.2 Perspectives and policy objectives of the energy transition in Europe and Italy, and gap analysis to 2030 49

Part 2
The state of the art and prospects of key decarbonisation-related industrial value chains in Europe and Italy **54**

2.1 Definition and state of the art of key industrial sectors to achieve decarbonisation targets 60
2.2 Photovoltaic: mapping, quantification and analysis of the value chain in Europe and Italy 65
2.3 Batteries: mapping, quantification and analysis of the value chain in Europe and Italy 96
2.4 Heat pumps: mapping, quantification and analysis of the value chain in Europe and Italy 124

Part 3
Policy proposals and guidelines for the development of key decarbonization-related industrial value chains in in Europe and in Italy **148**

3.1 The rising global competition on green industrial value chains 154
3.2 The proposals to develop industrial value chains n Europe and Italy 158

Bibliography 182

The project team is composed of an **Advisory Board**, responsible for the strategic steering of the research, a **Scientific Committee**, who provided scientific advice and direction to the Study, and of a **Research Team**, in charge of the development of the Study.

The Advisory Board is composed by:

Carlo Papa	→	Managing Director, Enel Foundation
Valerio De Molli	→	Managing Partner and Chief Executive Officer, The European House – Ambrosetti
Simone Mori	→	Member of the Scientific Committee, Enel Foundation

The Scientific Committee is composed by:

Joaquín Almunia	→	Former Commissioner for Economic and Monetary Affairs, European Commission; Former Vice-President and Commissioner for Competition, European Commission
Sonia Bonfiglioli	→	President, Bonfiglioli Group
Maria Chiara Carrozza	→	President, Consiglio Nazionale delle Ricerche – CNR
Timur Gül	→	Head of the Energy Technology Policy, International Energy Agency

Special thanks to:

Fatih Birol	→	Executive Director, International Energy Agency

The Research Team is composed by (alphabetic order):

Giovanni Abramo	→	Analyst, The European House – Ambrosetti
Daniele Maria Agostini	→	Head of Energy and Climate Policies – European Affairs, Enel
Mirko Armiento	→	Senior Researcher, Enel Foundation
Filippo Barzaghi	→	Analyst, The European House – Ambrosetti
Laura Basagni	→	Head of Brussels Office, The European House – Ambrosetti
Giorgio Bernabei	→	Energy and Climate Policies – European Affairs, Enel
Laura Giovannini	→	Deputy Director, Enel Foundation
Ines Lundra	→	Assistant, The European House – Ambrosetti
Mariano Morazzo	→	Deputy Director, Enel Foundation
Carlo Napoli	→	Deputy Director, Enel Foundation
Nicolò Sartori	→	Senior Researcher, Enel Foundation
Nicolò Serpella	→	Consultant, The European House – Ambrosetti; Project Coordinator
Lorenzo Tavazzi	→	Partner and Head of Scenarios & Intelligence Department, The European House – Ambrosetti
Giuseppe Tiralosi	→	Analyst, The European House – Ambrosetti

Special thanks to the Enel Group colleagues who contributed to the Study (alphabetic order):

Fabrizio Bizzarri
Michele Bologna
Ernesto Ciorra
Giuseppe Della Greca
Alejandro Falkner Falgueras
Valerio Mauro Felli
Guillermo Fumanal Achon
Marzia Germini
Filippo Italiano
Luigi Lanuzza
Nicola Lanzetta
Chiara Marricchi
Giovanni Matranga
Francesco Mattion
Luca Meini
Emiliano Micucci
Alessandra Ottanà
Rossella Petruazzoli
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Giorgio Corbetta	→	EU Affairs Director, EUROBAT
Walter Da Riz	→	Director, Assovetro
Vittore De Leonibus	→	Owner, Teknisolar
Monica Frassoni	→	President, European Alliance to Save Energy
Alberto Lampansona	→	Director Public Affairs, Eurocapable
Monica Manara	→	CCO – Chief Commercial Officer Photovoltaic, COVEME
Massimo Mazzer	→	Research Manager, Consiglio Nazionale delle Ricerche - CNR, Istituto dei Materiali per l'Elettronica e il Magnetismo – IMEM
Martina Miciano	→	PV Business Manager, COVEME
Thomas Nowak	→	Secretary General, European Heat Pump Association
Paolo Quercia	→	Studies and Analysis Division Director, Ministero delle Imprese e del Mande in Italy
Giovanni Sgaravatti	→	Research Analyst, Bruegel
Giacomo Vigna	→	Made in Italy and Creative Industries Director, Ministero delle Imprese e del Mande in Italy; Coordinator, Tavolo Nazionale per le Materie Prime Critiche
Paolo Rocco Viscontini	→	President, Italia Solare
Geert Vos	→	President and Chief Executive Officer, Daikin Italia
Simone Tagliapietra	→	Senior Fellow, Bruegel
Cecilia Trasi	→	Research assistant, Bruegel

The contents of this Study refer exclusively to the analysis and research carried out by The European House – Ambrosetti, Enel and Enel Foundation and represent their opinion which may not coincide with the opinions and viewpoints of the individuals interviewed and involved in the initiative.

Preface

Nicola Lanzetta
Head of Italy,
Enel

One year after the outbreak of the war in Ukraine, its massive implications on the international energy markets have set new patterns for the energy transition in Europe and at the global level, speeding up the pace of change and transformation.

The geopolitical crisis, coupled with the climate one, are indeed highlighting the vulnerability of the traditional energy model and its negative externalities on our societies at large, showing that a decisive evolution towards an energy system powered by clean energy technologies smartly distributed and efficiently consumed will encompass a substantial evolution. The challenge of finding the right balance between reliability, affordability and sustainability (i.e. so-called "energy trilemma"), which has characterized the EU's (and Member States') strategic approach towards the energy transition for at least two decades, could be eventually overcome provided a coordinated and convinced effort is put in place.

Indeed, the massive deployment of clean energy technologies will *per se* reduce our energy system vulnerability decoupling it from traditional commodities' availability and prices; however, to reap the massive socio-economic benefits of changes in progress, Europe as a whole and each Member State will need to develop the entire green energy value chain, reducing technology dependency from third countries.

Bottlenecks in the energy transition process have been already assessed by EU institutions and Member States, identifying the Chinese dominance over the strategic green energy supply chain as a risk to the bloc's strategic autonomy, as well as a potential constraint to its decarbonization efforts. Europe, indeed, lags significantly behind China in the manufacturing of key materials, components, and end products – not to mention the critical materials relevance – accounting for just an average 14% of the global manufacturing production of the 17 strategic components in the main clean technologies, versus the 65% global production in the hands of China.

These concerns have been addressed by the EU through the adoption – in March 2023 – of the "Net Zero Industry Act" (NZIA), which sets the goal of achieving a domestic production of at least 40% of the annual demand for green technologies by 2030. Looking at the specific technologies analysed by our Study, the plan mandates Europe to reach 30 GW yearly production capacity for all stages of the photovoltaic chain, as well as at least 550 GWh manufacturing capacity for the battery value chain and 31 GW for heat pumps.

To move faster and safer with the energy transition in Europe and in Italy, the deployment of green capacity is a necessary, but not sufficient condition.

While the 2022 Study "*Net Zero E-conomy 2050*" highlighted that investing financial resources to reach "Net Zero" by 2050 would take Europe and Italy faster towards a clean, sustainable and energy secure future, creating more jobs and bringing more significant savings than in case of less ambitious pathways, the current international debate stimulated a deeper reflection on the need to ensure a sound industrial and technological revival to sustain the decarbonization efforts at the continental and national level.

Starting from this assessment, this year's Study "*Energy transition strategic supply chains: industrial roadmap for Europe and Italy*" highlights that current geopolitical trends and energy markets dynamics force the EU and its Member States to do their utmost to recover from a prolonged loss of international competition in key green segments such as solar photovoltaic and batteries. A situation driven in particular by a number of bottlenecks, i.e. higher investment costs, higher lead times for industrial deployment, higher cost of energy, and a generalized lack of specialization and integration of the green industry across the european continent.

While critical, the situation is not irreversible and – as demonstrated by the Study – Europe and Italy, have the means to address it not only securing a faster energy transition, but also benefiting from these positive developments in terms of strategic autonomy and internal socio-economic development.

The issue of public funds is a case in point: against the common rhetoric about European institution underspending compared to the international competitors, the Study shows that public money is available, but that it needs to be managed in a more straightforward and effective way to ensure it unlocks industrial renaissance in the green domain within a reasonable time frame. In addition, better coordination of research activities currently scattered across the continent and an enhanced effort to develop an industry-wide circular approach based on higher recycling and substitution rates, would help exploiting and maximizing the sustainability advantage of the European supply chains in the international context.

Putting in place this structural effort and deploying in time the announced industrial investment would, in our estimates, allow Italy and EU to cover more that 50% of their 2030 needs for photovoltaic, around 90% of domestic batteries demand and more than 60% of heat pump deployment, speeding up the European journey towards decarbonization and heavily reducing the risks of supply disruption determined by the technological and industrial overreliance on third countries.

On the other hand, the Study highlights the socio-economic advantages enabled by these developments. Investments in the three key value chains are expected to generate massive economic returns in Europe both in terms of GDP and skilled jobs created. Adding together the net benefit of reduced imports and the direct, indirect and induced economic benefits coming from investments needed to reach the 2030 NZIA targets for the creation of local supply chains in the three technologies under analysis, the overall return on investment would be equal to up to around 640 billion Euros by the end of the decade, with relevant implications also on the costs of energy for final consumers, a fundamental item to be addressed by policymakers and energy stakeholders, particularly in light of the effects of the war in Ukraine on energy prices.

To achieve this goal, the EU and its Member States must firmly embrace a new strategic vision aimed at developing a competitive European-wide decarbonization industry and technological base built up on integrated and coordinated European value chains. Acknowledging the need to act fast, European and national institutions have identified the key targets. Indeed, in a context of international competition and mounting mistrust among global powers, this is already a very positive development. In the coming months and years, it will be a matter of deploying the tools to achieve this challenging yet vital objective for citizens and companies. On our side, fully aware of the huge work that lies ahead of us all, we are ready to do our part.

Valerio De Molli
Managing Partner
and CEO
The European House —
Ambrosetti

“The world of the future is in our making. Tomorrow is now”.

Eleanor Roosevelt

In 2022, the “*Net Zero E-conomy 2050*” Report by The European House - Ambrosetti and Enel Foundation analyzed the decarbonization trajectories in Italy in 2030 and 2050, estimating the related environmental, socio-economic and energy benefits associated with a more ambitious decarbonization pathway. The result was clear: being ambitious pays off and costs less.

To reap the full benefits of the current energy transition, it is not enough to make massive infrastructure investments, but it is also necessary to develop local skills and strengthen “green” industrial value chains. This process is of strategic relevance as it will make it possible to sustain the expected growth in the coming years, while reducing technological dependence on third countries, and it represents an unmissable opportunity to create jobs and value in the long term. The European Union cannot afford to shift from energy dependence to technological dependence.

Today, Italy and Europe lag far behind China in the production of key materials, components, and end products. The European share in the manufacturing production of the 17 strategic components of the main clean technologies is equal to 14% on average, compared to 65% in China.

To address these challenges, the European Union presented in March 2023 the “Net Zero Industry Act” (NZIA), which sets the objective of achieving a domestic production of at least 40% of the annual demand for green technologies by 2030.

To achieve these ambitious goals and come closer to the financing mechanisms provided by China and the United States, the European Union needs to redirect and effectively use the existing funds (EUR 695,1 billion between 2021 and 2027) to finance net-zero technologies.

To this end, the 2023 Report focuses on the key industrial supply chains for the energy transition in Europe and Italy, namely photovoltaics, batteries and heat pumps.

Each of these three supply chains has been broken down in detail into three basic stages: raw materials, components and assembly. For each supply chain, a qualitative-quantitative analysis was carried out based on specific key performance indicators. The aim was to take a snapshot of the state of the art and identify the main obstacles at the Italian and European level to the development of domestic supply chains for the technologies considered.

After analyzing the main bottlenecks, the Report focuses on the main existing risks and development opportunities for Italy and Europe in these value chains. Finally, the Report takes in account the projections on future demand and installations for each of the three technologies considered, in order to better understand the gap between the annual deployment needed to meet the policy targets and domestic manufacturing capacity, also in the light of recent plans drawn up at European and national level.

We have found that photovoltaics and battery production in Italy and the EU is currently more expensive than in China, due to higher investment costs (CAPEX and OPEX 2.2 to 5.6 times higher), longer lead times (up to 1.7 times), higher energy costs (45% higher), lack of specialisation (skills and adjacent industries) and integration (raw material extraction and refining) in the upstream phases. Although heat pump technology is mature and well established, the related market is at an early stage of development, with some uncertainty about how growth expectations will translate into actual market demand, and a shortage of specialized installers. These factors tend to slow down the reconversion of the boiler value chain.

Fortunately, it is not just a matter of obstacles; the European Union and Italy have some development levers that represent an opportunity to be seized. Effective use of available funds, environmentally and socially sustainable production processes, increased recycling capacity, R&D and innovation are the main factors that the EU and Italy can activate for the development of local photovoltaic, battery, and heat pump value chains. However, a transparent, stable, and favourable fiscal and regulatory framework for all these levers at EU and national level is crucial.

The Report estimates that by exploiting these opportunities and realising the announced projects on time, Italy and the EU can cover >50% of the 2030 demand for PV, ~90% for batteries and >60% for heat pumps, thus meeting the NZIA targets.

As Eleanor Roosevelt also said, "Tomorrow is now and it depends on us; we cannot miss this opportunity." To promote the development of an integrated local value chain, Europe and its Member States should adopt a new strategic vision aimed at developing a competitive European-wide decarbonisation industry, achieving integrated and coordinated European value chains and promoting greater diversification in the supply of technology components and critical raw materials, also leveraging already existing partnerships and complementarities with countries outside the EU. To this end, the Report identified 11 policy proposals (7 at the Italian level and 4 at the European level).

This ambitious Report would not have been possible without the concerted efforts of the top management of Enel and Enel Foundation in exploring an issue at the forefront of today's debate, and without the invaluable contribution of the Scientific Committee – Joaquìn Almunia (former Commissioner for Economic and Monetary Affairs, European Commission; former Vice-President and Commissioner for Competition, European Commission), Sonia Bonfiglioli (President, Bonfiglioli Group), Maria Chiara Carrozza (President, Consiglio Nazionale delle Ricerche - CNR) and Timur Gül (Head of the Energy Technology Policy, International Energy Agency - IEA) – to whom I would like to express my deepest gratitude.

Lastly, my heartfelt thanks go to The European House – Ambrosetti team: Lorenzo Tavazzi, Nicolò Serpella, Laura Basagni, Giovanni Abramo, Filippo Barzaghi, Giuseppe Tiralosi and Ines Lundra.

Remarks by the Scientific Committee

Joaquín Almunia
Former Commissioner for Economic and Monetary Affairs, European Commission;

Former Vice-President and Commissioner for Competition, European Commission

One of the biggest global challenges our generation will face in the coming years is the energy transition. Much time has been lost since global warming became "an inconvenient truth". From now on, there is enough scientific evidence to make the possibility of further delays intolerable. We must do our best to meet the commitments agreed at the COP21 in Paris in 2015, defined at EU level by the goal of achieving a climate neutral economy by 2050. Success in saving the planet also opens huge opportunities for those who will come after us in the second half of this century. Together with the digital transition, both strategies are intended to provide the best guidance for public policy in the medium to long term to create the right framework for the behaviour of economic actors and the well-being of our citizens.

To achieve this, it will be necessary to allocate a significant amount of public and private resources to the major investments required. Part of this should be devoted to making major efforts in research and development of a wide range of technologies associated with a green economy. At the same time, the costs of this transition cannot be ignored, and major obstacles need to be overcome. Some of the most important of these are the subject of this Report: the analysis of sustainable value chains to cater for the needs of the main sources of renewable energy, such as photovoltaic plants, the production of the type of batteries needed for e-vehicles and the manufacture and installation of heat pumps.

Today, we are still trying to reduce our reliance on fossil fuels given the urgency of minimising CO_2 emissions, in a context of serious tensions in the energy markets, exacerbated for geopolitical reasons. New difficulties are emerging. On the one hand, a high degree of foreign agreements ought to be taken into account given the origin of many critical raw materials that are also needed in other sectors such as aviation, space or digitalization. On the other hand, our external reliance on clean technologies associated with the production of photovoltaic panels, batteries and heat pumps is also a matter of concern. Geopolitics is a key word here. China's role as the main supplier of certain inputs and technologies in these areas is extremely important, and the potential risks associated with other countries will become crucial as well.

Nevertheless, our dependencies and potential scarcities also require attention in cases where the solutions will come from policies and measures to be decided by our own European and national authorities. Policy decisions are needed to increase the amount and availability of financial resources and to give the right signals to investors. Better coordination of research and development at European level and the promotion of innovation are a perquisite for the development of domestic value chains based on the substitution of what would otherwise come from foreign suppliers. Reducing the administrative burden weighing on the approval of investments can help to reduce the cost advantage of our competitors.

This aspect can also be addressed with a more efficient vertical integration of our companies. Improving the skills of our workforce should also help. And, last but not least, a responsible use of energy must be embraced in order to facilitate the success in the difficult tasks ahead of us. This Report aims to put forward a number of proposals to make that success possible.

Sonia Bonfiglioli
President, Bonfiglioli Group

Those of us, like myself, who have chosen to be an entrepreneur have a duty to encourage and support the transition towards a green economy. The centuries-long pattern of development and production has had the dangerous effect of contaminating our planet and, while refraining from engaging in entrepreneurship would have left us in a primitive state, the new awareness we have reached today should spur us to counter the devastating trajectory we are on.

Whilst it is true that enabling technologies of the digital evolution offer us new solutions, it is equally clear that the path ahead is largely still to be paved, and every country is currently engaged not only in a race for technological leadership, but also must secure its own energy autonomy, technical independence, and sustainability. Personally, I do not believe that "degrowth" is the solution, but instead, I champion and promote sustainable development.

The Report that is being presented delves into the current state of several key sectors driving the “green transition”, offering insights from both a European and Italian perspective on competitive positioning.

The challenge we face is multifaceted: achieving greater energy autonomy for Italy and Italian businesses, reducing harmful emissions, and increasing controlled technologies and supply chains dedicated to related production processes. There are no winners or losers yet, but we are all competing in an Olympic-like challenge to crown the new champions.

In this scenario, the Report shows that the heat pump sector sees both Europe and Italy well-poised; the proposed technical solution offers undeniable benefits not only for home heating but also represents a viable solution for industry. The clear advantage over the use of gas leads us to predict a promising growth, limited essentially only by the availability of labour tasked with installation. This limit could however turn into an excellent area of competence for upskilling and reskilling projects.

Less exciting, however, is the position held by both Europe and Italy regarding technologies, control of processes, and supply chains related to photovoltaic and battery production, as what has not been done in past years is a burden that weighs us down. Despite this, dedicated recycling processes can offer opportunities today to create new supply chains, with a great benefit in terms of sustainability as well.

We cannot ignore that the steel production chain from raw materials, along with those of plastic and cement, are among the processes with the highest CO_2 impact while their respective reutilization processes have the enormous advantage of recovering these wastes as well as of being much less impactful in terms of emissions. Europe, but especially Italy, now have champion companies that cover many recycling chain processes.

In addition to other sectors presented in the Study, Italian and European industry can leverage on its leadership in the manufacturing of wind technology; for example, new offshore wind turbines have reached record sizes exceeding the height of the Eiffel Tower.

There are many sports in an Olympic event, as are the technologies and supply chains that will be involved in this transition, but never have Pierre de Coubertin's words "The most important thing is not winning but taking part" been so apt, because whatever the result, putting ourselves to the test in this competition will mean that we are all running and competing for a single challenge: to secure a future for our planet.

Maria Chiara Carrozza
President, Consiglio Nazionale delle Ricerche – CNR

The climate change debate has reached a fever pitch in recent years. Devastating natural disasters have occurred all around the world, raising concerns about the risks that humanity will face in the near future if no further action to accelerate the ecological transition is taken. To address these challenges, the European Union has set ambitious targets for reducing CO_2 emissions , increasing the use of renewable energy sources and improving energy efficiency, with the overall goal of becoming "climate neutral" by 2050.

Huge steps are therefore needed to accelerate the energy transition in a decisive manner. To this end, an often underestimated enabling factor is the creation or development of key decarbonisation-related industrial value chains. In this sense, the present Report makes a relevant contribution, enriching the literature on the state of the art, bottlenecks and opportunities of the most promising industrial value chains for decarbonisation at the Italian and European level.

The importance of these value chains in enabling the energy transition has led the major economies to allocate funds and resources to their development. Today, however, Italy and Europe are lagging behind, and the goal of achieving strategic autonomy and promoting the development of integrated domestic value chains in Europe requires further acceleration and leveraging of key game changers.

In this sense, research and development is one of the most relevant for Italy and Europe to unlock the untapped potential of the clean energy technologies. Despite its main focus on the Italian and European industrial strategy, the Report tries to provide a possible link between the future industrial development and the innovation trends, with the aim of capturing some future possible technological solutions that can help Italy and European Union to reduce their current technological dependence.

In fact, as reported, R&D – in both its "research" and "development" aspects – could make it possible to overcome some of the critical issues along the value chains analyzed in the Report. For instance, with regard to the photovoltaics value chain, there are several research activities in Italy and in the EU, while there are highly relevant opportunities along the battery value chains, especially with regard to disruptive technologies (e.g., Na-ion batteries) and already developed and disseminated technologies such as lithium-phosphate batteries.

It will also be particularly critical to prioritise investments in green chemistry and in recycling technologies, which are two key enablers of the energy transition and the development of decarbonisation-related industrial value chains identified in the Report.

Italy has an opportunity to take advantage of a discontinuity that is not only technological, but also industrial and geopolitical, in which the industrial and innovation systems can act as an enabling technological platform, contributing to the overall economic development of the country.

Today, however, Italy has to face some critical challenges to make research and development an effective competitive factor in the creation and development of clean energy technologies. A higher vision must be adopted at the national level, facilitating the creation of synergies between public administration, universities and research centres, and also allowing the public sector to take advantage of the human capital present in these institutions. Finally, further investment is needed in competences and skills for the energy transition and related industrial value chains.

This is a time of transitions, and the energy one means providing an effective response to climate change: nowadays, however, climate change is not intended only as having impact on climate. Its effects are far-reaching, and this also affects the revision of the concept of "planetary boundaries", updated to take into account the fact that everyone, especially the most vulnerable members of the population, has an absolute right to water, food, energy and health, in addition to the right to a clean environment. Thus, the need to ensure an equitable energy transition from which everyone can reap the relative benefits.

Science has a leading role to play in this scenario. As researchers, we are fully committed in making our contribution and opening up the relevant opportunities for everyone in the context of the transitions that will take place in the coming years. Indeed, our future depends on our ability to stimulate and support innovation processes. Innovation, especially disruptive one, depends on the willingness to strengthen basic research to improve technology transfer mechanisms and the ability to collaborate.

Today, more than ever, we need to understand change and become protagonists. We must decide today what we want to be tomorrow.

Timur Gül
Head of the Energy Technology Policy, International Energy Agency

The energy transition required to achieve net zero greenhouse gas emissions by 2050 depends on secure, resilient and sustainable clean energy and technology supply chains. These supply chains are currently undergoing extraordinary development thanks to growing consumer demand for key technologies such as electric vehicles, increased investment by manufacturers, and supportive policies as different countries pursue energy, climate and industrial strategy goals.

In early 2023, the IEA's latest "*Energy Technology Perspectives*" report set out the scale of the transition underway, with an overview of the current state of global clean energy supply chains and the opportunities for their development, as well as potential risks that need to be addressed. More recently, our special briefing on the "*State of Clean Technology Manufacturing*" provided an update showing just how quickly manufacturing is evolving: in the four months to the end of March 2023, the projected output in 2030 from announced solar PV manufacturing projects increased by 60%.

Setting industrial strategies for clean energy supply chains is an opportunity to address climate, energy security and economic growth goals together, and to ensure that the energy transition leaves no one behind. As events in recent years have shown, energy security today is increasingly about access to resources and goods, and the ability to respond quickly to any volatility in the balance between supply and demand. In this context, a secure, resilient and sustainable supply chain is essential.

Many clean energy technologies rely on components, materials, or minerals for which supply chains are highly concentrated in a few countries, and as such may be vulnerable to incidents that could affect the wider supply chain. It is important to recognise that it is not realistic for most countries to compete effectively in all supply chain or in all supply chains. The IEA has therefore called for international cooperation as part of the effort to build a resilient foundation for tomorrow's industries.

This Report is a timely contribution to the analysis of strategic supply chains for the energy transition in Europe and in Italy in particular. As the Report shows, countries' clean energy industrial strategies need to build on the identification of their own strengths and use strategic partnerships to fill any gaps. The transition to a new energy economy offers significant opportunities for growth and jobs, relying on domestic policies to support manufacturing and remove barriers to progress, and on international cooperation to facilitate and scale up improvements. Developing decarbonization-related industrial value chains in countries and regions around the world requires a systems vision of international and regional opportunities, as well as detailed information on how to overcome potential bottlenecks at the national level.

Europe and Italy can build on consumer demand for certain technologies, a supportive policy and funding environment, experience in sustainable manufacturing, and strengths in research and development. Much remains to be done: a considerable increase in ambition is urgently needed to develop supply chains that can meet the needs of a pathway to net zero emissions by 2050. This Report is a timely contribution to that goal.

Key messages of the Study

1 →

Europe and Italy have set ambitious targets for renewable energy sources' deployment and electrification of end uses. However, the supply chains for the key decarbonization technologies needed are heavily concentrated outside of the European continent, mainly in China (65% of the total on average). For Europe and Italy, this represents both a risk of energy-technology dependence and an opportunity to develop strategic value chains and thus reap the related socio-economic benefits.

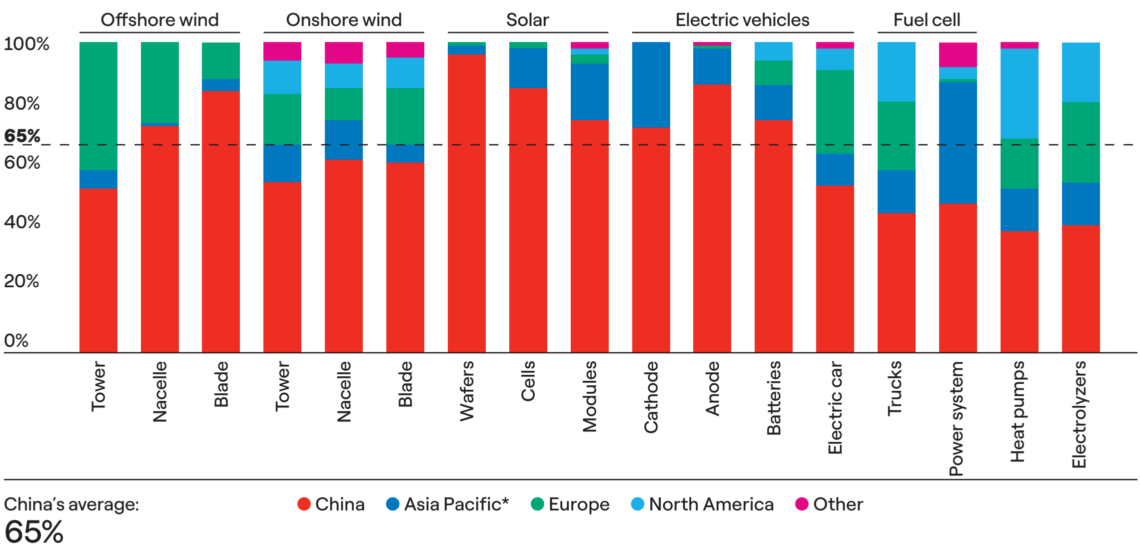
Renewable energy sources (RES) are crucial to supporting decarbonization while ensuring energy security and economic affordability. In this sense, **renewables, joined with reliable digital power networks and electrification of end uses, make it possible to overcome the traditional "Energy trilemma**", because they can match **economic affordability** (lowest power generation cost), **energy security** (no need to import fuel) and **decarbonization** (lowest life cycle emissions).

To fully reap the benefits of the current energy transition, it is not enough to deploy the massive infrastructural investments needed, but it is also necessary to **locally develop skills and strengthen "green" industrial value chains**. This process is of **strategic relevance** as it will on one hand allow to **sustain the expected growth** in the coming years and at the same time reduce the technology **dependence** from third countries; on the other hand, it represents an unmissable opportunity to generate **jobs and value in the long-term**.

From a strategic perspective, over the last 30 years China has aimed at achieving global leadership in a set of key value chains[1]. On the contrary, Europe has focused on policies that resulted in industrial delocalization and growing reliance on global value chains. This led Europe to lose market share, competitiveness and know-how in key industrial domains. Only recently the EU and its Member States have slowly started to shift their strategic stance to address this issue.

Europe and Italy **lag significantly behind China in the manufacturing of key materials, components, and end products**. The **European share** in the manufacturing production of the **17 strategic components** in the main clean technologies[2] is equal to **14%** on average (compared to **65%** of China).

Figure I → **Share of clean-energy technologies' manufacturing capacity by region, 2021** (% values)



* Excluding China.

Source → Elaboration The European House - Ambrosetti and Enel Foundation on IEA data, 2023.

To address these challenges, the European Union presented in March 2023 the "**Net Zero Industry Act**" (NZIA), setting the objective of achieving a domestic production of at least **40%** of the annual demand for green technologies by 2030: Europe should reach a **30 GW** yearly production capacity for all stages of the photovoltaic chain, as well as at least **550 GWh** manufacturing capacity for the battery value chain and **31 GW** for heat pumps.

1
This posture dates back at least to 1992, when Deng Xiaoping, former Chinese leader said: "*The Middle East has oil, China has rare earths*".

2
According to IEA, the main clean technologies are offshore wind, onshore wind, solar, electric vehicles, fuel cells, heat pumps and electrolyzers.

To reach these ambitious targets and get closer to the financial support provided by China and USA[3], the European Union needs to **redirect and effectively use the existing funds** (**EUR 695.1 billion between 2021 and 2027**[4]) to finance net zero technologies. However, the EU funds **focus predominantly on the early stages of technological development**, with **just a few of these that can currently cater for support to strengthen manufacturing capacities**[5]. Indeed, the issue of public funds is a case in point: against the common rhetoric about European institution underspending compared to the international competitors, public money is available, but that it needs to be managed in a more straightforward and effective way to ensure it unlocks industrial renaissance in the green domain within a reasonable time frame. In addition, better coordination of research activities currently scattered across the continent and an enhanced effort to develop an industry-wide circular approach based on higher recycling and substitution rates, would help exploiting and maximizing the sustainability advantage of the European supply chains in the international context.

2 → This Study focuses on photovoltaic (PV), batteries and heat pumps (HP), the decarbonization technologies which will have the largest growth by 2030 in the sectors of energy production, distribution, and consumption respectively, and which value chains are either not robustly present (PV, and batteries) or which market is at an early stage of development (HP) in the EU and Italy.

Achieving a fully decarbonized energy system will require the deployment of a wide range of technologies along the whole value chain. The bulk is represented by renewable generation, storage, energy transmission and distribution and final uses. Among these technologies, based on the growth perspective and the development level of the European and Italian value chains, this Study focuses on **three key industrial sectors related to decarbonization: photovoltaic, batteries and storage systems and electric heat pumps**.

3
A comparison between NZIA and IRA is not fully appropriate since the two mechanisms are different (IRA is based on tax credits, unlike the European mechanism).

4
As reported in the "Net Zero Industry Act" Staff Working Document.

5
Such as the Innovation Fund – mostly for first-of-a-kind installations – "REPowerEU" package under RRF or financial products established under the InvestEU Programme, and the Modernisation Fund. Even if they have a different financing mechanism, also Important Project of Common European Interest (IPCEI) have this limitation, focusing mainly on developing new technologies instead of enhancing production capacity

As far as network technology, **digital distribution and transmission networks will play a key enabling role** in a system dominated by renewable power generation and electrified end-uses, and therefore will undergo a tremendous **growth and renewal both in terms of capacity and capabilities**. Nevertheless, for this technology both Europe and Italy can rely on a strong supply chain and industrial sector and don't show dependency issues[6]. For this reason, this Study doesn't focus on this set of technologies.

Concerning energy production technologies, the **largest increase in installed capacity** is expected for photovoltaics, the cheapest power generation technology available. The latest trajectories and scenarios foresee between 2021 and 2030 in the EU an increase of **+432 GW** for **solar power**, compared to +323 GW for wind. In the same period, **in Italy an increase of +58 GW is expected for solar power**, while wind power is expected to expand by +25 GW[7].

Batteries and storage systems[8] are essential to facilitate the **penetration of variable RES, the deployment of electric vehicles and the changes in electricity demand patterns**. As a result, these technologies are expected to grow strongly over this decade. Within the European Union, batteries production capacity is expected to grow by **+810 GWh** by 2030 (over 10 times the current capacity of 76 GWh), whereas in Italy is expected to grow by **60-106 GWh** (over 20-30 times more than the current 3.35 GWh). At the same time, it is forecasted that by 2030 there will be **51 million** electric vehicles in the EU (8 times more than the current 6.1 million) and **6 million** electric vehicles in Italy (17 times the current 300,000).

Renewable powered **electric heat pumps** are the most effective way to efficiently decarbonize building heating and cooling. With respect to traditional alternatives, heat pumps feature a lower **levelized cost of heat** and **3 to 5 times higher efficiency**[9]. Heat pumps are also the most efficient technology for low to medium temperature industrial applications, with one of the highest levels of technology maturity.

Based on recent estimates by the European Heat Pump Association (EHPA), **60 million additional heat pumps** are expected to be installed by 2030 in Europe, rising from 17 million in 2021 to **77 million** in 2030. In Italy, **10 million** additional heat pumps are expected to be installed by 2030, from 1.6 million in 2020 to 11.6 in 2030.

6
Source: "*La filiera italiana delle tecnologie per le energie rinnovabili e smart verso il 2030. Le potenzialità di sviluppo della filiera elettrica e i benefici sul sistema socio-economico italiano*", Althesys, Elettricità Futura ed Enel Foundation, 2023.

7
EU values for 2030 refer to the targets in the European Commission's "REPowerEU" scenario. The values for Italy in 2030 refer to the latest policy scenario set by Elettricità Futura on the basis of the targets in the European Commission's "REPowerEU" scenario. At the time of writing the Report, the National Energy and Climate Plan (NECP) is being revised and updated. The targets could therefore be more ambitious.

8
Electric vehicles' batteries, storage utility scale and storage behind the meter. At the time of writing the Report, the National Energy and Climate Plan (NECP) is being revised and updated. In particular, the plan envisages an increase in the capacity of storage systems by 15 GW.

9
Efficiency is expressed by the performance coefficient, calculated as the ratio of energy input to energy output.

Figure II → **Key facts and figures of the key decarbonization-related industrial value chains analysed in the Study, 2030 vs. 2021**

Photovoltaic	Batteries	Heat Pumps
By 2030	By 2030	By 2030
+432 GW → in Europe	**+810 GWh** → in Europe	**+60 mln** → in Europe
+58 GW → in Italy	**+60-106 GWh** → in Italy	**+10 mln** → in Italy
according to the latest trajectories*	according to current projects announcements**	according to the latest scenarios***
Cheapest power generation technology (LCOE)	**Crucial role** to facilitate the penetration of RES and EVs deployment	Best combination of **technology readiness, efficiency** and the **lowest cost of heat** vs. traditional heating solutions

* 2030 targets reflect the "REPowerEU" for European Union and the Elettricità Futura scenario (inspired by the "REPowerEU" plan) for Italy.
** Announced, planned/partially financed, under construction/in operation.
*** 2030 expected demand according to EHPA and Enel and Agici report "*Electrification Of Domestic Heating And Hot Water Systems In Italy*".

Source → Elaboration The European House - Ambrosetti and Enel Foundation on various sources, 2023.

3 →

Producing photovoltaics and batteries in EU and Italy is currently more expensive than in China, due to higher investment costs (CAPEX and OPEX), higher lead times, higher cost of energy, lack of specialization (competences and adjacent industries) and integration (raw materials extraction and refining) in the upstream phases. Despite heat pumps technology is mature and well established, the related market is at an early stage of development, presenting some uncertainties about how growth expectations will turn into actual market demand, and a shortage of specialized installers. These factors tend to slow down the boiler value chain reconversion.

Over the years, China built its industrial capacity leveraging on **policies specifically aimed at achieving global leadership in green tech value chain**, while Europe's strategy led to **industrial delocalization and growing reliance on global value chains**. The slow adjustment of the European and Italian strategic vision led to some **competitive disadvantages** compared to China, **especially regarding photovoltaic and batteries**.

With respect to China, investment costs are higher in EU and Italy. Photovoltaics investment cost in Italy – and EU – is **2.2 to 5.6 times higher**. At the same time, the CAPEX for a new battery gigafactory is **47% higher** (EUR 100 million per GWh in Europe vs. EUR 68 million per GWh in China), and the manufacturing cost of batteries in EU is **33% higher** than in China. Also on **operating costs**, China has a more attractive environment. European and Italian **industry energy price** is **45% higher** than in China and the **EU CO_2 emission cost** is **10 times** than the Chinese one. Lastly, Europe and Italy have an **average hourly wage** that can be up to **5 times** higher than in China.

Secondly, **developing manufacturing plants** takes much more time in Europe than in China. In Europe new PV manufacturing plants can take **20 to 40 months** to become operational, compared to **12 to 24 months** in China. **Lead times is an open issue also for batteries**: in fact, gigafactories can take **up to five years** to be built and become fully operational.

A third issue consists in the **lack of specialization**[10]. This is particularly marked in the photovoltaics market: some phases require **highly skilled labour and access to state-of-the-art production technology**, in a context in which **there are no equipment suppliers in upstream segments in Italy**. Chinese dominance in photovoltaics technology also stems from the development of **adjacent industries**, primarily **glass and aluminium**. In fact, the growth of domestic module production is only possible if a network of industries supporting the related production with the necessary ancillary materials and expertise is present. Overall, as **production in Europe is limited** and Chinese companies have **accumulated experience and expertise** - also thanks to the industrial policies they have undertaken - European counterparts encounter an **additional barrier to entry**.

Lastly, the lack **of integration in the upstream phases** is another criticality for photovoltaic and batteries. In photovoltaic value chain, for both Europe and Italy, there is no vertical integration and **there is no single company operating in the downstream segments** (cells and modules) **which is also active in the upstream ones** (polysilicon, ingots, wafers). Therefore, **European companies are more subject to profit volatility**, as well as exposition to crises and **unexpected shocks**. With regards to batteries, the lack of vertical integration is particularly noticeable by looking at **raw materials extraction and refining**: the extraction of the key raw materials for batteries is highly concentrated in few countries (EU imports **100%** of lithium and **81%** of cobalt), whereas the processing capacity is primarily located in **China** (thanks to **massive Chinese foreign investments** deployed in the last 15 years and directed to those Countries where the critical raw materials are located). In this context, the stringent European regulation in terms of mining/extraction brings the total time necessary from the mining discovery to the actual extraction up to **15/17 years** vs. **3 months in China**. Also, **European recycling capacity is currently very limited**, raising concerns on the possibility to increase the provision of **secondary raw materials**: as of today, **81%** of the **global lithium** battery **recycling capacity is concentrated in China**, where also more than **90%** of the expansion of this capacity in the coming years is expected.

When it comes to the **heat pumps**, a first consideration regards the **early stage of development of the market**, which is **not mature yet in Europe** (as opposed to technology that is instead mature) and is characterized by several uncertainties that complicate the investment planning process of companies. Technological advancements, changes in **government policies or incentives, uneven installation requirements and buildings codes**, environmental concerns, and consumer preferences can significantly **influence the demand** for heat pumps. These uncertainties make it difficult for industry players to precisely gauge the potential growth and market size in the coming years. The **uncertainties surrounding the heat pump market** can **discourage established industries**, such

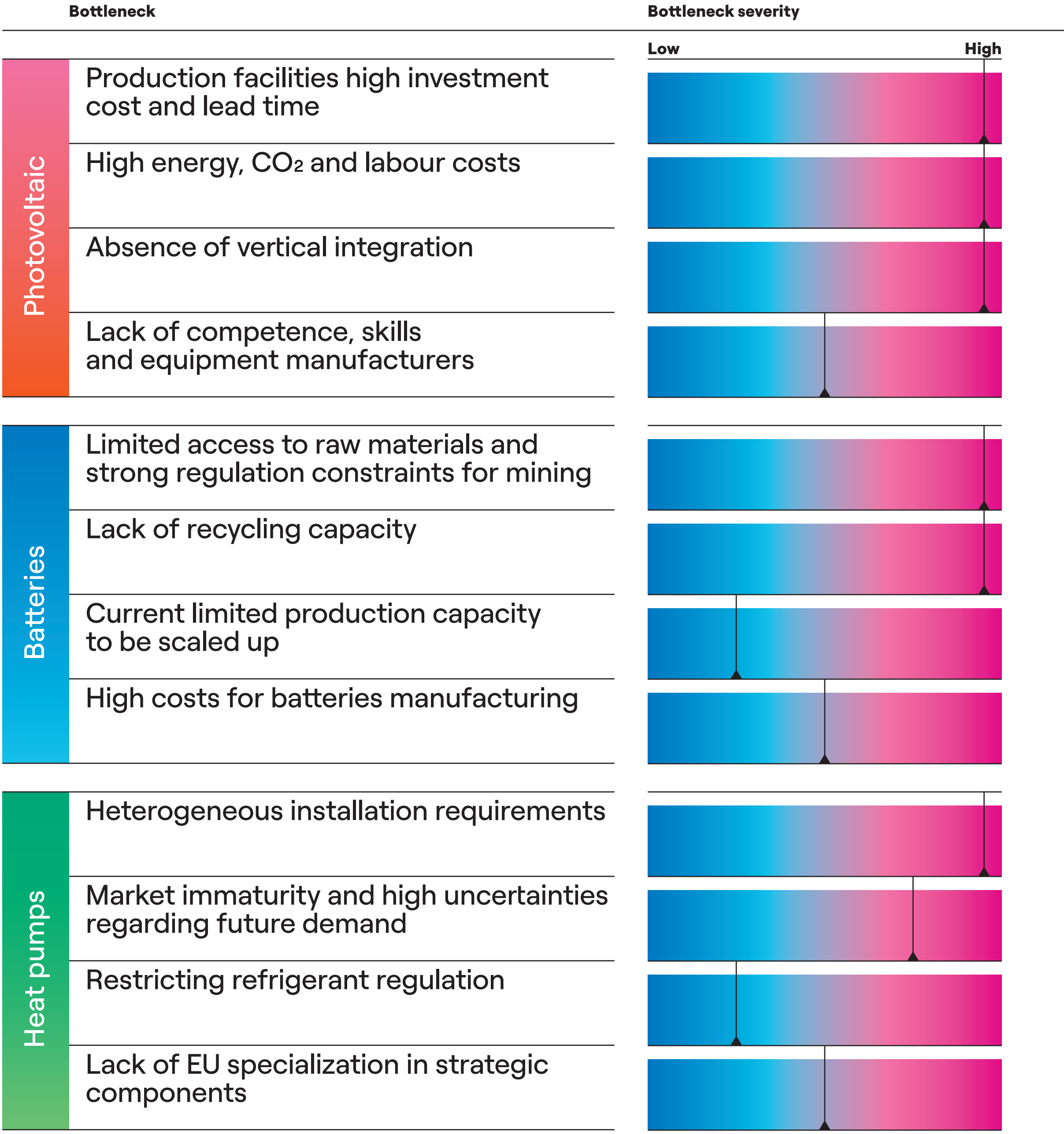
10
As it emerges from the Report "The World Energy Employment" published by IEA, with the support and analytical contribution of Enel Foundation, the energy sector demands more high-skilled workers than other industries, with 45% of the workforce requiring some degree of tertiary education.

as the gas boiler one, from investing in the conversion or integration of heat pumps into their existing infrastructure. This can **slow down the pace of innovation, investment in infrastructure and expansion of production capacity** in the heat pump industry.

In addition to difficulties on the manufacturing front, the EU and its Member States currently suffer from a **shortage** of heat pump **installers**. Currently, there are about **1.5 million** installers in Europe (85 thousand in Italy) of all kinds of heating appliances, most of them small companies[11]. The European Heating Industry, however, estimates that the **number of installers** must **increase by 50%** to reach the "REPowerEU" targets, in addition to the need for **50% of existing installers to upgrade their skills**. The skills needed to install heat pumps are similar to those of many standard occupations in construction but require **additional specialisations** (e.g. handling of refrigerant fluids).

11
For the analysis the following ATECO code has been considered: 43.22.01. Installation of plumbing, heating and air conditioning (including maintenance and repair) in buildings or other construction works.

Figure III → **The main bottlenecks at European and Italian level along the photovoltaic, battery and heat pumps value chains**



Source → Elaboration The European House - Ambrosetti and Enel Foundation on various sources, 2023.

Reasoning

- → **CAPEX 2.2 to 5.6 times higher** in EU and Italy than in China
- → **Lead times** up to **1.7 times longer** in EU and Italy than in China

- → The EU and Italian industry energy price is **45% higher** than in China
- → EU CO_2 emission cost is **x10** than the Chinese one
- → EU **average hourly wage up to x5** than in China

- → In Italy and in Europe there is **no single company vertically integrated along the PV value chain** making them more **subject to unexpected shocks**

- → Some PV **segments require advanced technologies, know-how, skilled labor** and access **to state-of-the-art production technology**
- → **Lack of equipment suppliers** in upstream segments in EU and Italy

- → **100%** of lithium and **81%** of cobalt is imported in EU
- → **15-17 years** to get a permit for mining in EU vs. **3 months in China**
- → In Italy competence for mining titles is in the hands of the **Regions**, generating a **lack of homogeneity**

- → China holds **81%** of current global capacity for EV and stationary storage batteries
- → EU has **low recycling rates** for batteries' raw materials (e.g., **0%** for lithium, **32%** for cobalt and **43%** for nickel)

- → **Limited production capacity of EU and Italy** (**80%** of EU batteries production capacity in the hands of Asian manufacturers)
- → Gigafactories need about **5 years to build and fully ramp up** in EU

- → **The manufacturing cost of batteries** in EU is **33% higher** than in China, with the CAPEX for setting up a new gigafactory that is **47% higher**

- → Several building **requirements** (space, distribution system, electricity and insulation), high cost of installation (**~€6,000 for air-source** HP) and lack of installers (need to increase by **50%**) and **50%** of existing ones need reskilling

- → **Immature market**, implying **uncertainties** about future demand evolution, disincentivizing the conversion of existing structured industries (e.g. gas boiler) and companies' investment plans

- → **EU HFC's phase-down plan** can obstacle the development of HP market while increasing the **cost of refrigerants** (+394% between April 2021-April 2022) without relevant environmental benefits

- → **63% of EU compressors' demand is imported** and their market is **concentrated.** Manufacturers might not be able to **scale up** their production due to **cost competition** and the massive scale of the few existing global manufacturers

4 →

Effective use of available funds, environmentally and socially sustainable production processes, boosting of recycling capacity, R&D and innovation are the main levers that EU and Italy can activate for the development of PV, batteries, and HP local value chains. A transparent, stable, and favourable fiscal and regulatory framework for all these levers at EU and national level is crucial. Exploiting these opportunities and realizing in time the announced projects can allow Italy and EU to cover >50% of 2030 needs for PV, ~90% for batteries and >60% for HP, reaching the NZIA targets.

Despite the presence of several bottlenecks, **Europe and Italy present some levers that can be activated to develop the photovoltaic, batteries and heat pumps value chains**.

Firstly, there are already **available funds** that could expand photovoltaic and batteries manufacturing capacity. Concerning Italy, in the NRRP (National Recovery and Resilience Plan) **EUR 400 million** are allocated to innovation in PV value chain and **EUR 1 billion** to support, *inter alia*, the Italian storage industry and create a capacity of **11 GWh**. For batteries, since the launch of the European Battery Alliance (EBA) in 2017 two Important Project of Common European Interest (IPCEIs) were promoted with an overall budget of **EUR 6.1 billion** (of which EUR 1 billion allocated to Italy). The EBA instead has directly provided the European battery industry with **EUR 100 billion** until now with the forecast to reach **EUR 600 billion** by 2030.

Second, European PV and batteries value chains are characterized by environmentally and socially sustainable production processes. In fact, a relevant part of the Chinese cost advantage is due to a **lower attention to sustainability issues and lower standards on human and labour rights**.

Indeed, total emissions from the production of the photovoltaic modules in Europe are estimated at **0.46 kg CO_2 equivalent per W_p**[12], compared to **0.75 kg in China**[13]. Looking only at the polysilicon production stage, the estimated emissions in China are 0.33 kg CO_2 equivalent, **more than double** the 0.15 kg in Europe. Concerning batteries, Europe reports **33%** lower emissions compared to China, 31% compared to Japan and 25% compared to South Korea. Regarding human and labour rights, **China has been accused to adopt forced labour in its polysilicon facilities**, especially in Xinjiang[14].

Third, **EU has a relevant, yet fragmented, R&D capability on PV**. R&D resulting in high-quality and efficient industrial products could be a key lever for Europe to strengthen its position in the photovoltaic and batteries value chains. However, Europe needs to boost its efforts and **coordinate** the different research centres, **pooling the knowledge and expertise** already present; concerning batteries, there are high opportunities related to **disruptive technologies** (e.g., Na-ion batteries) but **limited funds and coordination** across EU institutions and Member States.

The heat pumps value chain presents several, but different opportunities compared to the ones of PV and batteries value chain. First, European and Italian heat pump industry is far from being irrelevant. Despite still at an early stage of development, the EU accounts for **15% of global HP production** and covers **77% of domestic demand** (whereas Italy only 28%), with great potential to **convert gas boilers' value chain**.

Moreover, **European policies** have recognized the role of heat pumps for decarbonization, aiming to install **an additional 60 million heat pumps** by 2030. This European target has been complemented by national policies in favour of more energy consumption from heat pumps and more installations. In **Italy**, a target has been set to install **10 million additional heat pumps** by 2030.

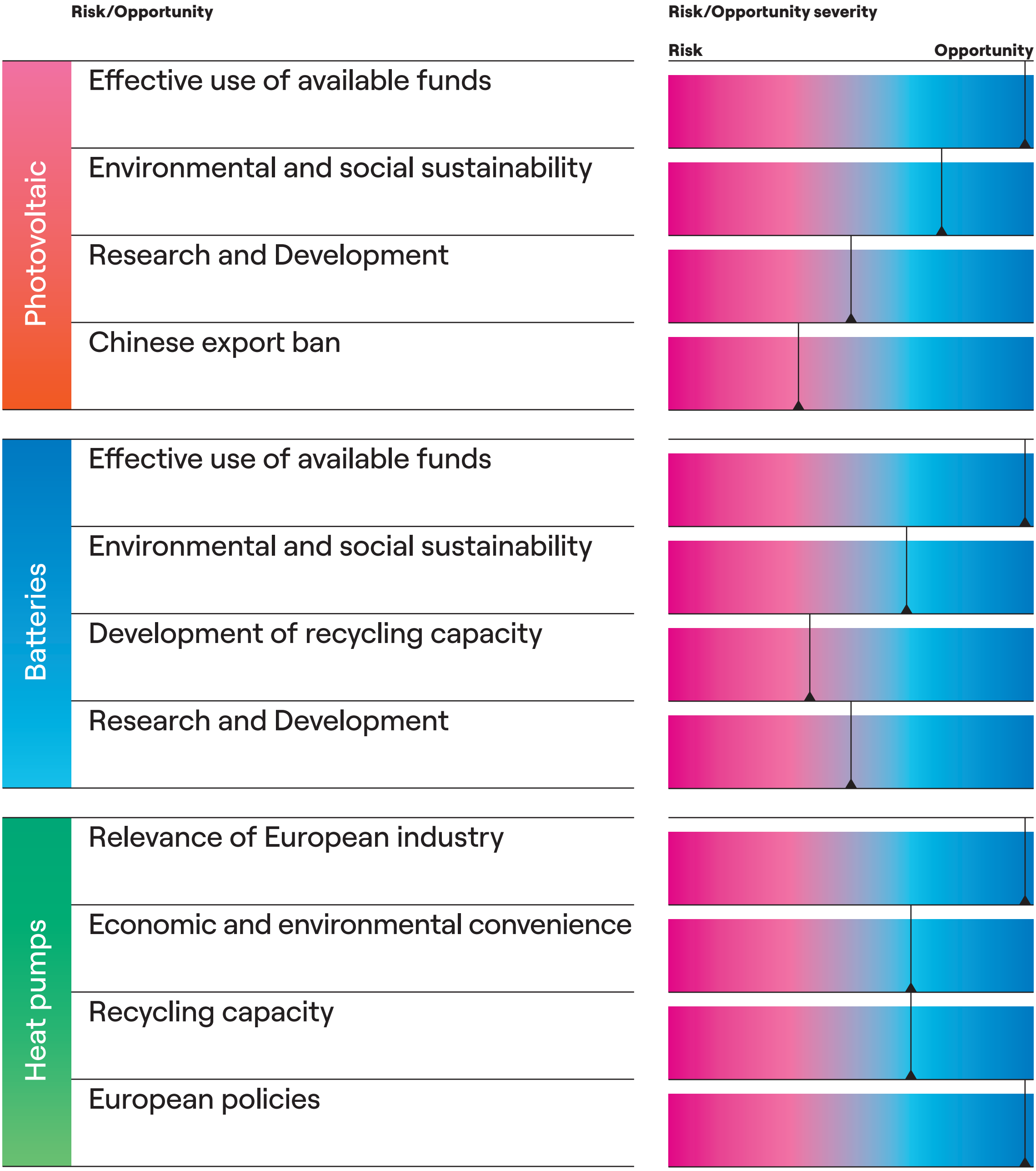
Finally, despite the relevance of several raw materials for the heat pump value chain and the associated costs, most materials is characterized by **high recycling and substitution rates**. In fact, the recycling rate in 2022 was **90%** for **steel**, **80%** for **cooling materials**, **75%** for **aluminium** and **70%** for **copper**. The ability to reuse materials can mitigate the problems of price volatility and raw material scarcity, providing a significant *stimulus* for the heat pump industry.

For the battery value chain, although recycling could be a key tool to reduce dependency from raw material import, its close-to-zero current rates and insufficient growth perspective make this a very difficult lever to activate: by 2030, recycling capacity is expected to increase by **x50** but it will still cover only **6%** of lithium demand, **7%** of nickel and **10%** of cobalt.

12
Watt peak, unit of measurement of power.
13
Source: "*Sustainable PV Manufacturing in Europe*", Fraunhofer ISE.

14
In June 2021 the US Government banned polysilicon from China's western region of Xinjiang over human rights concerns, via the Uyghur Forced Labor Prevention Act, requiring American companies to prove that their supplies are not derived from forced labour imposed on ethnic minorities in China and to map every step in the production of imported materials.

Figure IV → **A summary view of the main opportunities and risks for the development of the photovoltaic, batteries and heat pumps value chains in Europe and Italy**



Source → Elaboration The European House - Ambrosetti and Enel Foundation on various sources, 2023.

Reasoning

- In EU and Italy, **funds are already available, but need to be effectively channeled** to expand and scale-up PV manufacturing capacity, coordinating and integrating current capabilities across the EU
- The **manufacturing of PV modules in Europe is more environmentally sustainable** vs. China, even if the latter might **quickly catch up**. China has been accused to adopt **forced labor** in its polysilicon facilities
- Different research centers in EU and Italy but **need of higher coordination**. China R&D in the sector is strong and can leverage on the huge production capacity
- 3 Chinese technologies to manufacture PV modules might be **prohibited for export**. This is a risk but EU could promote the development of a local industry, but this **takes time**

- In EU and Italy, **funds are already available, but need to be effectively channeled** to expand and scale-up batteries manufacturing capacity, coordinating and integrating current capabilities across the EU
- The **manufacturing of batteries in Europe is more environmentally and socially sustainable** vs. China, even if the latter might **quickly catch up**
- By 2030, recycling capacity is expected to increase by **x50** but it will cover only **6%** of lithium demand, **7%** of nickel and **10%** of cobalt: further development of recycling capacity requires **higher investments** and **targeted R&D**
- High opportunities related to **disruptive technologies** (e.g., Na-ion batteries) but **limited funds and coordination** across EU Institutions and Member States

- With respect to the current market size (still at an early stage of development), the EU accounts for **15% of global HP production** and covers **77%** of **domestic demand**, with great potential to **convert gas boilers' value chain**
- Despite high initial investment costs (cost of the machine and installation), HP is the best technology in terms of **total cost of ownership and adaptability to a variety of climates**, minimizing the impact on the environment
- In the longer term, recycling can be an **effective strategy to solve the price volatility and scarcity problems**
- The growth of heat pumps market is boosted by **European policies** aimed at reducing gas dependence

Exploiting the opportunities presented above and realizing in time the announced projects can allow Italy and EU to cover **>50%** of 2030 needs for PV, **~90%** for batteries and **>60%** for HP, reaching the NZIA targets.

Regarding the **photovoltaic value chain**, if all the production capacity announcement were implemented, Europe would come close to the NZIA expectations (annual domestic production of **30 GW by 2030**), especially in the **polysilicon and modules segment**. In fact, at the European level it is expected **48.6 GW** of domestic production capacity for polysilicon, **20.8 GW** for ingots and wafers, **19.5 GW** for cells, and **31.7 GW** for modules. In Italy, the current announced projects will lead to an **increase in domestic production in the module and cell stages**, while there **are no plans to intervene in the upstream stages of the value chain** (polysilicon, ingots, and wafers).

Concerning the **batteries value chain**, if all the production capacity announcements were implemented, Europe could reach an annual domestic production of about **900 GWh**, meeting the EBA target of producing domestically **90%** of the expected annual domestic demand. Similarly, at the Italian level, the realization of all the projects announced could allow to reach **109 GWh** in production capacity by 2030, which is also in line with the expected production capacity to reach the **90%** EBA target by 2030.

Regarding the **heat pumps value chain**, the EU will have to reach a level of **76.8 million installed heat pumps by 2030** (+60 million compared to 2021), to reach policy targets. In Italy, according to scenarios elaborated by Enel and Agici, a strong growth of installed heat pump units is expected in the coming years. In particular, the country is expected to reach a level of **11.6 million heat pumps by 2030** (+10 million compared to 1.6 million units in 2020).

5 →

The achievement of integrated and coordinated European and Italian value chains requires the implementation of policy actions aimed at supporting competitiveness. On the supply side by: incentivizing CAPEX, OPEX, and value chain conversion; establishing nimble permitting procedures; creating green finance mechanisms. On the demand side, by: reducing the price differential of Italian and EU products vs. Chinese ones by distributing (for example with a fiscal mechanism) the strategic value generated by the increased reliance on a local supply chain. An enhanced EU governance to support coordination and integration of EU and national value chains is needed.

Besides the development of a European (and Italian) value chain along these three sectors, the EU needs to make sure that the domestic products are fairly competitive on the market. This requires action on **2 main fields**:

- Taking actions aimed at **reducing the cost** of European products (**reducing imports** from third countries, achieving **economic and social benefits** of investing in local value chain and **achieving economies of scale**).
- Creating a **level playing field** in overall production conditions to smooth the differences between the European market and the Chinese market (thanks to the CBAM introduction).

Adding the **net benefit of reduced imports and the direct, indirect and induced economic benefits coming from investments needed to reach the 2030 NZIA targets** for the creation of local supply chains in the three technologies under analysis, **the overall return on the investments would be equal up to EUR 642 billion**, with a corresponding **multiplier between 4 and 7 times the initial investment**[15].

15
The multiplier is obtained dividing the overall return on the investments by the estimated minimum and maximum investments in the 3 decarbonization-related industrial value chains.

Moreover, **creating a level playing field** with the introduction of the Carbon Border Adjustment Mechanism while, at the same time, **establishing large-scale local value chains** might reduce or eventually close the gap between European and Chinese manufacturing costs; for example, **economies of scale, short term incentives and CBAM mechanism** could even reverse[16] the European Chinese PV cost gap.

The possibility to achieve these significant benefits, again suggests the importance of developing these crucial integrated local supply chain at sufficient scale.

This Study suggests that, to achieve this goal, Europe and its Member States should adopt a **new strategic vision** aimed at developing a competitive European-wide decarbonization industry, achieving **integrated and coordinated European value chains** and **promoting greater diversification in the supply of technology components and critical raw materials**, also leveraging on the already existing partnerships and complementarities with countries outside the EU.

To this end, the Study identified **11 policy proposals** (7 at the Italian level and 4 at the European one).

Italian level
→

At the **Italian level** it is suggested to:

1. → Applying **streamlined and predictable permitting procedures** at all levels of the value chain, giving **priority status** at national level to ensure rapid administrative treatment and **strengthening** (skills and headcount) the offices in charge of authorization procedures.

2. → Favoring the realization photovoltaic and batteries[17] gigafactories by providing **competitive incentives** both in terms of **CAPEX** (e.g., tax exemption on investments) and **OPEX** (e.g., energy and labour costs) for the entire value chains, to reduce the competitiveness gap between Europe and China and proving additional resources that can cover **100%** of the funding gap[18].

3. → Promoting decarbonization through **efficient electric technologies such as heat pumps**, by putting in place **guaranteed contracts** for the installation of heat pumps and targeted incentives for **building construction and renovation**.

4. → Creating a system of incentives to promote the **conversion of boiler value chains**.

16
This estimation does not consider the improvement in Chinese costs.

17
Heat pumps represent a less mature market in which Europe already can count on a relatively good positioning.

18
It corresponds to the difference between the costs and revenues of an activity that contributes to climate objectives compared to the costs and revenues of a similar, but less environmentally friendly activity.

→

5. Implementing a **clear strategy to ensure critical raw materials supply**, facilitating agreements with supplier countries with which good economic, commercial and diplomatic relations are already in place, and, in the medium-long term, setting up a **recycling capacity** adequate for the amount of end-of-life key decarbonization-related industrial value chains' components that will be present in Italy in the coming years.

→

6. Creating dedicated **green finance mechanisms** (e.g., **SACE green guarantees**[19]) – to develop key decarbonization-related industrial value chains – that provide funds also with **premium mechanisms based on criteria other than price, facilitating access for national firms that follow ESG criteria** in designing and manufacturing components.

→

7. Promoting **upskilling** and **reskilling** activities, both quantitatively and qualitatively for example by creating **specialization courses with professional institutes**, using tax credits to support investments in training activities and the acquisition of certifications, tax breaks for new hires, etc.

European level

At the **European level** it is suggested to:

→

1. Favoring the **distribution to companies and citizens of the strategic value** generated by the development of local supply chains, defining **financial mechanisms**, such as **VAT exemption on technologies produced in Europe**, that would make domestic products cheaper precisely because of the benefits they generate.

→

2. Fostering **greater cooperation among EU Member States** on **R&D** and **industrial innovation**, to consolidate a coordinated approach in these areas and promote higher competitiveness of European industries. In addition, it is essential, on the one hand, to invest more in existing and more widespread technologies (as in the case of lithium batteries and LFP batteries) and, on the other hand, to launch pilot projects on the most disruptive technologies (as, for example, it is the case with sodium batteries).

→

3. Providing **specific financial tools** to ensure that all the clean technology products (e.g. photovoltaic, batteries and heat pumps) installed and imported in the EU are **designed, manufactured, and delivered following binding ESG criteria**.

→

4. Establishing a **common frame for the governance** by creating mechanisms **aimed at guaranteeing coordination and integration** in the realization and implementation of European and Member States policy actions **to develop European key decarbonization-related industrial value chains**.

19
Additional information can be found here:
https://www.sace.it/soluzioni/dettaglio-categoria/dettaglio
prodotto/garanzie-green.

The reference context of decarbonization pathways in Europe and in Italy

1.1 → The state of the art of energy transition in Europe and in Italy

1.2 → Perspectives and policy objectives of the energy transition in Europe and Italy, and gap analysis to 2030

Key Messages

1 → Solving the traditional "**Energy trilemma**", i.e. to strike a balance between **economic affordability, security of supply** and **decarbonization** is fundamental to secure Italy's and Europe's economic, environmental, and social future. **Renewables (RES) – together with electrification of final uses – make it possible to overcome the traditional trilemma**, because they can match economic affordability (lowest power generation cost), energy security (reduced need to import energy sources) and decarbonization (lowest life cycle emissions).

2 → With reference to **economic affordability**, the uncertainty surrounding gas supply from Russia had a **strong impact on European prices for both gas and electricity**, which reached record levels. The price of gas on the Dutch TTF market was, on average, **EUR 15.7 per MWh between 2017 and 2020**. However, this value gradually increased accelerating after the outbreak of the Russian-Ukrainian conflict, **peaking at EUR 235.2 per MWh in August 2022**. In this context, RES are the **cheapest** way to generate electricity. Globally, the Levelised Cost of Electricity (LCOE) averaged **USD 36 per MWh** in 2021 for solar

generation, and **USD 38 per MWh** for wind. These values are lower when compared to the **USD 60 per MWh** of natural gas or the **USD 108 per MWh** of coal.

3 → Regarding **energy security**, in 2021 the European Union **imported approximately 56%** of its gross available energy. **Italy** ranked sixth in EU in terms of energy dependence, with a value of **74%.** Italy was also the country with the **highest dependence on natural gas** in 2021 (**38%**, +18 percentage points compared to the European average). In this context, RES reduce the need for **fuel imports and nuclear power and have higher resilience to the price volatility of fossil commodities, thus fostering energy security.** With respect to 2012, production from RES in 2021 was **31% higher**, while production from fossil sources was **35% lower.** At the same time, energy dependency decreased from **79%** to **74%.**

4 → With reference to **decarbonization, most European countries actually uses coal, natural gas and oil as primary energy sources,** mostly imported from foreign countries. In this context, RES have **the lowest life cycle carbon emissions** (greenhouse gas emissions to generate one GWh) among electricity generation technologies: **between 32 and 85 tonnes CO_2-eq. for photovoltaics** and **between 10 and 26 tonnes CO_2-eq.** for

hydro and wind power (significantly lower than those for fossil fuel technologies, equal to **1,069 tonnes of CO_2-eq. per GWh** for lignite, more than **735 kg** for oil and more than **443 kg** for natural gas).

5 → **Along with RES, demand electrification also plays a crucial role in resolving the energy trilemma**, as it enhances general efficiency, thus **reducing energy demand**. Moreover, integrating distributed renewable generation and electrification of uses requires the **development of efficient digital distribution grids**, which thus play a **fundamental enabling role** in achieving decarbonization goals.

6 → To fully tap the benefits of RES and gradually reduce reliance on Russian imports, **the EU revised its main 2030 energy policy targets upwards. The share of RES in total electricity generation** has been raised to **69%** in the "REPowerEU" plan, up from 65% as of the "Fit for 55" plan (currently 37,5%). Moreover, the "REPowerEU" aims to achieve **1,282 GW of RES capacity** (currently 570 GW), an **electrification rate** of 34% (currently 23%), 51 million **electric vehicles** (currently 6.1 million) and **final energy consumption** not exceeding 715 Mtoe (currently 940 Mtoe). In Italy, the 2019 National Energy and Climate Plan (NECP) aims to increase the share of RES in total electricity generation to **57%** (currently

36%), achieve an electrification rate of **26%** (currently 22%), reach **6 million electric vehicles** (currently 355,200) and an energy consumption below **103.8 Mtoe** (compared to the current 113 Mtoe). Lastly, based on other scenarios elaborating on REPowerEU targets, such as those proposed by **Elettricità Futura**, anticipate that the installed RES capacity could reach **143 GW** by 2030.

7 → In the period 2017-2021 Europe installed, on average, **32.7 GW** per year, while, in 2022, the EU has recorded an acceleration, installing 52.5 GW per year (+60% compared to the average of the period 2017-2022). To achieve the policy targets, it will need to reach a level of **89 GW** installed per year. In **Italy**, the average annual increase in renewable capacity was **1.2 GW/year** in the period 2017-2021. In 2022, the country took a significant step forward, installing **3.1 GW of additional capacity**. However, to reach the 2030 target set by the latest official and definitive policy documents, the pace of installation needs to reach **8 GW/year** (more than **2.5 times the current level**). The even more ambitious **2030 Plan for the electricity sector** (elaborated by Elettricità Futura), which converts the objectives defined by "REPowerEU" at the Italian level, expects to reach **143 GW** by 2030, requiring an annual installation rate from 2023 to 2030 of **almost 10 GW**.

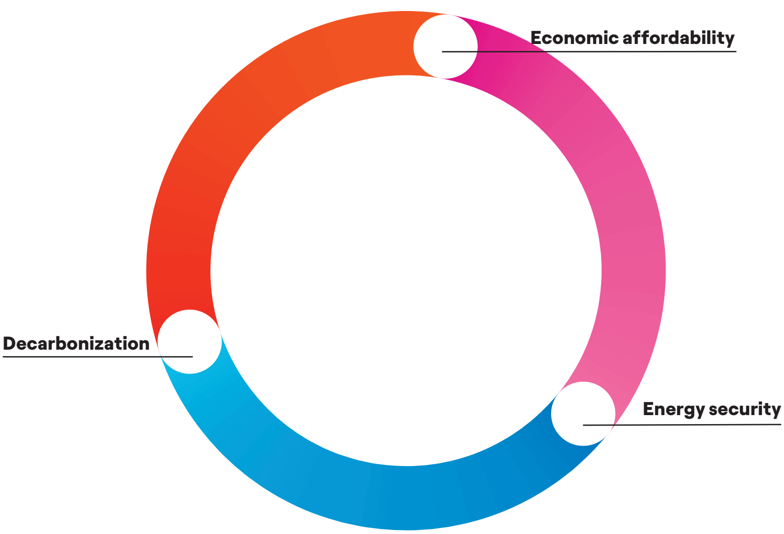
1.1

The state of the art of energy transition in Europe and in Italy

The first Chapter aims to provide a framework for the energy transition scenario in Europe and Italy, considering the current geopolitical context, exacerbated by the Russian-Ukrainian conflict. Specific attention will be paid to European and Italian decarbonization policy objectives.

Solving the traditional "**Energy trilemma**", i.e. to strike a balance between **economic affordability**, **decarbonization** and **energy security** is fundamental to secure Europe's and Italy's economic, environmental, and social future. This analysis allows us to focus on the **structural criticalities** of the European energy system.

Figure 1 → **The traditional "Energy trilemma"** (illustrative)



Source → Elaboration The European House - Ambrosetti and Enel Foundation on European Commission data and various sources, 2023.

→ Economic affordability → state of the art

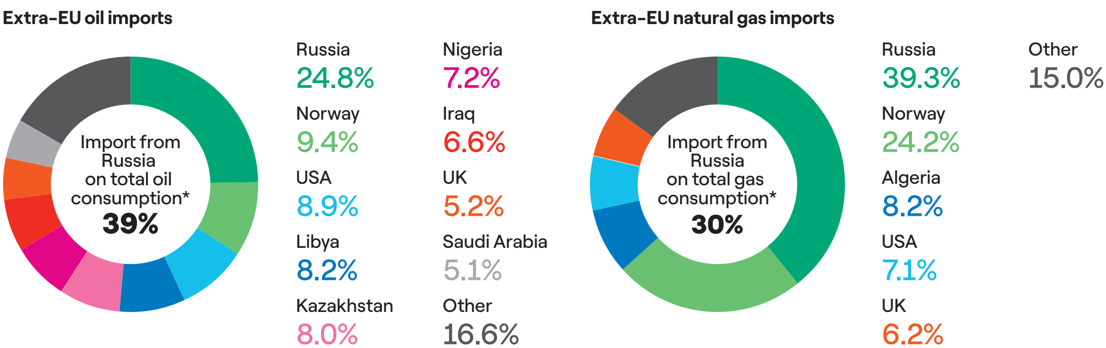
With reference to affordability, in the past year, the spiraling of gas price translated into an increase of electricity price – being this directly related to the price of gas. In fact, the price of electricity is determined by the marginal price mechanism, by which the price depends on the most expensive energy source among those needed to fully satisfy demand. For instance, in 2022, gas plants were the marginal technology that set the price of electricity in 62% of the cases in Italy. Therefore, the gas price surges translated into the price spikes experienced by consumers.

The uncertainty surrounding gas supply from Russia **had a strong impact on European prices** for both gas and electricity, which reached record levels. The price of gas on the Dutch TTF market was, on average, **EUR 15.7 per MWh** between 2017 and 2020. However, starting in January 2021, when it amounted to EUR 20.3 per MWh, this value **gradually increased** accelerating after the outbreak of the Russian-Ukrainian conflict, peaking at **EUR 235.2 per MWh** on average in August 2022. In the following months, the price **gradually decreased**, also thanks to European energy policies, liquified natural gas terminals, favourable weather conditions and high gas storage, but still remained above the levels of early 2021. At the time of writing (July 2023), the price settled at around **EUR 29.7 per MWh**.

→ Energy security → state of the art

Regarding **energy security**, in 2021, Russia was the **main supplier** of both oil and natural gas to the European Union. In fact, that year, the European Union imported **24.8%** of oil and **39.0%** of gas from Russia.

Figure 2 → **On the left: Value of extra-EU oil imports, 2021** (% values)
On the right: Value of extra-EU natural gas imports, 2021 (% values)



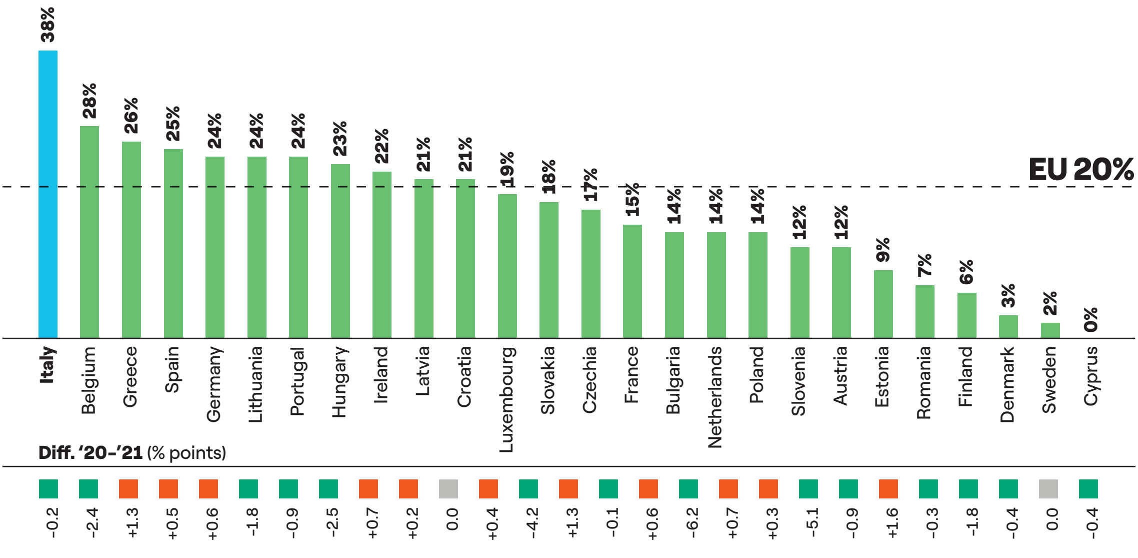
N.B. CN codes analysed for international trade are "27111100: Natural gas, liquefied" and "27112100: Natural gas in gaseous state" for natural gas, and "27090010 Petroleum oils from natural gas condensates" and "27090090: Petroleum oils and oils obtained from bituminous minerals, crude" for oil.
***** As of October 2021.

Source → Elaboration The European House - Ambrosetti and Enel Foundation on Comext data, 2023.

Overall, in 2021 the European Union **imported approximately 56%** of its gross available energy. **Italy** ranked sixth in terms of energy dependence, with a value of 74% (+18 p.p. compared with the European average, +0.1 p.p. compared to 2020). This represents a higher dependence than Germany (64%), France (44%) and Spain (69%).

Italy was also the country with the **highest dependence on natural gas** in 2021, with a value of **38%**, i.e. +18 percentage points compared to the European average. This value is well above that of other European countries (+10 percentage points compared to Belgium, the second most dependent country on gas).

Figure 3 → **Dependence index* on natural gas in EU, 2021** (% values)



N.B. Malta is not included because of incomparability of the data.
* The Dependence index has been calculated by multiplying the share of imported gas in each country by the share of natural gas on primary energy consumption. Therefore, the index evaluates European countries' exposure in terms of both natural gas imports and relative weight of natural gas in the energy mix.

Source → Elaboration The European House - Ambrosetti and Enel Foundation on Eurostat data, 2023.

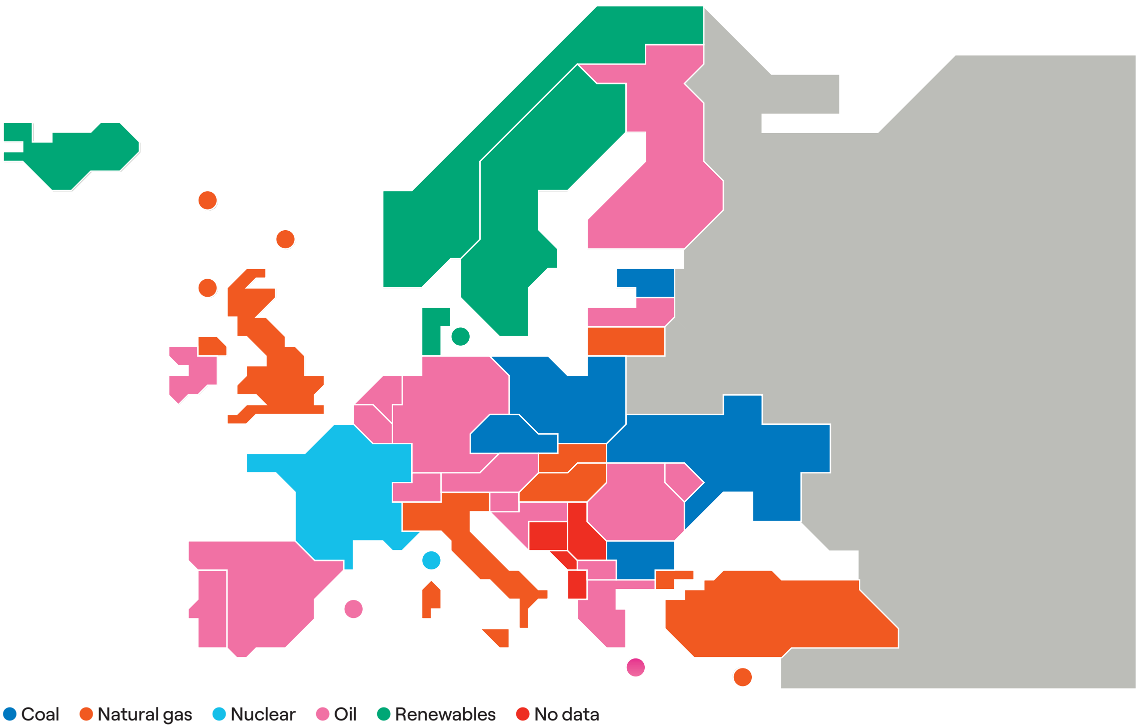
In 2022, energy security was undermined by Russia gradually cutting its gas supply to Europe. Deliveries via Yamal-Europe and Nord Stream pipelines were stopped and exports via Ukraine sharply cut. The overall gas supply from Russia was slashed down from **10.1 billion cubic metres** in November 2021 to **1.9 billion cubic metres** in November 2022.

Alongside gas supply disruptions, the European Union has experienced an electricity market crisis. Electricity generation in the EU was significantly lower in 2022 due to the **shortfall of French nuclear** (due to reactor maintenance and safety issues), the **scarcity of hydropower generation** due to drought in Southern Europe and the **closure of three German nuclear power plants**.

→ Decarbonization → state of the art

Finally, with reference to **decarbonization**, **most European countries use coal**, **natural gas and oil as primary energy sources**, mostly imported from foreign countries. However, the European landscape is quite **diversified**: France, for example, is the only European country where **nuclear energy** is the most widely used energy source. Denmark, on the other hand, is the only country that uses mostly **wind energy**, while Iceland, Norway and Sweden rely mainly on **hydroelectric power**. Overall, the snapshot of the energy landscape in Europe shows clearly why **discussions on the region's energy crisis are complex and articulated**.

Figure 4 → **The most used energy sources in Europe, 2021** (illustrative)



N.B. The map represents the most used energy source by consumption in exajoules as a percentage of the total consumption.

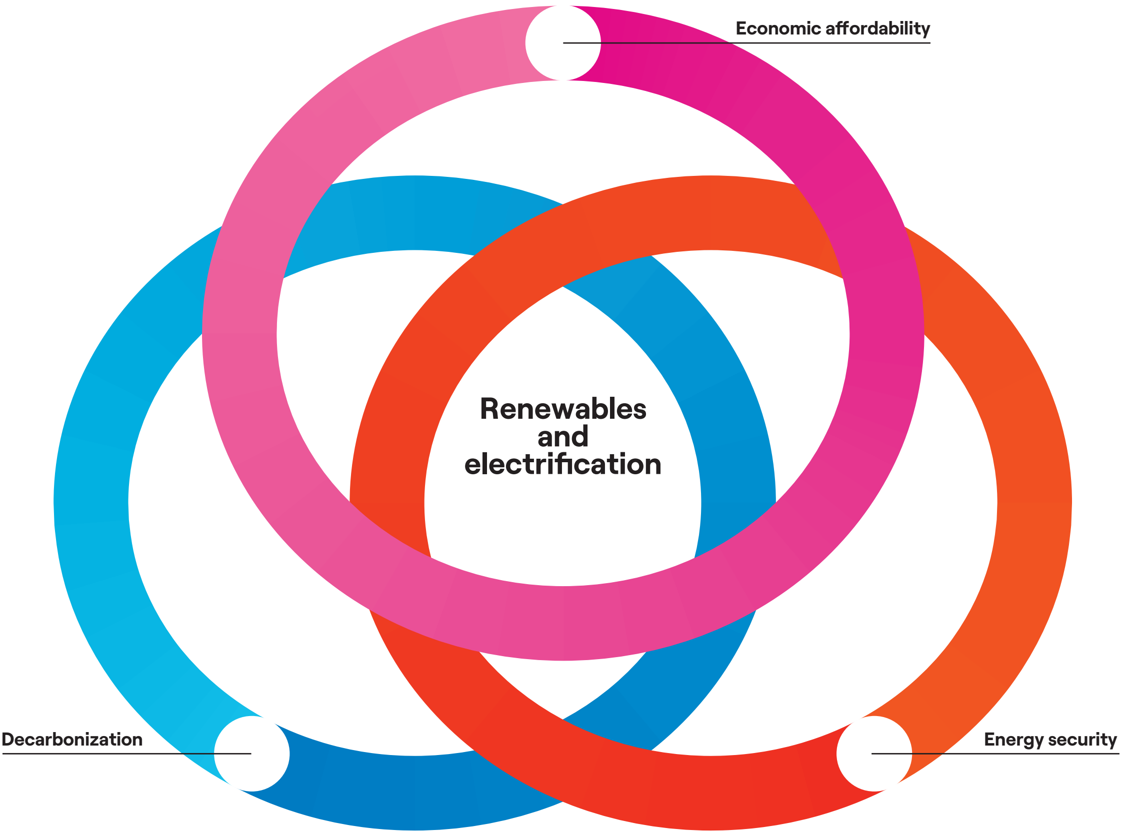
Source → Elaboration The European House - Ambrosetti and Enel Foundation on Eurostat data, 2023.

It is fundamental to mention that, along with renewable energy sources, **electrification** of end-uses also plays a crucial role in resolving the "Energy trilemma", as it **enhances general efficiency**, thus **reducing energy demand**.

Lastly, **integrating distributed renewable** generation and **electrification** of uses **requires** the development of efficient **digital distribution grids**, which thus play a **fundamental enabling role** in achieving decarbonization goals. In the next few years, therefore, digital networks will have to grow, strengthen and evolve to reap the benefits of these new distributed resources driving decarbonisation.

Overall, **renewable energy sources** (RES) **and electrification** are crucial to support decarbonization while ensuring energy security and affordability. In this sense, **renewables make it possible to overcome the traditional "Energy trilemma"**, because they can match economic affordability – lowest power generation cost –, energy security – no need to import fuel –, and decarbonization – lowest life cycle emissions.

Figure 5 → **The role of renewables in the renewed "Energy trilemma"** (illustrative)

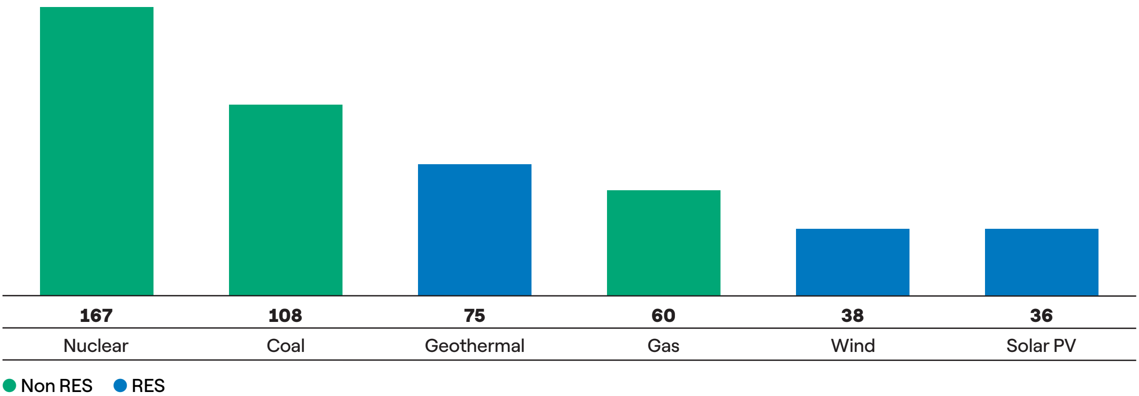


Source → Elaboration The European House - Ambrosetti and Enel Foundation, 2023.

→ Economic affordability → the role of clean electrification

Renewables are the **cheapest** way to generate electricity. Globally, the Levelised Cost of Energy (LCOE) averaged **USD 36 per MWh** in 2021 for solar generation, and **USD 38 per MWh** for wind. These values are lower when compared to the **USD 60 per MWh** of natural gas or the **USD 108 per MWh** of coal.

Figure 6 → **Global Levelized Cost of Energy (LCOE) by power generation technology, 2021 or last available year** (mean LCOE, USD/MWh)



Source → Elaboration The European House – Ambrosetti and Enel Foundation on Lazard data, 2023.

→ Energy security – the role of clean electrification

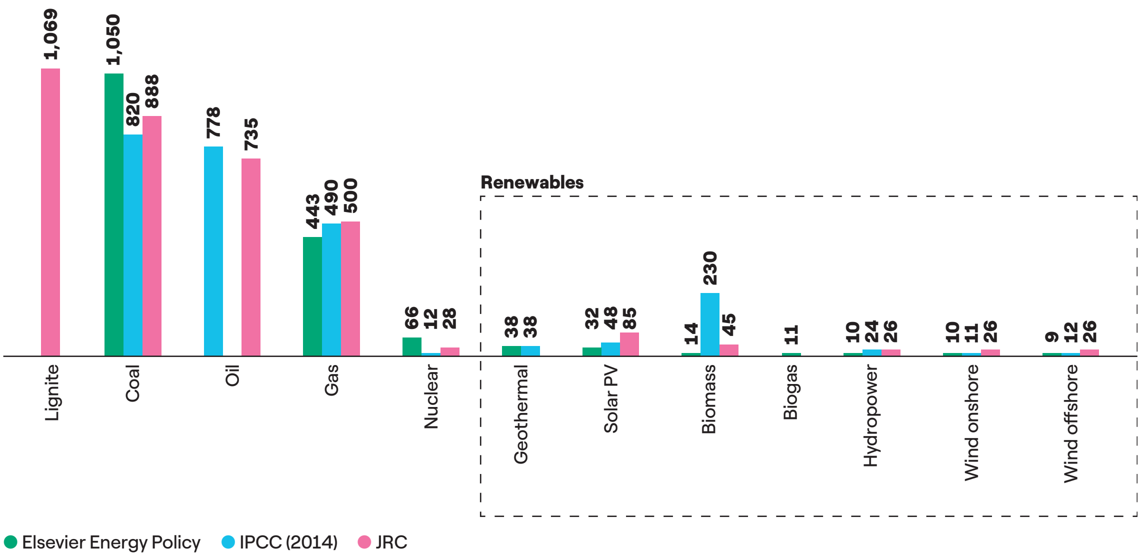
Renewables reduce the need for **fuel imports and nuclear power and have higher resilience to the price volatility of fossil commodities, thus fostering energy security**. With respect to 2012, electricity production from RES in 2021 was **31% higher**, while production from fossil sources decreased by **35%**. At the same time, energy dependence decreased from **79%** to **74%**. Developing renewable sources is, therefore, a **key factor in reducing energy dependence**. However, as previously mentioned, renewables alone can only make a part of the energy security issue. In fact, the other lever to take in consideration is **electrification** which – by reducing primary energy demand for the same downstream services – **make it easier to be energy independent**, thus increasing energy security together with renewables.

→ Decarbonization – the role of clean electrification

Renewable energy sources have the lowest life cycle carbon emissions among electricity generation technologies. Lifecycle carbon intensity (greenhouse gas emissions to generate one GWh) is estimated **between 32 and 85 tonnes CO_2 equivalent for photovoltaics** and **between 10 and 26 tonnes CO_2 equivalent for hydro and wind power**. These values are significantly lower than those for fossil fuel technologies. Lifecycle emissions amount to **1,069 tonnes of CO_2 equivalent**

per GWh in the case of lignite (**12.5 times** the highest estimate for photovoltaics), more than **735 kg** for oil (more than **8.6 times** the highest estimate for photovoltaics) and more than **443 kg** for natural gas (more than **5.2 times** the highest estimate for photovoltaics). Only nuclear power has carbon emissions comparable to those of renewable sources but, besides the safety issues, it still requires to import and manage nuclear fuel.

Figure 7 → **Life cycle GHG emission intensity of electricity production by technology, 2021 or last available year** (tonne of CO_2-eq. per GWh)



Source → Elaboration The European House - Ambrosetti and Enel Foundation on JRC, Elsevier Energy Policy and IPCC data, 2023.

Renewable energy sources act on the **supply side**, allowing for cheaper energy, reduced dependence and lower carbon intensity. To maximize the benefit of a renewable based system, acting on the demand side by means of efficient **electrification of final uses** is of fundamental importance to reduce final energy needs.

1.2

Perspectives and policy objectives of the energy transition in Europe and Italy, and gap analysis to 2030

In response to the changing energy scenario and rising prices, the European Union has proposed several actions and measures to **phase out its dependence on fossil fuels, particularly those from Russia**. Prior to that, the European Union had already introduced a set of measures known as the "toolbox", which included short-term measures and medium-term structural policies to support low-income households and businesses with respect to energy costs.

In March 2022, in the immediate aftermath of the invasion of Ukraine, the "**REPowerEU**" plan was presented, and later revised in May with upward energy targets and an indication of the path to phase out EU's dependence on Russian fossil fuels by 2030. To achieve this goal, the plan focused on three directions: **accelerating the energy transition, diversifying energy sources, and promoting energy savings**.

The objectives set by the "REPowerEU" plan

The "REPowerEU" plan aims at **phasing out European dependence on fossil fuels from Russia by 2030**. It has set three main types of objectives: **accelerating the energy transition**, **diversifying energy sources** and **saving energy**.

As for the first, it has been established that the share of RES **in final energy consumption** will have to reach 42.5% with an additional 2.5% indicative top up that would allow to reach 45% by 2030, while a **dedicated EU Solar Strategy** has been designed to double solar photovoltaic capacity by 2025. Meanwhile, a **Solar Rooftop Initiative** has mandated to install solar panels on new buildings, and other measures have **tackled slow and complex permitting** to accelerate major renewable projects.

With respect to diversification, a **biomethane action plan** has set a new production target of **35 bcm/year by 2030**, while the **Hydrogen Accelerator** has aimed to achieve **10 million tonnes** of domestic renewable hydrogen production and **10 million tonnes** of imports by 2030. In addition, a **EU energy platform** has been set up to enable common purchase of gas, liquefied natural gas (LNG) and hydrogen.

Finally, the European Commission has focused on **long-term energy efficiency** by increasing the binding Energy Efficiency Target from initial **9%** under the "Fit for 55" package to **11.7%**. Further attention has been focused on **short-term behavioural changes**, which could cut gas and oil demand by **5%**, while **fiscal measures** have been adopted to encourage energy savings.

Source → Elaboration The European House - Ambrosetti and Enel Foundation on various sources, 2023.

To fully tap the benefits of renewable energy and gradually reduce reliance on Russian imports, the EU revised its main energy policy targets upwards. **The projection for the share of RES in total electricity generation** has been raised to 69%, up from 65% as of the "Fit for 55" plan. This is challenging, as only 37.5% of the electricity produced in Europe currently comes from renewable sources. Moreover, the "REPowerEU" aims to achieve **1,282 GW** of **renewable capacity** (currently at 570 GW), an **electrification rate** of 34% by 2030 (currently 23%), 51 million **electric vehicles** (compared with the current 6.1 million) and **final energy consumption** not exceeding 763 million tonnes of oil equivalent (Mtoe), compared with the current value of 940 Mtoe.

Figure 8 → **Current scenario and main European policy objectives by 2030**

Parameter	Current value 2022 or latest available year	2030 policies and scenarios	
% RES on electricity generation	37.5%	65%	69%
RES capacity*	570 GW	1,197 GW	1,282 GW
Electrification rate**	23%	30%	34%
# Electric vehicles* (stock)**	6.1 mln	51 mln	
Final Energy Consumption	940 Mtoe	782 Mtoe	763 Mtoe
Net GHG emissions	3,602 Mton CO_2-eq.	At least -55%	

● State of the art ● "Fit for 55" ● "REPowerEU" plan

N.B. "Fit for 55" targets refer to the ones contained in the EC MIX-FF55 scenario.
* Detailed RES capacity – "Fit for 55": 530 GW solar, 469 GW wind, 131 GW hydro and 67 GW other RES. Detailed RES capacity – "REPowerEU" targets: 592 GW solar, 510 GW wind, 133 GW hydro, 47 GW other RES. Overall RES capacity includes also bioenergies.
** Direct electrification rate in final energy consumption.
*** Electric vehicles refer only to passenger cars (BEV and PHEV).

Source → Elaboration The European House – Ambrosetti and Enel Foundation on European Commission data, 2023.

Meanwhile, Italy will also have to **decisively change** its pace in terms of decarbonization to meet national and EU targets by 2030. The National Energy and Climate Plan (NECP) aims to increase the share of renewable energy sources in total electricity generation to **57%**, which is 21 percentage points higher than the current 36%. The NECP also aims to achieve an electrification rate of **26%** (currently 22%), **6 million** electric vehicles (compared with approximately 355,200 today), and energy consumption below **103.8 Mtoe** (compared to the current 113 Mtoe)[1]. The National Plan for Ecological Transition (PTE), on the other hand, has set targets of **126-131 GW** of installed RES capacity (currently 63.6 GW) and a **51%** reduction

1
At the time of writing the Report, the NECP is being revised and updated. The targets could therefore be more ambitious.

in climate-changing emissions compared to 1990 levels. Finally, other scenarios elaborating on "REPowerEU" targets, such as those proposed by **Elettricità Futura**, anticipate that the installed RES capacity could reach 143 GW by 2030.

Figure 9 → **Current scenario and main Italian policy objectives by 2030**

Parameter	Current value 2022 or latest available year	2030 policies and scenarios	
% RES on electricity generation	36%	57%	
RES capacity	63.6 GW	95 GW	126-143 GW*
Electrification rate**	22%	26%	
# Electric vehicles*** (stock)	355.2 thousand	6 mln	
Final Energy Consumption	113 Mtoe	103.8 Mtoe	
Net GHG emissions	418 Mton CO_2-eq.	-37%	-51%

● State of the art ● NECP 2019

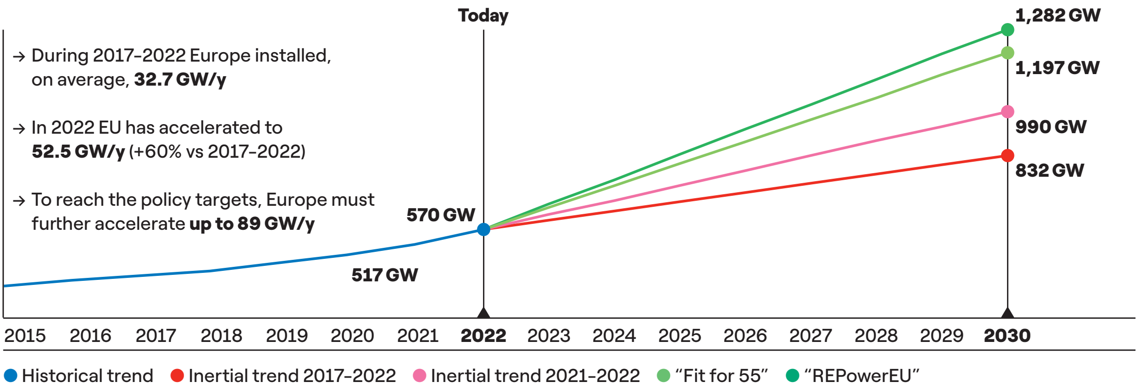
● National Ecological Transition Plan and increased ambition announcements

N.B. GHG emissions in 2020 amounted to 381 Mton CO_2-eq., however the value was reported for 2019 as it was considered more significant since it was not affected by the pandemic. At the time of writing the Report, the NECP is being revised and updated. The targets could therefore be different.
* The lower threshold comes from the National Ecological Transition Plan (PTE), the upper threshold comes from the increased ambition set by Elettricità Futura based on "REPowerEU" targets
** Direct electrification rate in final energy consumption.
*** Electric vehicles refer only to passenger cars (BEV and PHEV).

Source → Elaboration The European House - Ambrosetti and Enel Foundation on various sources, 2023.

With the increased pressure on the energy markets coming from the Russian-Ukrainian conflict, RES installed capacity in the EU surged in 2022, although a further acceleration will be needed in coming years. Indeed, in the period 2017-2022 Europe installed, on average, **32.7 GW** per year, while, in 2022, the EU has recorded an acceleration, installing **52.5 GW** (+60% compared to the average of the period 2017-2022). To achieve the policy targets, it will need to reach a level of **89 GW** installed per year.

Figure 10 → **Historical and inertial trend of the installed renewables capacity in EU, comparison with past and current policy, 2015-2030E**
(absolute values in GW)



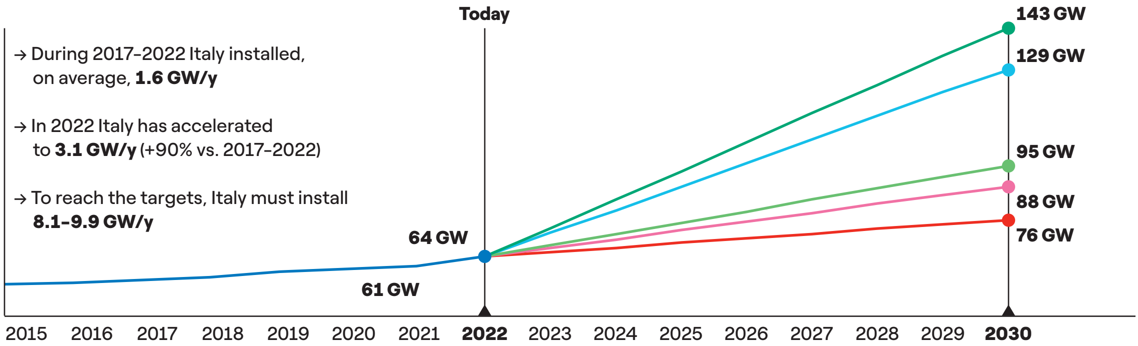
N.B. The inertial trend is calculated by projecting the average annual capacity installed from 2017 to 2022 and from 2021 to 2022. Policy targets ("REPowerEU" plan and "Fit for 55" plans) refer to the last official communications provided by the European Commission. Renewables include: solar (PV and thermal), wind, hydro, geothermal and bioenergies.

Source → Elaboration The European House - Ambrosetti and Enel Foundation on Irena data and various sources, 2023

In **Italy**, the average annual increase in renewable capacity was **1.2 GW/year** in the period 2017-2021. In 2022, the country took a significant step forward, installing **3.1 GW of additional capacity**. However, to reach the target of **129 GW** by 2030, the pace of installation needs to reach **8 GW/year**, which is more than **2.5 times the current level**. The even more ambitious trajectory suggested by the 2030 Plan of the electric sector elaborated by Elettrcità Futura of **143 GW** by 2030 would require an annual installation from 2023 to 2030 of **almost 10 GW**.

Figure 11 →

Historical and inertial trend of the installed renewables capacity in Italy, comparison with past and current policy, 2015-2030E
(absolute values in GW)



N.B. The inertial trend is calculated by projecting the average annual capacity installed from 2017 to 2022 and from 2021 to 2022. Policy targets ("REPowerEU" plan and "Fit for 55" plans) refer to the last official communications provided by the European Commission. Renewables include: solar (PV and thermal), wind, hydro, geothermal and bioenergies. 129 GW represents the average between 126 GW and 131 GW as reported by National Ecological Transition Plan.
* Increased ambition set by Elettricità Futura inspired to "REPowerEU" targets.

Source → Elaboration The European House - Ambrosetti and Enel Foundation on European Commission data, 2023.

To achieve these ambitious objectives and fully reap the benefits of the current energy transition, it is necessary to create and develop local skills and strengthen **"green" industrial supply** chains to sustain the growth expected in the coming years and to gradually eliminate reliance on third countries. However, it will, on the one hand, be crucial **to avoid shifting from energy dependence to technological dependence** in this process; on the other hand, the decarbonization process is an unmissable opportunity to **strengthen the local green value chains**, thus generating **long term jobs and value**. In fact, it has been demonstrated that the acceleration in renewables deployment and the strong development of a local value chain can bring up to **EUR 361 billion as economic benefits** and **540,000 new jobs by 2030**[2].

In conclusion, Europe and Italy will need to i**nstall significant production capacities of renewable technologies** to achieve their decarbonization targets and they should do so avoiding/preventing a scenario of technological dependence while maximizing the social and economic benefits. This would require meeting a larger proportion of domestic demand through domestic production. The second part of the Report will therefore aim to identify the **key supply chains for decarbonization**, the relative obstacles to the development of related domestic production in Europe and Italy, as well as the main relative opportunities and risks.

2
Source: *"La filiera italiana delle tecnologie per le energie rinnovabili e smart verso il 2030. Le potenzialità di sviluppo della filiera elettrica e i benefici sul sistema socio-economico italiano"*, Althesys, Elettricità Futura and Enel Foundation, 2023.

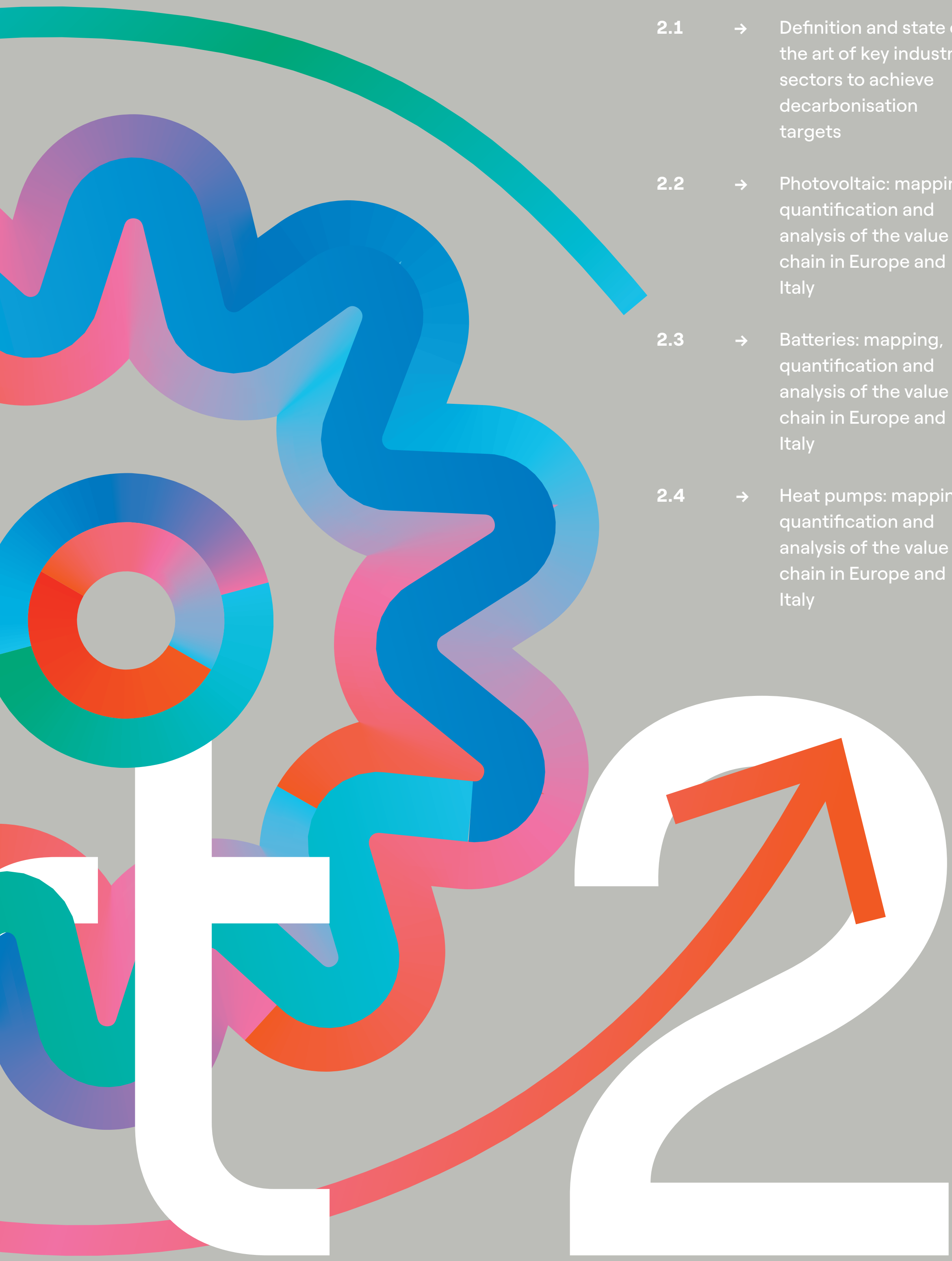
The state of the art and prospects of key decarbonisation-related industrial value chains in Europe and Italy

2.1 → Definition and state of the art of key industrial sectors to achieve decarbonisation targets

2.2 → Photovoltaic: mapping, quantification and analysis of the value chain in Europe and Italy

2.3 → Batteries: mapping, quantification and analysis of the value chain in Europe and Italy

2.4 → Heat pumps: mapping, quantification and analysis of the value chain in Europe and Italy



Key Messages

1 → The Study focused on the most relevant supply chains according to **price competitiveness, expected growth, technology readiness level and contribution to emission reduction**. Based on these considerations, **three key industrial sectors related to decarbonization** were identified: **photovoltaic** (energy production), **batteries and storage systems** (flexibility and optimisation of energy flows) and **electric heat pumps** (consumption).

2 → With respect to **photovoltaic**, the main bottlenecks of the value chain are related to production facilities, high **investment costs and lead time**, high **energy, CO_2 and labour costs**, absence of **vertical integration**, and lack of **competence, skills and equipment manufacturers.** On the other hand, effective use of available **funds**, environmental and social **sustainability**, the presence of different **research centers** and the **Chinese export ban** represent the main opportunities and risks to be addressed for the development of the value chain.

3 → Between 2022 and 2030 the **EU** is expected to install approximately **+389 GW** of photovoltaic capacity. In **Italy** between **73 GW and 81 GW** of photovoltaic installed power are

estimated by the end of the decade. To cope with the growing demand and limited domestic production, several European players have planned expansive interventions in the various stages of the photovoltaic module value chain. Against an annual domestic production target of 30 GW, **48.6 GW** of production capacity is expected for **polysilicon**, **20.8 GW** for **ingots and wafers**, **19.5 GW** for **cells**, and **31.7 GW** for **modules**. In Italy, although there is no binding target for domestic manufacturing production, it is worth pointing out that at all stages of the chain there is a gap with respect to the annual power to be installed of **7 GW**, which is necessary to reach the objectives set by the "REPowerEU".

4 →

With respect to **batteries and storage systems**, the main bottlenecks of the value chain are related to **access to (virgin) raw materials** due to import dependence and strong regulation constraints for mining, lack of **recycling capacity**, current limited **production capacity** to be scaled up and high **costs for batteries manufacturing**. On the other hand, effective use of **available of funds**, environmental and social **sustainability** of production, development of **recycling capacity** and **Research & Development** in new disruptive technologies represent the main opportunities and risks to be addressed for the development of the value chain.

5 → With reference to the expected demand for batteries in 2030, the European Battery Alliance estimates that demand for lithium batteries will **reach 1,000 GWh in Europe** by 2030, while the NZIA estimates a demand of **610 GWh**. Based on these two scenarios, demand for **Italy** is estimated at **73 GWh** (NZIA scenario) and **120 GWh** (EBA scenario). To date, several projects are underway in Europe covering all stages of the battery supply chain. However, considering a 5-year ramp-up necessary until the gigafactory reaches full capacity, the European Commission estimates that **886 GWh** (89% of expected demand) will be ready by 2030, a gap of 114 GWh compared to the **expected demand of 1,000 GWh** estimated by the EBA. Regarding **Italy**, four investments are currently planned for a total estimated production capacity by 2030 of **109 GWh**.

6 → With respect to **heat pumps**, the main bottlenecks of the value chain are related to high **installation requirements**, **market immaturity** and high uncertainties regarding **future demand**, restricting **refrigerant regulation** and lack of **EU specialization in strategic components** (compressors, in particular). On the other hand, the relevance of **European industry**, economic and environmental **convenience**, **recycling capacity** and **European policies** aimed at reducing gas dependence represent the main opportunities and risks to be addressed for the development of the value chain.

7 → Based on the policy targets, the EU will have to reach a level of **76.8 million installed heat pumps** by 2030, i.e., **+60 million** compared to 2021. Also in **Italy**, according to scenarios elaborated by Enel and Agici, the country is expected to reach a level of **11.6 million** heat pumps by 2030, **+10 million** compared to 1.6 million units in 2020. At the European level, several investments are already planned or underway to meet heat pump demand. If all these investments are implemented, the EU will have very good chances of meeting the 60% NZIA goal of domestic production by 2030.

2.1

Definition and state of the art of key industrial sectors to achieve decarbonisation targets

The second Chapter of the Report aims to identify the key decarbonisation-related industrial value chains in Europe and Italy, analyse their competitiveness, and highlight risks and opportunities. An initial mapping and selection of the supply chains considered will then be followed by a qualitative and quantitative analysis of Europe's and Italy's positioning with respect to the rest of the world within these supply chains. An attempt will then be made to understand and assess the main competitive factors and possible weaknesses, identifying strategic components and possible differentiated production strategies to highlight the risks and opportunities that can be seized.

Among energy technologies, an initial distinction can be made between energy **production technologies**, technologies for **flexibility** and **optimisation of energy flows**, and **consumption-related** technologies. The Study focused on the most relevant supply chains according to price competitiveness, expected growth, technology readiness level and contribution to emission reduction. Based on these considerations, **three key industrial sectors related to decarbonisation** were identified: **photovoltaic** (energy production), **batteries and storage systems** (flexibility and optimisation of energy flows) and **electric heat pumps** (consumption).

→ Photovoltaics

In the near future the **largest increase in installed capacity** is expected for photovoltaics. Based on the latest targets and policy scenarios, between 2021 and 2030 it is estimated in EU an increase up to **+432 GW** for **solar power**, compared to +323 GW for wind, +12 GW for biomass and other RES and +4 GW for hydro. At the same time, **in Italy an increase of +58 GW is expected for solar power**, while wind power is expected to expand up to +25 GW. Finally, a growth of +1 GW is expected for biomass, other RES and hydro[1].

1
EU values for 2030 refer to the targets in the European Commission's "REPowerEU" scenario. The values for Italy in 2030 refer to the 2030 Plan for the electricity sector, elaborated set by Elettricità Futura on the basis of the targets in the European Commission's "REPowerEU" scenario.

Photovoltaic is, in addition, the **most economically competitive electricity generation** solution. In fact, solar photovoltaics has one of the lowest levelized cost of electricity (LCOE) in Europe[2].

Figure 12 → **Capacity additions from renewable energy sources in EU and Italy, 2021-2030** (absolute values in GW)

Type of RES	Variation between 2021 and 2030	
	EU	Italy
Solar	**+432**	**+58**
Wind	+323	+25
Biomass and other RES	+12	+1
Hydro	+4	+1

N.B. EU values for 2030 refer to the targets in the European Commission's "REPowerEU" scenario. The values for Italy in 2030 refer to the 2030 Plan of the electricity sector, elaborated set by Elettricità Futura on the basis of the targets in the European Commission's "REPowerEU" scenario.

Source → Elaboration The European House - Ambrosetti and Enel Foundation on data from European Commission, Terna, IRENA and Elettricità Futura, 2023.

→ Batteries and storage systems

Batteries and storage systems are essential to facilitate the **penetration of variable renewable energy sources** and the **diffusion of electric vehicles**. As a result, these technologies are expected to grow strongly over this decade. In fact, within the European Union, electricity supply from batteries is expected to grow up to **38 TWh** by 2030 (38 times the current capacity of 1 TWh), whereas in Italy is expected to grow up to **1 TWh** (33 times more than the current 0.03 TWh). At the same time, it is forecasted that by 2030 there will be **51 million** electric vehicles in the EU (8 times more than the current 6.1 million) and **6 million** electric vehicles in Italy (17 times the current 300,000).

2
Source: *"Net Zero E-conomy 2050"* by The European House – Ambrosetti and Enel Foundation.

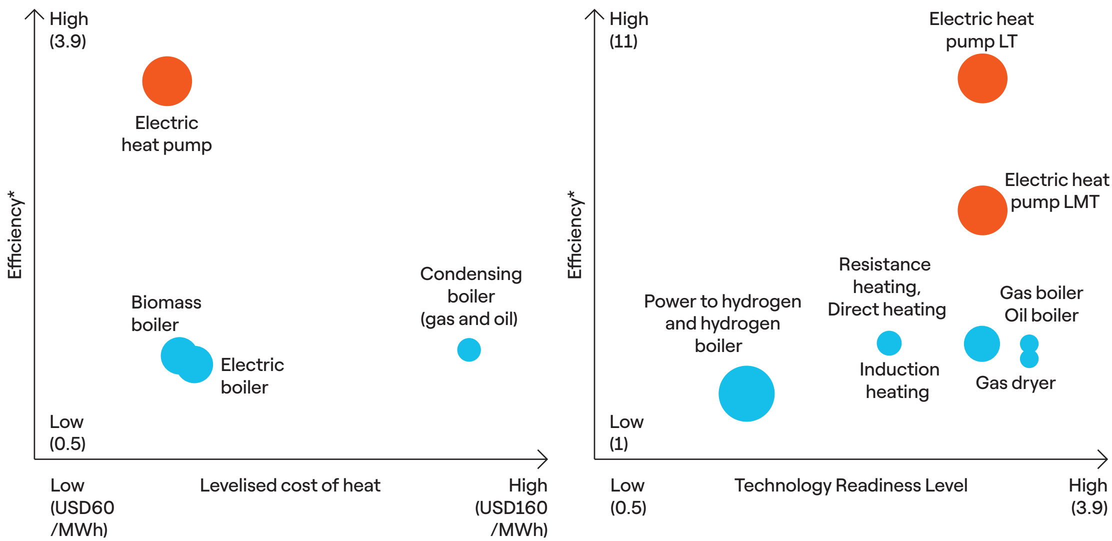
→

Heat pumps

Electrifying consumptions through an increased deployment of **electric heat pumps** powered by renewables can be the most effective way to reduce emissions in these sectors. In fact, this technology is associated with a **lower Levelized Cost of Heat** than biomass, electric and condensing boilers. In addition, heat pumps can be powered by renewable sources and have **3 to 5 times higher efficiency** than traditional thermal technologies. Similarly, heat pumps are also the most efficient technology for low to medium temperature industrial applications, with one of the highest levels of technology availability.

Figure 13 →

Left: Residential sector solutions by Levelised Cost of Heat (X-axis, EUR/MWh) **and efficiency** (Y-axis, energy input/production) **at European level, 2021. Right: Solutions for the industrial sector by level of technology availability** (X-axis, values 1 to 11) **and efficiency** (Y-axis, energy input/production)**, 2021.**



N.B. The reported technology dimension refers to investment costs. The higher the cost, the higher the dimension. For condensing boilers, the average between gas and oil boilers was considered. LT=low temperature (<100 °C). LMT=medium-low temperature (100 °C - 200 °C).
* Efficiency is expressed as the coefficient of performance, calculated as the ratio between energy input and energy output.

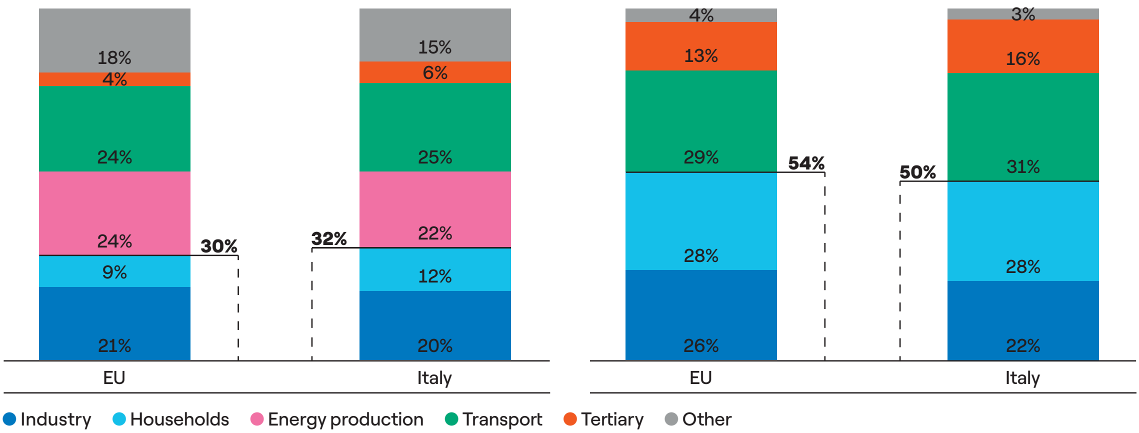
Source → Elaboration The European House - Ambrosetti and Enel Foundation on data Enel Foundation, Politecnico di Torino and MIT, 2023.

At both the Italian and European level, **industry** and **households** are responsible for **about 30% of greenhouse gas emissions**, beyond only the transport and energy production sectors, which have a greater impact in terms of emissions. In fact, within the European Union, approximately **21% of greenhouse gas** emissions are produced by industry, while households contribute for **9%**. Similarly, in Italy, industry and households are associated with **20%** and **12%** of greenhouse gas emissions, respectively.

Furthermore, industry and households contribute to **final energy consumption by more than 50%**. In the European Union, industry and households account for approximately **26%** and **28%** of final energy consumption, respectively. In Italy, industry is responsible for **22%** of consumption, while households account for **28%**. Only the transport sector has a higher incidence.

Figure 14 →

Left: Greenhouse gas emissions by sector in EU and Italy, 2020 (% values)
Right: Final energy consumption by sector in EU and Italy, 2021 (% values)



Source → Elaboration The European House - Ambrosetti and Enel Foundation on Eurostat data, 2023.

Based on recent estimates by the European Heat Pump Association (EHPA), **60 million additional heat pumps** are expected to be installed by 2030 in Europe, rising from 17 million in 2021 to **77 million** in 2030. In 2021, there was an increase of more than 2 million heat pumps in Europe, corresponding to **+34%** compared to the previous year's sales. It will, however, be necessary to **further increase the pace** in the coming years. High fossil fuel prices, carbon pricing systems and national plans for "clean" heating can stimulate growth. In Italy, **10 million** additional heat pumps are expected to be installed by 2030, from 1.6 million in 2020 to 11.6 in 2030.

For the purposes of the analysis, each of these three supply chains was divided into three basic stages: **raw materials**, **components** and **assembly**. For each supply chain, a quali-quantitative analysis was carried out based on specific key performance indicators. The objective is to take a snapshot of the state of the art and highlight the main obstacles which, at Italian and European level, hinder the development of domestic supply chains for the technologies considered. Further points of attention concern the **recycling and disposal** of the materials used for each technology.

After having analysed the main bottlenecks, the Study focuses on the **main existing risks and development opportunities** for Europe and Italy in these value chains. Lastly, the Study takes in consideration the projections on future demand and installations for each of the three technologies considered, to better understand the **gap between annual deployment needed to reach policy targets and domestic manufacturing capacity**, also in the light of recent plans drawn up at European and national level.

It should also be emphasised that the analysis focuses solely on the **manufacturing component** of each supply chain, not taking into consideration other aspects such as design and trade. Furthermore, only the raw materials and components of **greatest relevance and impact** on each supply chain are analysed in detail, as emerged from an in-depth analysis of the relevant literature.

Finally – although outside the scope of this Study – it is important to keep in mind that adequate **digital distribution grids** play a **key enabling role** in a system dominated by renewable power generation and electrified end-uses. In the next few years, therefore, digital networks will have to grow, renew and evolve to reap the benefits of these new distributed resources driving decarbonisation, even though the **development of new solutions** such as markets for procurement of local flexibility services, **guaranteeing security of supply and quality of service** in the most efficient way. Nevertheless, for this technology both Italy and Europe can rely on a strong supply chain and industrial sector and does not show dependency issues[3]. For this reason this Study does not focus on this set of technologies.

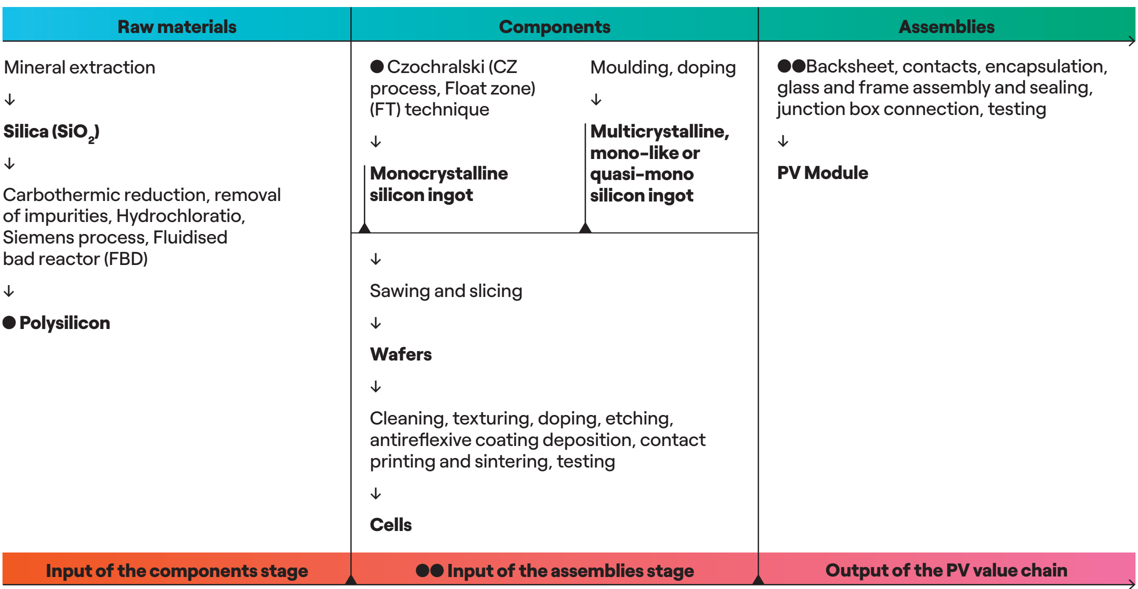
3
Source: "*La filiera italiana delle tecnologie per le energie rinnovabili e smart verso il 2030. Le potenzialità di sviluppo della filiera elettrica e i benefici sul sistema socio-economico italiano*", Althesys, Elettricità Futura ed Enel Foundation, 2023.

2.2

Photovoltaic: mapping, quantification and analysis of the value chain in Europe and Italy

Starting from the breakdown indicated above, with reference to the photovoltaic value chain, the first stage starts with the extraction of the relevant minerals, to then obtain metallurgic silicon and **polycrystalline silicon (polysilicon)**. The components stage, on the other hand, consists in the further processing of the polysilicon, whereby monocrystalline or polycrystalline silicon ingots are first obtained. These are then cut into wafers which are then further processed into photovoltaic cells. Finally, the cells are assembled into modules together with glass and other components.

Figure 15 → **The photovoltaic value chain: stages, processes and outputs.**



N.B. For the purpose of the analysis, the most widespread PV technology was considered, i.e., crystalline silicon modules (market share of about 94.7%).

Source → Elaboration The European House - Ambrosetti and Enel Foundation on IEA data, 2023.

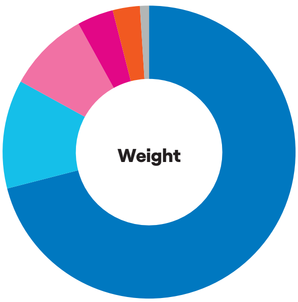
→

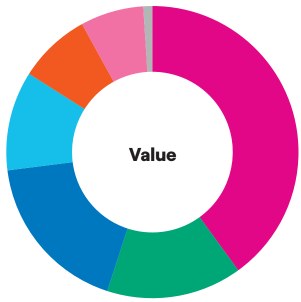
State of the art and critical issues in the photovoltaic value chain stages: raw materials

The starting point of the photovoltaic value chain is represented by **silicon**, which is the fundamental material of photovoltaic modules and is obtained from quartz. Although constituting **less than 5%** of a module's weight, this element is responsible for **more than 40%** of the module's total cost.

Figure 16 →

Material composition shares of silicon solar PV modules by weight (left chart, % values) **and value** (right chart, % values)**, 2023**





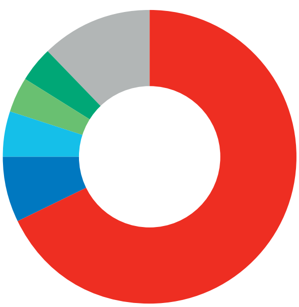
* "Other" includes zinc, lead, tin.

Source → Elaboration The European House - Ambrosetti and Enel Foundation on IEA data, 2023.

Silicon is the **second most abundant element on earth**, crucial for the production of ferroalloys and silicon metal. However, because of targeted industrial policies carried out by the Chinese government, the production of silicon is **highly concentrated**: around **70%** of it is located in China.

Figure 17 →

Top five countries by global silicon production, 2023 (% values)



N.B. The value is calculated based on the share of silicon in domestic production of ferrosilicon and silicon metal.
Germany accounts for about 1% of global silicon production.

Source → Elaboration The European House - Ambrosetti and Enel Foundation on USGS data, 2023.

China plays a dominant role in the polysilicon segment. In fact, **all the world's top five producers** are in China. In a decade, China's market share in polysilicon production grew **from 29% to 90%** in 2022, because of new polysilicon factories built in China over the past 10 years.

Figure 18 → **Annual polysilicon factory additions between China and the rest of the world, 2005-2019** (% values)

Source → Elaboration The European House - Ambrosetti and Enel Foundation on BloombergNEF data, 2023.

The expansion has taken place in the **Xinjiang** province, which alone can meet almost all the world's polysilicon demand. It must be recognised, however, that Chinese production has increased thanks to **extraction and refining systems that are not allowed in other parts of the world for environmental reasons**[4].

4 Source: BloombergNEF.

Figure 19 → **Top-5 polysilicon manufacturers, 2023** (% values)

Company	Country	Market share
Tongwei	**China**	**19%**
Xinte Energy	**China**	**14%**
GCL Poly	**China**	**14%**
Daqo Group	**China**	**11%**
Asia Silicon	**China**	**9%**

N.B. Polysilicon production capacity in 2021: **676,873 metric tonnes**

Source → Elaboration The European House - Ambrosetti and Enel Foundation on IHS Markit and BloombergNEF data, 2023.

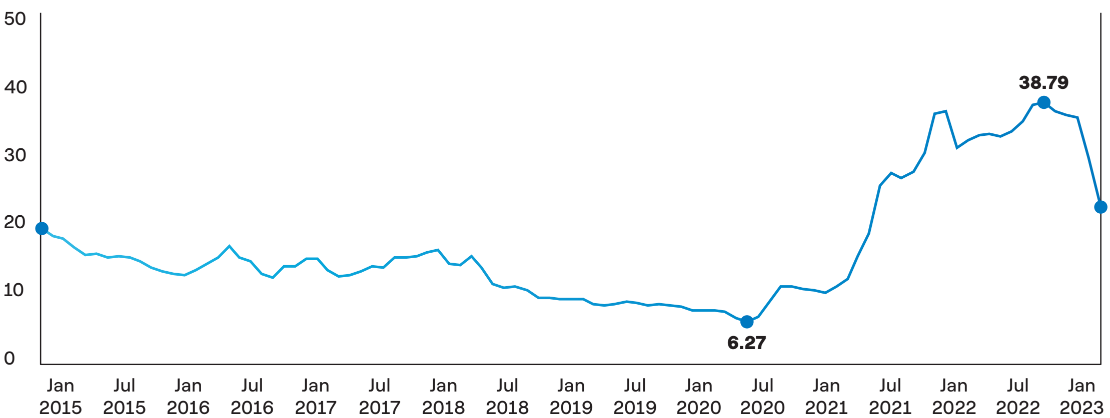
Price volatility of silicon: 6-time increase between May 2020 and August 2022

Polysilicon prices increased from USD 6.27 per kg in May 2020 to USD 38.79 per kg in August 2022 (6.2 times), mainly due to a supply/demand imbalance caused by significant capacity expansion in wafer and cell manufacturing.

China's dominant position in the polysilicon segment allows it to **better face potential rising commodity prices**, which could increase the cost of producing PV modules.

Generally speaking, China is better equipped, not only for the dominant position in the polysilicon segment. In fact, **Chinese companies are vertically integrated along the PV value chain**, hence they are able to compensate for losses in one segment through profits in another.

Figure 20 → **Spot prices of polysilicon, Jan 2015-Jan 2023** (USD/kg)



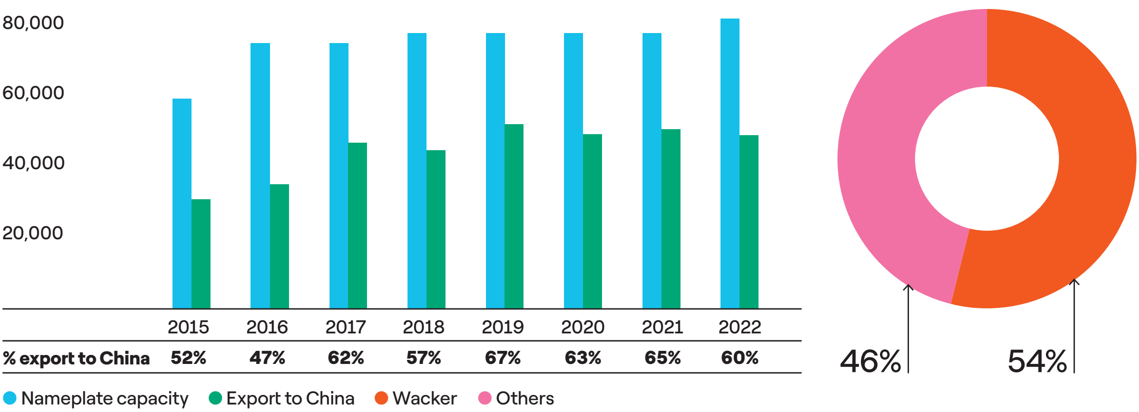
Source → Elaboration The European House - Ambrosetti and Enel Foundation on BloombergNEF data, 2023.

At the European level, only **two companie**s are active in the polycrystalline silicon production segment. Germany's **Wacker Chemie** is **the only non-Chinese company in the world's top ten manufacturers** and is associated with a production of **more than 20 GW** of cells and modules equivalent (**93%** of the European total). The Norwegian company **REC Solar**, on the other hand, has an annual production capacity of **1.5 GW**, about 7% of the European total. Overall, total European polysilicon production capacity is equal to **23.2 GW per year**.

It should be noted, however, that around **60%** of Wacker Chemie's polysilicon production capacity is exported to China. In fact, 54% of the polysilicon imported from Beijing comes from the German company. At the root of this large export share lies **Europe's lack of production capacity at the next stage in the photovoltaic value chain**, which paradoxically forces Wacker to sell to China. At the same time, this situation has led - and is leading - to **less incentive to invest in the midstream stages in Europe**, not least in light of the agreements already signed between Wacker Chemie and its Chinese counterparts.

Figure 21 →

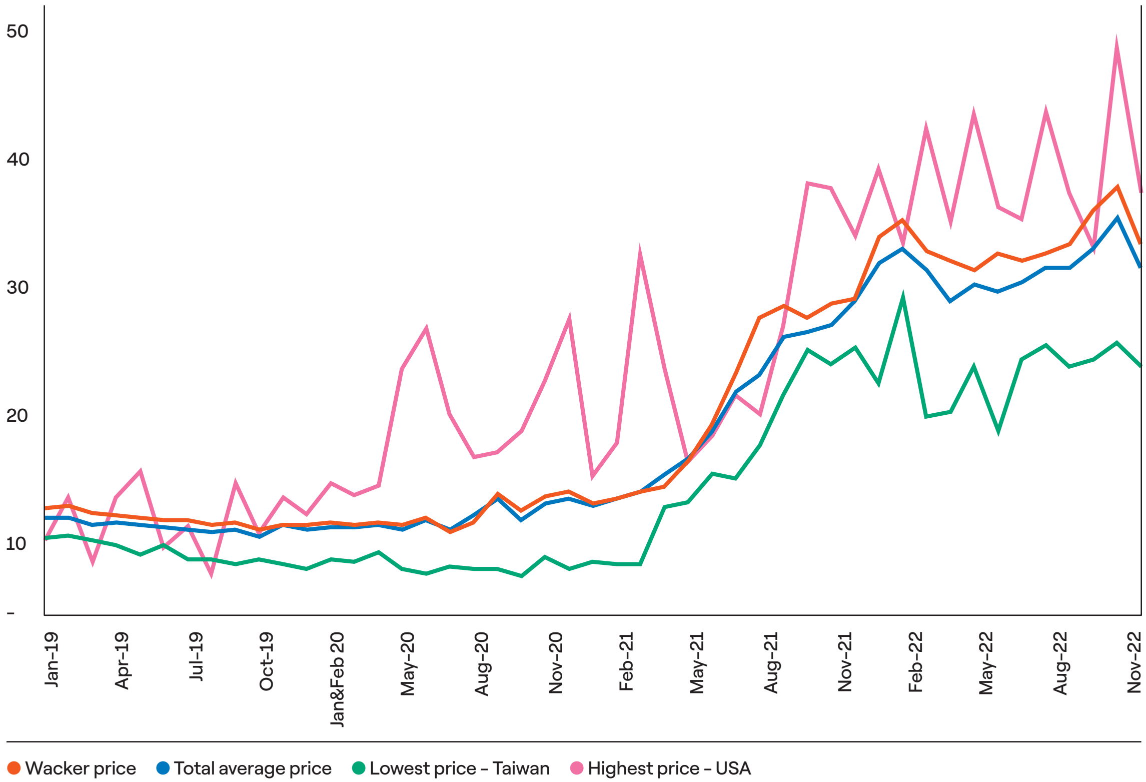
Nameplate capacity and exports to China from Wacker, 2015-2022 (left chart, metric tonnes) **and share of Wacker's polysilicon imported by China, 2022** (% values)



Source → Elaboration The European House - Ambrosetti and Enel Foundation on IHS Markit and BloombergNEF data, 2023.

German-Chinese cooperation is expected to continue in the coming years: in 2021, Wacker signed a **long-term contract** with the Chinese company Jinko Solar for the supply of 70,000 metric tonnes of polysilicon (**85%** of Wacker's nominal production capacity as of 2022) between 2021 and 2026. Consequently, the existing European production capacity is largely directed to China **at least until 2026**, thus limiting the possibility of expanding the photovoltaic value chain in Europe. At the root of the Chinese purchase of the German company's polysilicon is the **quality of the product** and the superior **ability to avoid contamination** during the process, which is a point of advantage for Wacker Chemie and other international companies over their Chinese competitors. These characteristics compensate for the **price**, which is higher in the case of Wacker than in the case of Chinese manufacturers. **Quality production** therefore **has market recognition, representing a factor on which Europe can focus to develop a successful value chain.**

Figure 22 → **Average selling price of polysilicon, Jan 2019-Dec 2022** (USD/kg)

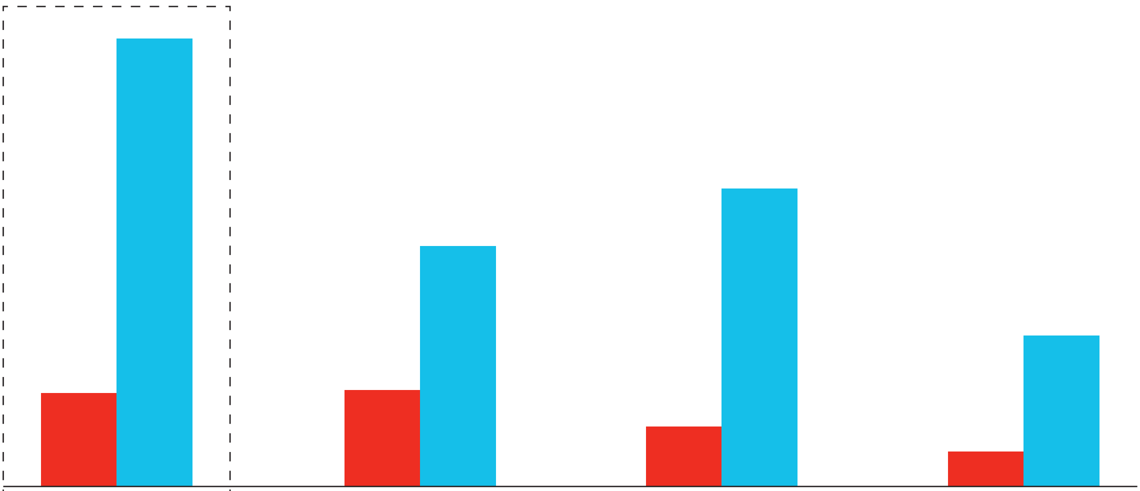


Source → Elaboration The European House - Ambrosetti and Enel Foundation on IHS Markit and BloombergNEF data, 2023.

In this context, a significant **competitive disadvantage** of Europe relates to the higher **investment costs** and longer **lead times required** to develop polysilicon manufacturing plants. In Europe, new plants can take **20 to 40 months** to become operational, compared to **12 to 24 months** in China. Furthermore, the initial investment cost for polysilicon plants is estimated to be up to **5 times lower in China than in Europe**. The main drivers behind this situation include: *i)* **national incentives** (which allowed for cheaper/free land); *ii)* **preferential loans**; *iii)* **lower equipment costs**. In general, China benefits from **lower CAPEX and OPEX** thanks to an integrated and larger-scale model, fostered by industrial policy and substantial state aid: it is estimated that, in the **last 10 years**, Chinese industry has received **EUR >170 billion** in subsidies.

The polysilicon segment is, moreover, **crucial for the entire value chain**, as it is the one where it is most complex to add production capacity and has the longest lead times. Overall, **high capital intensity** promotes industry consolidation, hence **not facilitating new entrants**.

Figure 23 → **Investment costs along the PV manufacturing value chain in China and Europe, and corresponding lead times to build manufacturing plants (months), 2022** (EUR million per GW)



	Polysilicon	Ingots and Wafers	Cells	Modules
China	59	61	36	21
Europe	150-300	130-160	120-200	60-100

Lead times in China and Europe (months)

	Polysilicon	Ingots and Wafers	Cells	Modules
China	12-24	6-18	3-12	3-12
Europe	20-40	12-24	6-18	6-18

● China ● Europe

N.B. The range for investment costs are based on IEA and Enel internal data. In particular, lower bounds are based on investment estimates announced by companies for more than 100 manufacturing projects in various value chain segments, as reported by IEA. Upper bounds are based on Enel proprietary data.

Source → Elaboration The European House - Ambrosetti and Enel Foundation on IEA data, 2023.

Underlying the Chinese advantage, as previously anticipated, are the **industrial policies** of the Beijing government. Suffice it to say that Chinese subsidies still have an impact of around **34%** of investment costs in the polysilicon industry, compared to an estimated **3%** in the case of European subsidies. Thanks to low-interest loans, subsidies to banks, land grants and significantly lower wages[5], China's world market share of polysilicon production grew by **more than 60 percentage points** between 2010 and 2022.

5 Although labour costs are not the most critical issue in polysilicon processing which is heavily automated.

Figure 24 → **Chinese polysilicon manufacturing production share and policy incentives in China and EU, 2023** (% values)

Chinese relevance in the polysilicon segment	2010	2022
Chinese Global Manufacturing Capacity	24%	90% (+66 p.p.)
Top-3 Chinese Provinces Global Manufacturing Capacity	21%	71% (+50 p.p.)
Top-1 Chinese Province Global Manufacturing Capacity	15%	41% (+26 p.p.)

Policy incentives:	Impact:
Capital subsidies: cheap/free land, subsidised loan rate	~ USD¢ 2/W (34% of investment cost*)
Capital subsidies: e.g., EU Innovation Fund	~ USD¢ 0.5/W (3% of investment cost*)

● China ● Europe

* Assuming the investment cost for 1GW polysilicon plant in China is equal to EUR 59 million, the capital subsidies would cover around EUR 20 million. Assuming the investment cost for 1GW polysilicon plant in Europe is equal to EUR 147 million, the capital subsidies would cover around EUR 5 million.

Source → Elaboration The European House - Ambrosetti and Enel Foundation on ESMC and BloombergNEF data, 2023.

Chinese industrial policies in the polysilicon segment

China's transition from dependency on foreign producers for solar grade polysilicon (in 2005 China could produce only 80 tonnes of silicon annually) to becoming the **world's leading supplier** in almost a decade is the effect of the **strategic industrial policy of Chinese Government**.

In the early 2000's, in fact, the global supply of polysilicon was dominated by a **handful of chemical companies from advanced economies** (Wacker in Germany, MEMC and Hemlock in USA). Then, the Central Government of China took on the role of **encouraging domestic investment** in silicon production.

Developing silicon refinement technology was written into the **Ministry of Science and Technology's 11th Five-Year Plan (2006-2010)**, which set a research agenda and directed funding priorities via national R&D programmes. Among them, the 2007 "**Major Projects on the Industrialization of High-purity Silicon Material Technology**" by China's economic planning agency was a mission-oriented programme pushing for **industry development in the refining of polysilicon**. The programme formalised support for the entry of businesses into silicon production and **encouraged bank lending** for silicon production projects: about USD **10 billion** was invested between 2006 and 2008 (half coming from Chinese firms and half from State-owned banks), with **more than 50 Chinese companies racing into production**.

Source → Elaboration The European House - Ambrosetti and Enel Foundation on various sources, 2023.

Chinese industrial policies of the past few years have, moreover, had an impact on the initial investment costs in polycrystalline silicon production plants, as well as on **operating** costs, in relation to covering costs such as electricity, water and labour. In China, for instance, there are utility subsidies on electricity and water, which amount to **USD¢ 0.9 per W** (**15%** of the investments cost). At the same time, China offers indirect supply incentives through relaxed labour laws, which amounts to **USD¢ 0.7 per W** (**12%** of the investments cost). **In Europe, by contrast, there are currently no subsidies for operating costs**.

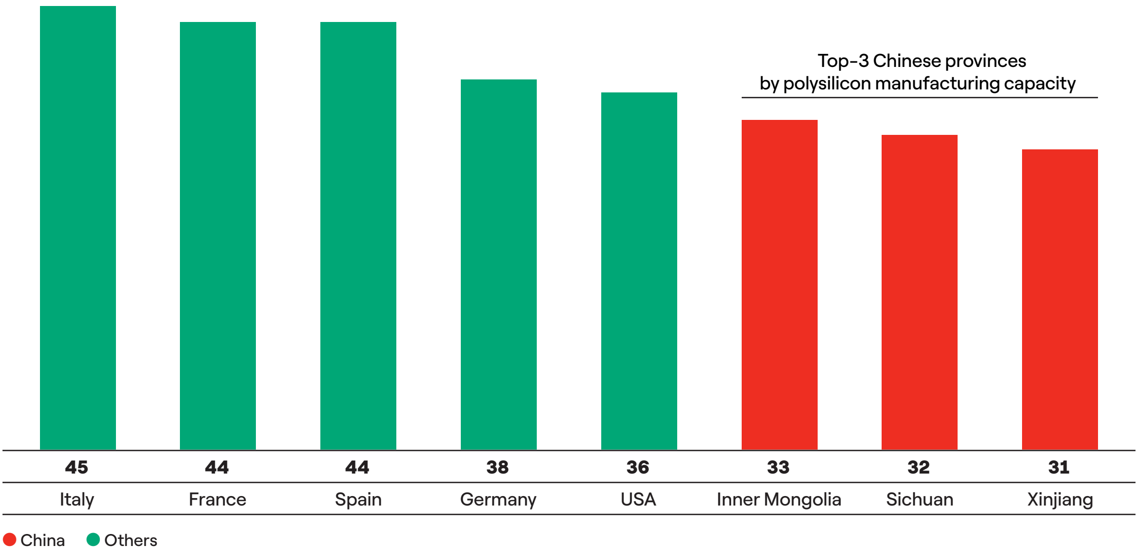
Still about the polysilicon segment, it should be noted that it is the **most energy-intensive** across the photovoltaic value chain. Overall, this production stage requires about 150-190 kWh/kW, **53%** of the total value chain (vs 11% in the modules segment, +42 percentage points).

Figure 25 → **Energy intensity per stage along the PV value chain, 2022** (% values)

Source → Elaboration The European House - Ambrosetti and Enel Foundation on Enel internal data, 2023.

Consequently, Europe and Italy have a further competitive disadvantage: between 2011 and 2020, the average wholesale price of electricity was **EUR 45 per MWh in Italy**, compared with values just over **EUR 30 per MWh in the main Chinese provinces** for polysilicon manufacturing capacity. In addition, the Chinese government provides subsidies to Chinese polysilicon producers to help reduce electricity production costs: the average wholesale electricity price for the latter, according to industry sources, is **EUR 18 per MWh**. This competitive disadvantage is particularly relevant also because the cost of producing polysilicon is largely determined by electricity prices (**41%** of the total), since factories have **high energy needs** for the process used to refine silicon metal into polysilicon.

Figure 26 → **Average wholesale electricity price for selected countries, 2011-2020**
(average absolute values in EUR/MWh)

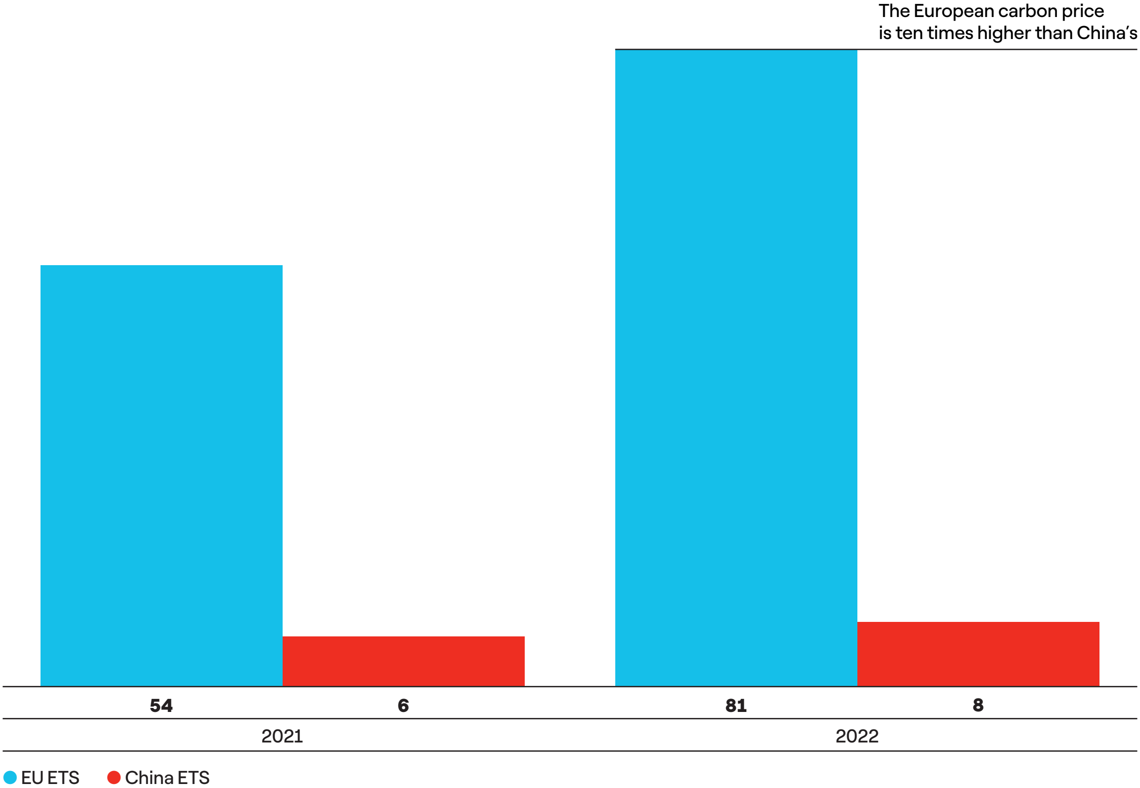


N.B. Exchange rate as of March 2023: EUR 1 = USD 1.06, EUR 1 = CHY 7.38.

Source → Elaboration The European House - Ambrosetti and Enel Foundation on data from China Electric Council, Energy Information Administration (EIA), German Federal Network Agency, EEX, RTE, Red Eléctrica de España, GSE and Terna, 2023.

Moreover, the higher cost of manufacturing in Europe and Italy is affected by a more aggressive **carbon pricing** mechanism than in China, having an impact on the average final price of electricity in the EU of around **10%**. Indeed, in the European Union, the Emissions Trading System (ETS) mechanism started operating in **2005** and reached a level of **EUR 81 per tonne of CO_2 equivalent in 2022**. In China, on the contrary, an emissions trading mechanism only came into operation in **2021** and is not harmonised with the European one, nor is it yet offset by an equalisation mechanism such as the Carbon Border Adjustment Mechanism (CBAM): in 2022, emissions allowances in China reached a price of only **EUR 8 per tonne of CO_2 equivalent**. Nevertheless, it is important to highlight that **CBAM is not expected to completely counterbalance the Chinese competitive advantage in the manufacturing of PV modules**. In fact, according to Fraunhofer data, CBAM might increase the cost of Chinese PV modules imported in Europe by **3.3 €ct/W_p**. However, at the moment, the difference between the cost of modules produces in EU with respect to the ones produces in China is equal to **4.8 €ct/W_p** (the cost of Chinese modules is **85%** the cost of EU modules).

Figure 27 → **The emission costs in Europe and China, 2021 and 2022**
(EUR/tonne CO_2-eq, annual average level)

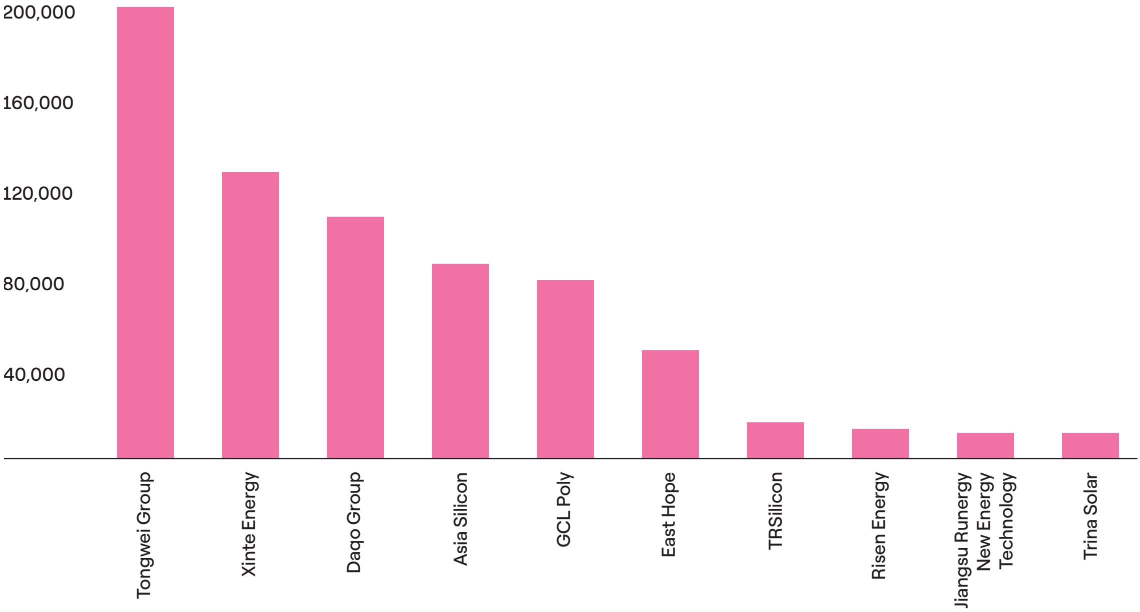


Source → Elaboration The European House - Ambrosetti and Enel Foundation on International Carbon Action Partnership data, 2023.

A further difference is **labour cost**, which averages around **EUR 20.5 per working hour in the EU manufacturing sector**, compared with values **between EUR 3.9 and 7.1 in China**[6]. This asymmetry has driven European companies to outsource production, preventing the development of a domestic solar PV value chain. Thanks to industrial policies and lower costs, Chinese companies are, however, able to achieve **greater economies of scale**. As a result, the capacity of Chinese polysilicon plants is currently about **five times** that of all other countries, with recent greenfield polysilicon plants in China ranging in size **from 40,000 to 100,000 metric tonnes**, almost tripling historical averages.

6
Source: Eurostat and NREL data.

Figure 28 → **Top-10 polysilicon manufacturers that increased production capacity, 2017-2022** (variation in metric tonnes)



Source → Elaboration The European House - Ambrosetti and Enel Foundation on BloombergNEF and HIS Markit data, 2023.

Finally, polysilicon production requires **complex technological skills and a highly qualified workforce**, with specific know-how for the sector, which - as seen above - in Europe appears to be **limited to just a few companies**, with a leadership that is **increasingly Chinese**, even though in past decades it was predominantly European and American. Therefore, as production in Europe is limited and Chinese companies have **accumulated experience** and expertise also thanks to the industrial policies they have undertaken, European counterparts encounter an additional barrier to entry. Lastly, polysilicon production requires access to the state-of-the-art production technology, in a context in which **equipment suppliers are scarce in upstream segments**. In Italy, for instance, **there are no suppliers of production equipment necessary to process polysilicon**, while there are 2 companies supplying production equipment for the modules stage, the market segment in which Italy is most present.

Figure 29 →

Core firm operating along the PV value chain and corresponding manufacturing equipment providers in Europe and Italy, 2023
(absolute values: number of firms)

Photovoltaic segment	Core firms (Europe)	Production equipment (Europe)	Core firms (Italy)	Production equipment (Italy)
Polysilicon	2	1	0	0
Ingots and wafers	3	10	0	0
Cells	4	7	1	0
Modules	54	15	10	2

● Europe ● Italy

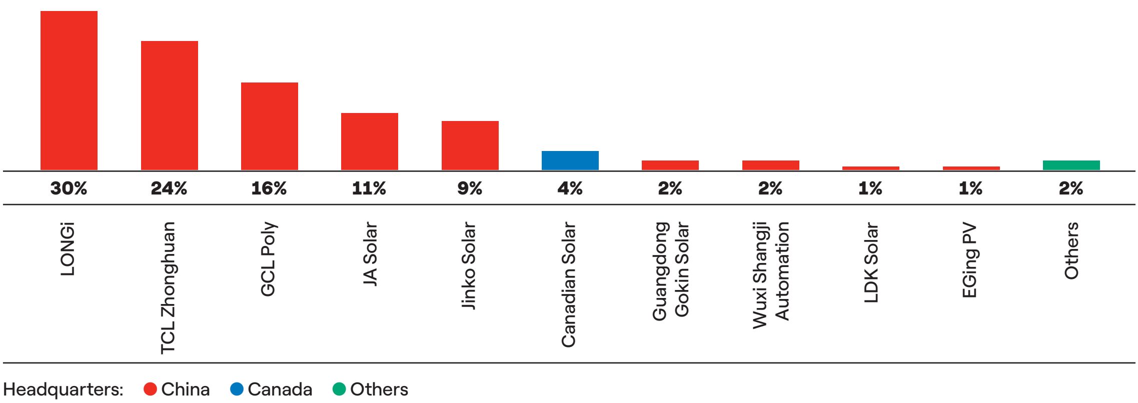
Source → Elaboration The European House - Ambrosetti and Enel Foundation on SolarPower Europe data, 2023.

→ State of the art and critical issues in the photovoltaic value chain: the components

As far as the component stage is concerned, however, the main critical issues are related to the production of **silicon ingots and wafers**, **the segment of the value chain with the highest manufacturing concentration**. Suffice it to say that the **top five Chinese** wafer-producing **companies** hold a **90%** market share, with **9 out of 10 firms headquartered in China**, with the only exception of Canadian Solar (Canada), even though the company has large manufacturing plants in China.

Figure 30 →

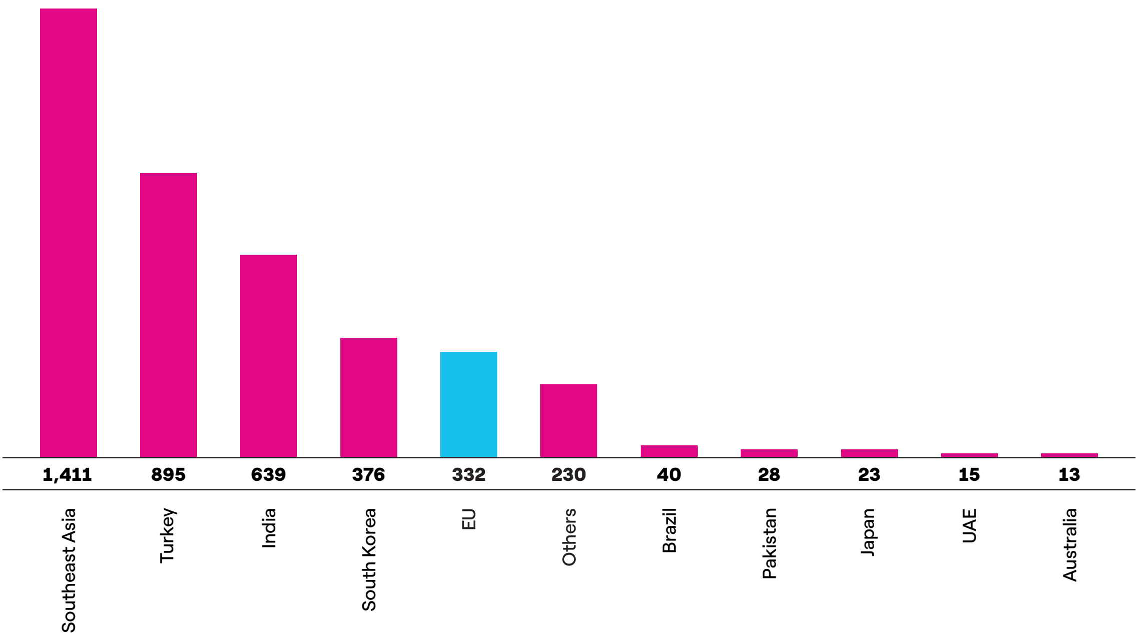
Top-10 solar wafer manufacturers by annual production, 2022 (% values)



Source → Elaboration The European House - Ambrosetti and Enel Foundation on BloombergNEF data, 2023.

With regards to solar cells, which together with wafers make up the **component stage**, Chinese manufacturing concentration is still relevant, though lower compared to wafers: the **top five Chinese** solar-producing **companies** hold a **52%** market share (-38 percentage points vs. wafers). Within this context, it is important to highlight that the European Union imports only a **marginal portion** of Chinese cell exports. While in 2022 more than USD **4 billion of solar cells** were exported from China (corresponding to nearly **24 GW** of solar modules), the EU imported PV cells for a total value of **USD 332 million** (**8.3%** of Chinese cell exports), equivalent to nearly **2 GW**. This is because the EU imports mainly **PV modules** from China (as it will be highlighted later in the Study) rather than PV cells.

Figure 31 → **Chinese cell exports by destination, 2022** (USD million)



Source → Elaboration The European House - Ambrosetti and Enel Foundation on BloombergNEF data, 2023.

In addition, in Europe **no company is integrated in all stages of the value chain**. Only three companies are active in the production of **ingots and wafers**, two in **Norway** and one in **France**, for a total annual production of **1.7 GW**. There are, on the contrary, no companies from these two countries operating in the cell segment, which is mainly dominated by **Germany** (for a total in Europe of **1.4 GW**). At the Italian level, one company is present in the production of cells (3SUN) and 10 in the production of modules, but **there are no operators in the segments further up the chain**.

Figure 32 → **Distribution and presence of European and Italian companies operating in the photovoltaic manufacturing value chain**

State of the art	Polysilicon	Polysilicon-ingots/ wafers	Polysilicon-ingots/wafers-cells	Polysilicon-ingots/wafers-cells-modules	Ingots/wafers	Ingots/wafers-cells	Ingots/wafers-cells-modules	Cells	Cells-modules	Modules
Company presence in EU	23.2 GW				1.7 GW			1.4 GW	1.4 GW	9.2 GW
Company presence in Italy								0.2 GW	0.2 GW	1.7 GW

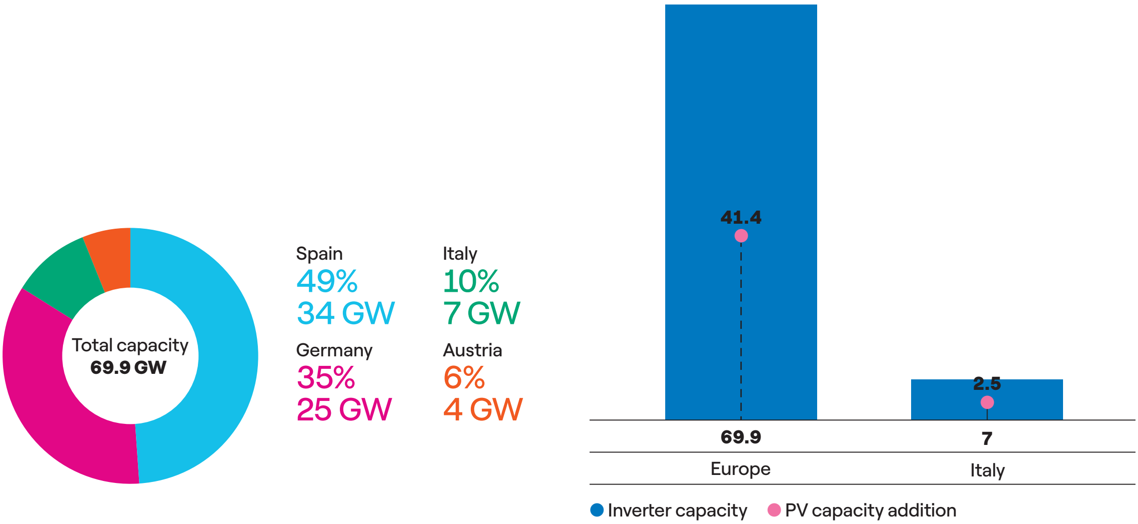
Source → Elaboration The European House – Ambrosetti and Enel Foundation on SolarPower Europe and Fraunhofer ISEE data, 2023.

The components segment of the photovoltaic value chain also has **high energy and manufacturing costs**, although significantly lower than the polysilicon segment. The production of silicon ingots and wafers requires, in particular, high temperatures for long periods of time, and is therefore **energy-intensive**. Altogether, ingots, wafers and cells account for about **36%** of the energy used to produce a photovoltaic module. Here, too, a further point of attention is the **high initial investment costs**. Once again, ingots and wafers require higher investment costs than cells and modules. Moreover, smaller plants do not allow for **economies of scale** and lower investment per megawatt. In this segment too, the considerations made above for polysilicon apply: China has significantly lower investment costs than Europe (**3 to 6 times lower than in Europe**), mainly due to the **industrial policies** implemented, as previously reported.

Finally, a positive aspect for Europe is the relatively higher development in the **production of** photovoltaic **inverters**. The total European production capacity is, in fact, **69.9 GW** for inverters, with Spain being the main producer (34 GW). **In Italy**, PV inverter production capacity is equal to **7 GW**, which is:

- **10%** of the overall European PV inverter production capacity.
- Almost **3 times** the PV capacity addition recorded in 2022 (2.5 GW).
- Equal to the **annual PV capacity addition required to reach "REPowerEU" targets**.

Figure 33 → **Production capacity in European countries for solar inverters** (left: % values and GW) **and comparison between solar inverter capacity and PV capacity addition in Europe and Italy, 2022** (right: GW)



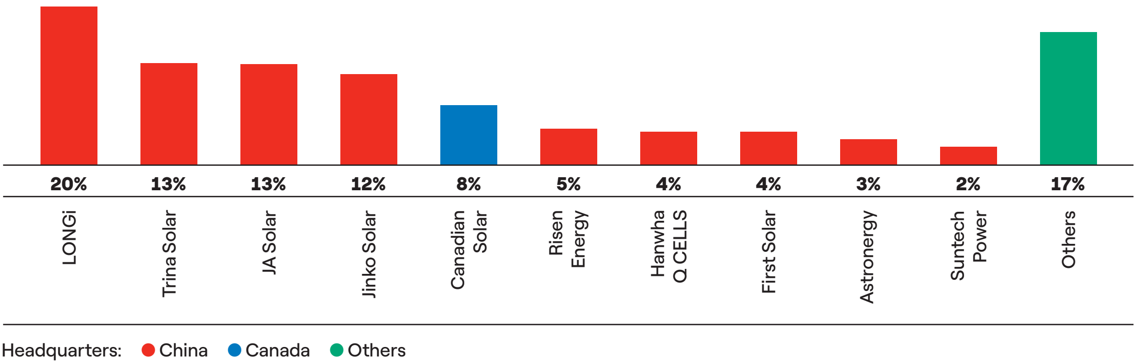
Source → Elaboration The European House - Ambrosetti and Enel Foundation on European Commission, SolarPower Europe and Fraunhofer ISE data, 2023.

At the same time, however, it should be borne in mind that the production of inverters is **linked to the silicon value chain**: to manufacture them, electronic components are needed and these are mostly manufactured using **monocrystalline silicon wafers**. In addition, the European market share in the PV inverter segment halved in the last 6 years (20% in 2015 vs 11% in 2021).

→ State of the art and critical issues in the photovoltaic value chain stages: assembly

In addition to processed raw materials and components, China also dominates the assembly stage of the photovoltaic value chain. In 2021, **83%** of photovoltaic modules was produced by the world's top 10 manufacturing companies, of which nine were Chinese.

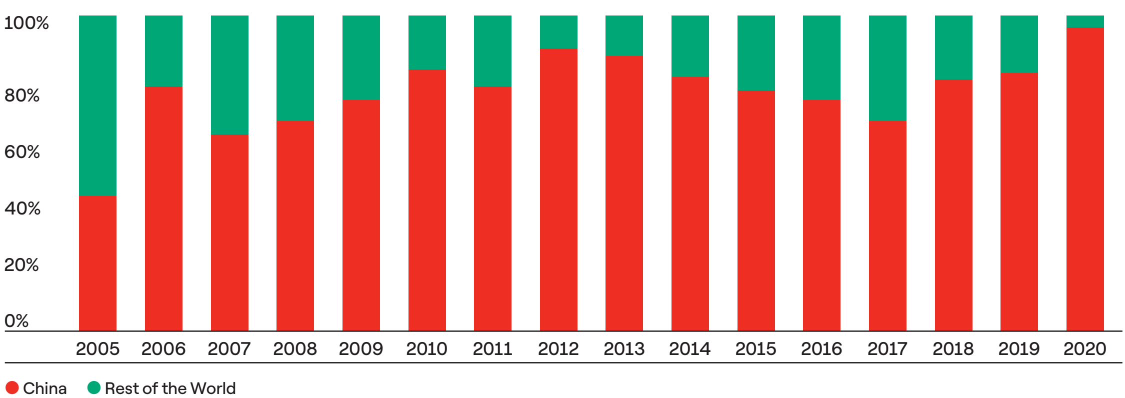
Figure 34 → **Top 10 solar module manufacturers by global shipments, 2022** (% values)



Source → Elaboration The European House - Ambrosetti and Enel Foundation on BloombergNEF data, 2023.

Building a new module factory has **lower technical hurdles** than wafer and polysilicon. Large module makers have been **regularly upgrading** their production lines to adjust for **new cell structures and other technological needs**. Factories that lack the most modern equipment **can quickly become obsolete** in the current competitive market environment. In this context, since 2017, almost **172 GW/year of c-Si module manufacturing capacity** has been built globally, **134 GW of which in China** (78%).

Figure 35 → **Annual silicon module factory additions between China and the rest of the World, 2005-2020** (% values)



Source → Elaboration The European House - Ambrosetti and Enel Foundation on BloombergNEF data, 2023.

Chinese dominance in this segment also stems from the **development of adjacent industries, primarily glass and aluminium**. In fact, the growth of domestic module production is only possible if, in parallel, there is a network of industries supporting the related production with the necessary ancillary materials and expertise.

Figure 36 → **Summary of PV value chain characteristics, 2023** (illustrative)

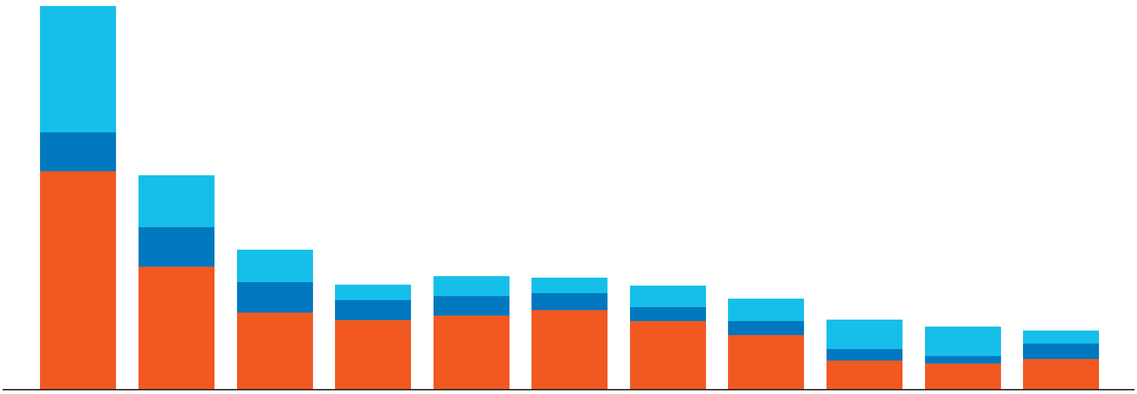
PV segment	Number of factories	Largest manufacturer	Market concentration (by country)	Market concentration (by company)	Adjacent industries	Barrier to entry
Overall	1,215	China	High	High	Power, silicon, glass	Medium
Polysilicon	77	China	High	High	Power, silicon	High
Wafers and Ingots	158	China	High	High	Crucibles, wire saws	High
Cells	363	China	High	Medium	Silver, aluminum	Medium
Modules	**617**	**China**	**High**	**Medium**	**Glass, aluminium**	**Medium**

Source → Elaboration The European House – Ambrosetti and Enel Foundation on BloombergNEF data, 2023.

Within this context, **Italy has the second highest photovoltaic module manufacturing capacity in Europe**, after Germany. In fact, **ten companies in the country are active in module production**, with a total capacity of around **1.7 GW**. In terms of production value, Italy is also the second largest country in Europe for photovoltaic modules, after Germany. However, Italian value of production has declined from EUR 815 million in 2011 to **EUR 312 million in 2021**, mainly due to the **decrease in the cost of production**, which has fallen by **75%** from USD 1.07/W to USD 0.27 per W over the same period, thanks to a **learning curve effect** triggered by the **significant growth in the PV installation. As a matter of fact, from 2011 to 2021 the Italian PV manufacturing capacity increased by 240%, moving from a PV production of 500 MW to a PV production of 1,700 MW**.

Figure 37 →

Total European value of production and top 2 European PV module producing countries, 2011-2021 (EUR million)



	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Rest of EU	**2,570**	**1,066**	**679**	**330**	**404**	**330**	**428**	**468**	**627**	**611**	**268**
Italy	**815**	**788**	**608**	**385**	**389**	**327**	**273**	**278**	**231**	**138**	**312**
Germany	**4,457**	**2,529**	**1,582**	**1,432**	**1,516**	**1,640**	**1,402**	**1,115**	**585**	**551**	**633**

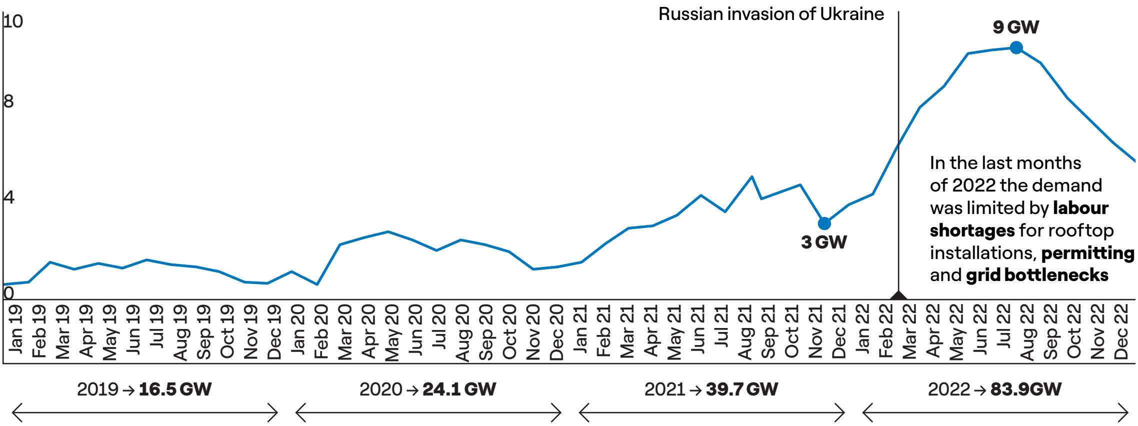
Germany · Italy · Rest of EU

Source → Elaboration The European House - Ambrosetti and Enel Foundation on ProdCom data, 2023.

In Italy, the main contribution comes from Peimar, which has a production capacity of **300 MW**. The largest contribution will come from 3SUN, owned by Enel Green Power, which is expected to have a module production capacity of **3 GW** by 2024. However, the country is still heavily dependent on **PV imports from China**, which amounted to **EUR 187 million in 2021**, **78%** of total extra-EU PV imports.

In 2021, the EU reported a **deficit of EUR 9.2 billion in the extra-EU trade balance for solar panels**, mainly due to the absence of significant domestic production. Overall, the EU mainly exports solar modules to the United States (total value of **EUR 1.1 billion between 2019 and 2021**, equal to **27%** of the EU production value during the same time period), while most of the imported modules **come from China (EUR 20.4 billion between 2019 and 2021). Imports of modules from China increased during 2022**, also in light of the fear of the consequences deriving from the Russian invasion of Ukraine. In fact, during the same year, on the other hand, the price of electricity rose dramatically, reaching an average of **EUR 375.75 per MWh** in the third quarter. In 2022, overall, Europe imported **84 GW** of solar modules (compared to a growth in installed PV in the same year of 41.4 GW), corresponding to **2.1 times the imports of 2021** (amounting to 40 GW) and **5 times those of 2017** (when they amounted to 17 GW).

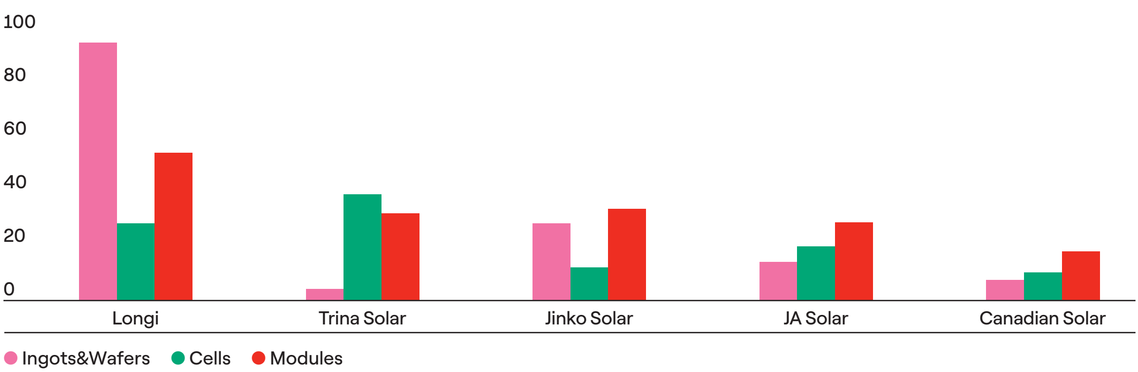
Figure 38 → **Chinese PV modules imported in Europe, Jan 2019-Dec 2022** (absolute values in GW)



Source → Elaboration The European House - Ambrosetti and Enel Foundation on BloombergNEF and HIS Markit data, 2023.

It is also significant to note that the world's leading manufacturers of photovoltaic modules have **vertically integrated value chains**. Chinese companies such as Longi, Trina Solar, Jinko Solar and JA Solar, world leaders in the sector, are active in module, cell, and component production. In contrast, **major European photovoltaic module manufacturers are not integrated upstream**, but only in the cell stage, hence limiting synergies and economies of scale.

Figure 39 → **Ingot&Wafer, cell, and module manufacturing capacities of selected leading module manufacturers, 2022** (absolute values in GW)



Source → Elaboration The European House - Ambrosetti and Enel Foundation on BloombergNEF data, 2023.

All these critical issues are the result of a **slow adjustment of the EU and Italy strategic vision**. Within this framework, **China has also shown a more far-sighted vision** in terms of industrial policy over the past 20 years. Since 2001, Beijing has supported photovoltaic technology and identified renewables as a significant choice to optimise China's energy mix in the long run, which has been followed by several programmes specifically dedicated to this sector[7]: overall, **China built its industrial capacity leveraging on policies specifically aimed at achieving global leadership in PV**. In contrast, **it was not until 2020 that the European Commission[8] recognised the photovoltaic industry as a strategic sector, 20 years after its Chinese counterpart**. In other terms, Europe's strategy resulted in industrial delocalization and **global value chains**. This delay accumulated over the last 20 years has generated a **competitive gap** with China, which appears to have a more attractive business model: even if Europe had the same initial investments (CAPEX) and operating expenses (OPEX) as China, **economies of scale, labour costs, social standards and incentives** would make the Chinese products cheaper.

7
These include the Five-Year Plans (2001, 2006, 2011, 2016), as well as the revision of the ″Catalogue of Chinese High-Tech Products for Export″ in 2004, the ″Golden Sun″ demonstration project in 2009, Research Programmes 973 and 863 (2011) and the 'Made in China 2005' plan (2016).

8
In 2022, the European Commission formally endorsed - in the context of the ″REPowerEU″ plan - the establishment of the ″European Solar Photovoltaic Industry Alliance″, with the aim of increasing production capacity.

Figure 40 → **The Chinese foresight vision about photovoltaic industry, 2001-2022**

2001

China's 10th Five-Year Plan identified RES as a significant choice to optimise the Chinese energy basket and **supported the promotion of PV** (increasing the production capacity of solar cells)

2004

The "Catalogue of Chinese high technology products for export" programme promoted solar PV production with **tax rebates, free land and low-interest government loans**

2006

China's 11th Five-Year Plan provided USD 6 million as annual funding for solar PV R&D

2009

The "Golden Sun" demonstration project, facilitating the growth and expand the scale of the PV power generation industry

2011

→ **China's 12th Five-Year Plan** increased the annual funding for solar PV R&D to **USD 75 million** to cover all segments of the value chain

→ **973 Programme and 863 Programme:** national research programmes for the development of key national strategic technologies

China Europe

Source → Elaboration The European House - Ambrosetti and Enel Foundation on various sources, 2023.

The European Commission defined **the photovoltaic industry a strategic sector** to focus on, especially looking at the critical raw materials involved

The European Union moved almost **20 years later** compared to China in PV industry

2016

→ **China's 13th Five-Year Plan** contained specific goals for solar PV technology innovation

→ **Made in China 2025:** goal of becoming a **major manufacturing power in 2025** for 10 core industries (also solar PV)

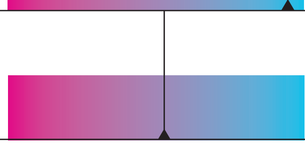
2020

2022

The European Commission formally endorsed the **Solar Photovoltaic Industry Alliance,** under the "REPowerEU" plan to **scale up production capacity**

To sum up, the slow adjustment of the EU and Italy strategic vision, led to some **competitive disadvantages** compared to China. First, as seen before, Europe and Italy report higher **investment costs** (**2.2 to 5.6 per MW higher** in Europe and Italy with respect to China) and longer **lead times required to develop PV manufacturing plants** compared to China (for all PV segments, lead times in Europe and Italy are up to **1.7 times longer** than in China). Another point of attention is represented by the **manufacturing costs**, both in terms of **energy, CO_2 and labour costs**. As reported before, energy price is 45% higher in EU than in China and carbon price is 10 times the Chinese one. Higher costs are also associated to labour force: Europe and Italy have an average hourly wage that can be up to **5 times higher** than in China. Further criticalities are associated to the **absence of vertical integration** along the photovoltaic value chain. In fact, in Europe and Italy **there is no single company operating in the downstream segments** (cells and modules) **which is also active in the upstream ones** (polysilicon, ingots and wafers). Lastly, another point of attention refers to the **lack of competence, skills and equipment manufacturers**, in a context in which, as it is in the case of Europe and Italy, there is latent know-how, no access to the state-of-the-art production technology and no equipment supplier in the upstream segments.

Figure 41 → **The main European and Italian bottlenecks along the photovoltaic value chain**

Bottleneck	**Bottleneck severity**	**Reasoning**
	Low High	
Production facilities high investment cost and lead time		→ **CAPEX 2.2 to 5.6 times higher** than in China → **Lead times** up to **1.7 times longer** than in China
High energy, CO_2 and labour costs		→ The EU and Italian industry energy price is **45% higher** than in China → EU CO_2 emission cost is **x10** than the Chinese one → EU **average hourly wage up to x5** than in China
Absence of vertical integration		→ In Italy and in Europe there is **no single company vertically integrated along the PV value chain,** making them **more subject to unexpected shocks**
Lack of competence, skills and equipment manufacturers		→ Some PV segments require **advanced technologies, know-how, skilled labor** and access to **state-of-the-art production technology** → **Lack of equipment suppliers** in upstream segments in EU and Italy

Source → Elaboration The European House - Ambrosetti and Enel Foundation on various sources, 2023.

→ The main opportunities and risks to be addressed for the development of the photovoltaic value chain in Europe and Italy

Despite the weaknesses, **Europe and Italy present opportunities for the development of the photovoltaic value chain stages**. Firstly, there are already **available funds** that could expand photovoltaic manufacturing capacity. Recent EU funds for sustainability are **comparable in amount to the recent US Inflation Reduction Act** (IRA) **plan**, except for renewable energy production, where they are even larger[9]. However, it is important to underline that **EU support is more fragmented and slower**, requiring public tenders and lengthy bureaucratic processes. Italy, with the PNRR (National Recovery and Resilience Plan), has allocated **EUR 400 million** to innovation in the photovoltaic value chain. Innovation and the opportunity to develop products with high efficiency and cutting-edge technology could allow European companies to 'attack' some particularly demanding markets where Chinese products may not be functional. Overall, the availability of funds represents a **huge development opportunity.**

Other significant development opportunities are related to **sustainability and human rights**, where - as of today – Europe registers a greater attention compared to China, in a context in which governments, policy-makers and investors are increasingly focusing on this theme. In fact, the Chinese competitive advantage is mainly due to a **lower attention to sustainability issues and respect for human and labour rights**. Indeed, Chinese production along the photovoltaic value chain has a larger **environmental footprint** than Europe's. Total emissions from the production of the individual stages of the photovoltaic value chain in Europe are estimated at **0.46 kg CO_2 equivalent per Wp**[10], compared to **0.75 kg in China**[11]. Looking only at the polysilicon production stage, the estimated emissions in China are 0.33 kg CO_2 equivalent, **more than double** the 0.15 kg in Europe, even though it is important to highlight that China might quickly catch up.

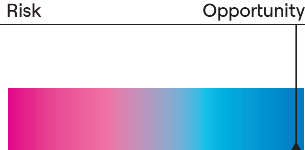
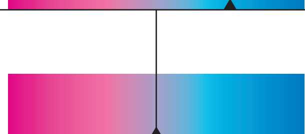
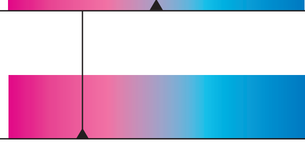
On the other hand, **increasing attention is being paid to the issue of human and labour rights**. In June 2021, the US government **banned the import of polysilicon from the Chinese region of Xinjiang**, obliging American companies to prove that their supplies are not derived from forced labour imposed on ethnic minorities in China and to map every step in the production of imported materials. Overall, China could be damaged by blockades imposed by partner countries. At the same time, China could weaponize its leadership in the clean technologies, starting from the dominant role in the critical raw materials necessary to manufacture the final product, reducing or even blocking the supply[12]. In this context, **Europe can leverage on a greater attention to human rights**, hence being in an advantageous position with respect to China, representing an additional reason why a local photovoltaic value chain should be developed.

9
Even if the funds are comparable in terms of amount, it is important to highlight that the Inflation Reduction Act is based on tax credits and therefore does not provide capital incentives on capital expenditure, unlike the European ones. Hence, the risk profile is different in the two cases.
10
Watt peak, unit of measurement of power.
11
Sustainable PV Manufacturing in Europe, Fraunhofer ISE.
12
Source: "*Materie prime critiche e produzioni industriali italiane. Le opportunità derivanti dall'economia circolare*", The European House - Ambrosetti ed Iren, 2023.

In addition, **research and development activities** could be a key lever for Europe to strengthen its position in the photovoltaic value chain. However, to reap the benefits from R&D, Europe needs - among other things - to **coordinate** the different research centres (in Italy there are 6 research centres), by **pooling the knowledge and expertise** developed.

Lastly, it is important to mention that the Chinese government recently announced a **revision of the list of banned** and export-restricted **technologies**. These include **technologies required to produce polysilicon and wafers**, which could be excluded from export. In this context, the European Union - by realising investments for the development of photovoltaic machineries and equipment - could **overcome Chinese protectionism**, turning a strategic and geopolitical risk into an **opportunity**. On the other hand, this situation can have **significant industrial implications**, as developing a domestic machinery value chain takes time and significant effort.

Figure 42 → **A summary view of the main opportunities and risks for the development of the photovoltaic industry in Europe and Italy**

Risk/Opportunity	Risk/Opportunity severity	Reasoning
	Risk — Opportunity	
Effective use of available funds		→ In EU and Italy, **funds are already available, but need to be effectively channeled** to expand and scale-up PV manufacturing capacity, coordinating and integrating current capabilities across the EU
Environmental and social sustainability		→ **The manufacturing of PV modules in Europe is more sustainable** vs. China, even if the latter might quickly catch up. China has been accused to adopt **forced labor** in its polysilicon facilities
Research and Development		→ Different research centers in EU and Italy, **but need of higher coordination.** China R&D in the sector is strong and can leverage on the huge production capacity
Chinese export ban		→ 3 Chinese technologies to manufacture PV modules might **be prohibited for export.** This is a risk but EU could promote the development of a local industry, but this **takes time**

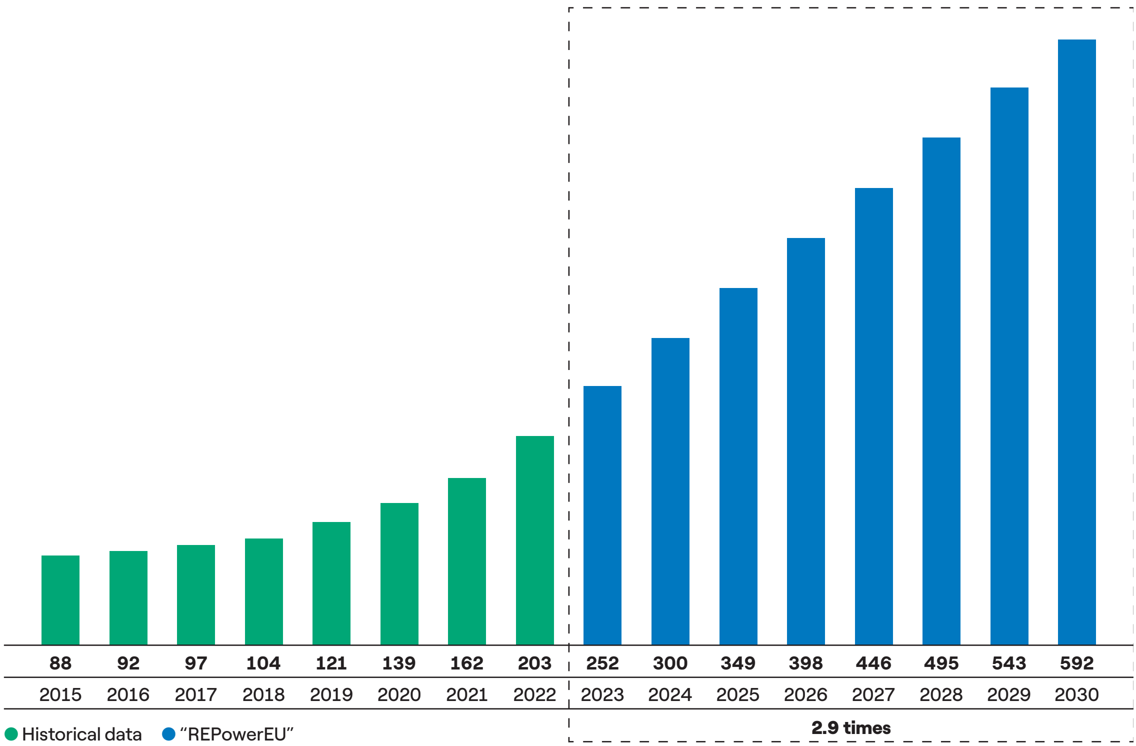
Source → Elaboration The European House - Ambrosetti and Enel Foundation on various sources, 2023.

→

Expected demand trends, gap analysis and announcements for photovoltaic projects in Europe and Italy

According to the targets set in the "REPowerEU" plan, the European Union should reach **592 GW** of installed PV power by 2030 (about three times the current level of 203 GW). In other terms, between 2022 and 2030 EU is expected to install approximately **+389 GW** of photovoltaic capacity, which would mean to install **48.6 GW of photovoltaic capacity per year** to reach the "REPowerEU" target by 2030 (vs **+41 GW between 2021 and 2022**).

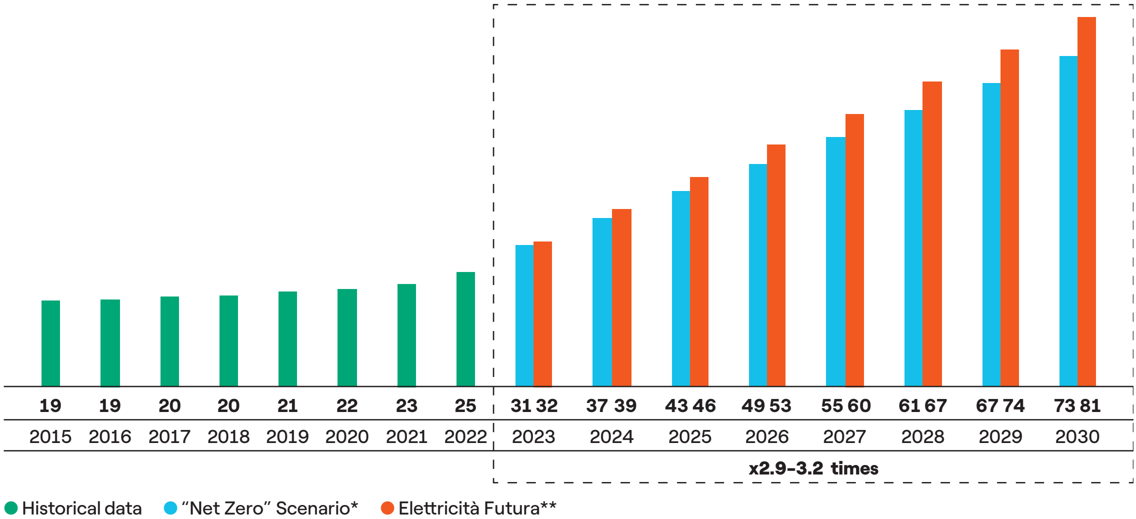
Figure 43 → **Expected evolution of solar PV cumulative installed capacity in Europe, 2015-2030E** (absolute values in GW)



Source → Elaboration The European House - Ambrosetti and Enel Foundation on various sources, 2023.

In Italy, similarly, installed photovoltaic power will have to increase by about three times the current **25 GW** by 2030. In fact, **between 73 GW and 81 GW** of photovoltaic installed power in the country are estimated by the end of the decade. In other terms, between 2022 and 2030 Italy will have to install around **7 GW of photovoltaic capacity per year** (vs **+2.5 GW between 2021 and 2022**).

Figure 44 → **Expected evolution of solar PV cumulative installed capacity in Italy, 2015-2030E** (absolute values in GW)



* Based on the Scenario elaborated in the study "*Net Zero E-conomy 2050*" by The European House – Ambrosetti and Enel Foundation.
** Increased ambition set by the 2030 Plan of the electric sector elaborated by Elettrcità Futura.

Source → Elaboration The European House - Ambrosetti and Enel Foundation, "*Net Zero E-conomy 2050*" and Terna data, 2023.

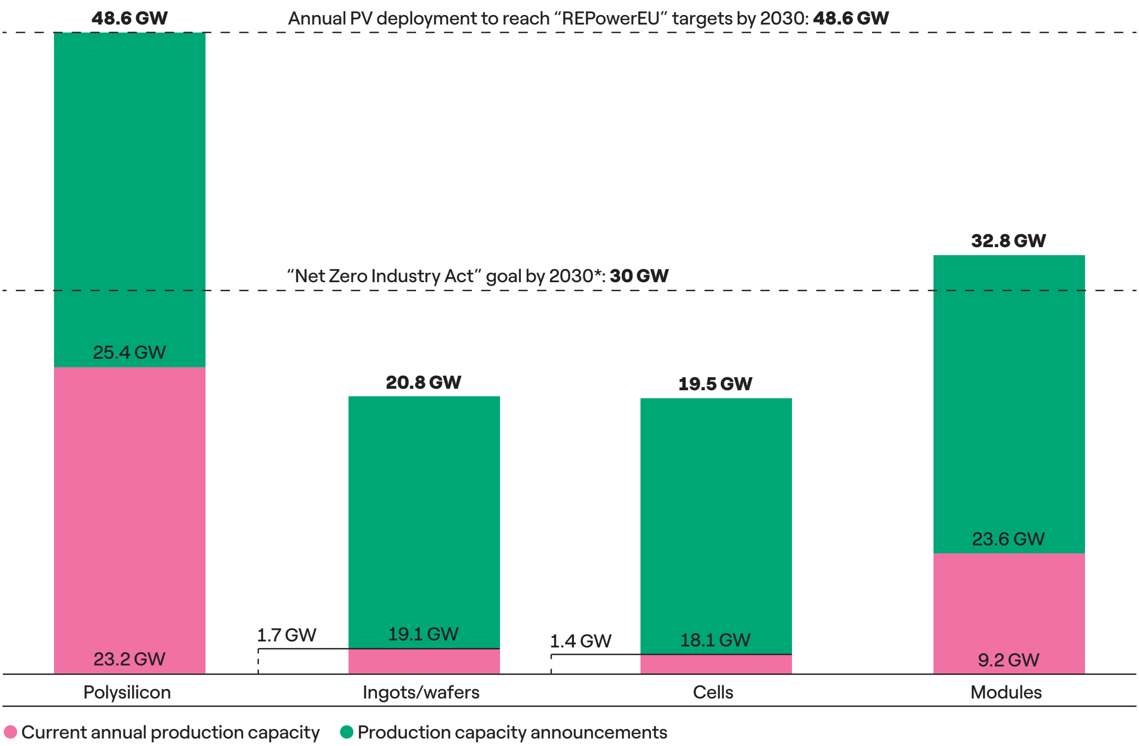
To cope with the growing demand and limited domestic production, **several European industrial players have planned expansive interventions in the various stages of the photovoltaic module value chain. Wacker Chemie, for example**, aims to increase its capacity by **+25.4 GW** by 2025. However, it is worth pointing out that Wacker Chemie has signed a **contract** (until 2026) with the Chinese company Jinko Solar for the supply of 70,000 metric tonnes of polysilicon, equal to about **23.3 GW**[13]. Further expansions are planned by European companies in the component and assembly stages. In Italy, 3SUN has planned to add 2.8 GW of photovoltaic cell and module production capacity by 2025. In total, the interventions announced to date will require European companies to invest between **EUR 10 and 17 billion**[14].

13
Assuming that 3 kg of polysilicon are required to produce a state-of-the-art 1 kW monocrystalline module with an efficiency of 21.5%.
14
The assumed investments per GW of plant along the photovoltaic value chain are as follows: EUR 150 million/GW (IEA data) and EUR 300 million/GW (Enel internal data) for polysilicon, EUR 130 million /GW (IEA data) and EUR 160 million/GW (Enel internal data) for ingots and wafers, EUR 120 million/GW (IEA data) and EUR 200 million/GW (Enel internal data) for cells, EUR 60 million/GW (IEA data) and 100 million EUR/GW (Enel internal data) for modules.

Based on the announced actions, Europe should be able to meet the trajectories set by the European "Net Zero Industry Act" plan for polysilicon and module production, but not at the intermediate stage of semi-finished products. Against an **annual domestic production projections of 30 GW, 48.6 GW of production capacity** is expected **for polysilicon, 20.8 GW for ingots and wafers, 19.5 GW for cells, and 31.7 GW for modules**. Overall, announced capacity could cover – depending on the value chain stage – **between 40% and 100%** of the PV annual deployment necessary to reach the policy goal by 2030.

Figure 45 →

State of the art of the PV industry in Europe, based on current and expected annual manufacturing capacity, policies for 2030* and requirements to reach the "REPowerEU" targets, 2022 and 2030
(absolute values in GW)

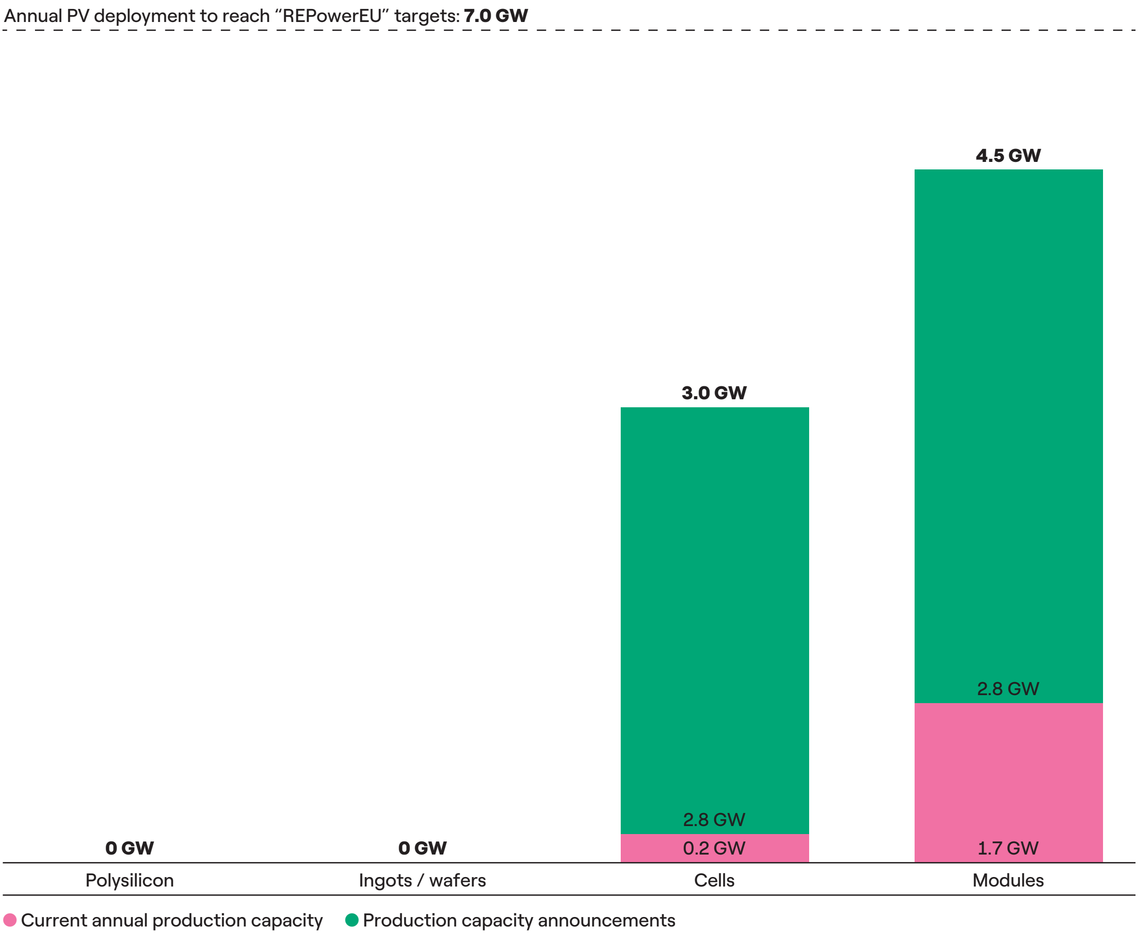


N.B. Expected annual production capacity is based on project announcements up to 2025
* Based on the "Net Zero Industry Act", which lists 30 GW as the minimum expectation by 2030. Annual PV development at European level is estimated based on European Commission and IRENA data.

Source → Elaboration The European House – Ambrosetti and Enel Foundation on SolarPower Europe and European Commission data, 2023

In Italy, the current announced projects will lead to an **increase in domestic production in the module and cell stages**, while there **are no plans to intervene in the upstream stages of the value chain** (polysilicon, ingots, and wafers). Overall, the Italian announced projects will strengthen the position in the **downstream stage**, contributing to the development of a **European integrated PV value chain**, reducing significantly the dependence on third countries.

Figure 46 → **State of the art of the PV industry in Italy, based on current and expected annual manufacturing capacity, minimum targets to 2030* and minimum requirements to reach the "REPowerEU" targets, 2022 and 2030**
(absolute values in GW)



N.B. The expected annual production capacity is based on projects announcements until 2025. The Italian annual PV deployment is estimated based on Terna and Elettricità Futura data.

Source → Elaboration The European House – Ambrosetti and Enel Foundation on SolarPower Europe and Terna data, 2023.

In conclusion, the **European Union is expected to register, by 2030, a production capacity in line with the "Net Zero Industry Act" only in the polysilicon and module segments**. At the same time, it must be said that reaching 30 GW of domestic production capacity by 2030 expected by the "Net Zero Industry Act" would mean a significant leap forward **compared to the current situation**: as of today, Europe registers - depending on the PV value chain stage - a **gap of between 7 GW and 29 GW with respect to the NZIA**.

In Italy, although there is no binding target for domestic manufacturing production, it is worth pointing out that at all stages of the chain there is a gap with respect to the annual power to be installed of **7 GW**, which is necessary to reach the objectives set by the "REPowerEU". Although a production capacity of **3 GW for cells** and **4 GW for modules** is expected by 2030, no projects have been announced for polysilicon, ingot or wafer production at the moment.

2.3

Batteries: mapping, quantification and analysis of the value chain in Europe and Italy

Currently, the key **raw materials** required to make batteries are copper, cobalt, nickel, lithium, graphite, manganese and silica. These materials are then processed to produce the **components**, i.e., anode, cathode, electrolyte, and separator. Finally, the assembly of these components results in the **final output**, consisting of the cells and the battery pack.

Figure 47 → **The batteries value chain: key stages, products and processes**

Raw materials		Components		Assemblies	
Mineral extraction	Processed raw material	Graphitization, carbonization, electrolysis	**→Anode** (graphite, lithium, silicon)	Electrode manufacturing and cell fabrication	**→Battery cell/Pack**
Copper ore	**→Copper**				
Cobalt ore	**→Cobalt**	Filtration, calcination, deagglomeration	**→Cathode** (lithium, nickel sulphate, cobalt sulphate, copper, manganese sulphate)		
Nickel ore	**→Nickel**				
Lithium ore	**→Lithium**	Solvent preparation, salt manufacturing process	**→Electrolyte** (salt, solvent)		
Graphite ore	**→Graphite**				
Manganese ore	**→Manganese**	Melt extrusion, stretching, winding and slitting	**→Separator** (plastics, ceramics)		
Silica (SiO_2)	**→Silicon**				
Input of the components phase		**Input of the assemblies phase**		**Output of the batteries value chain**	

Source → Elaboration The European House - Ambrosetti and Enel Foundation on various sources, 2023.

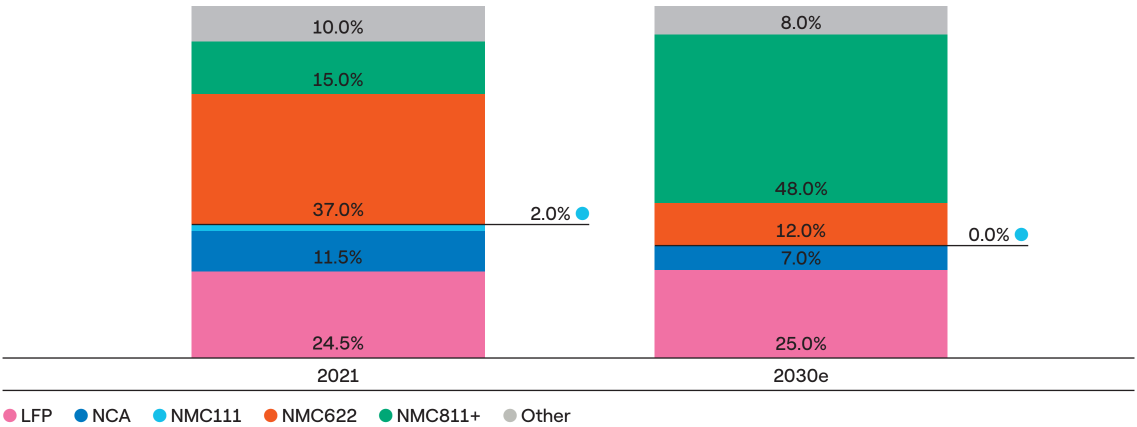
The relevance of batteries for the energy transition is expected to grow in the coming years: by 2030, globally, the capacity of installed batteries for electric vehicles will have to increase **7.7 times** (from 278 GWh in 2021 to 2,127 GWh in 2030), while that of batteries for energy storage[15] **9.3 times** (from 27 GWh in 2021 to 249 GWh in 2030)[16]. Batteries will be particularly crucial for the European Union, where, according to the "Fit for 55" scenario, 51 million electric vehicles will be circulating in Europe by 2030 (8.3 times more than the 6.1 million vehicles circulating in Europe in 2022). Also in Europe, the grid-scale energy storage market will have to increase its share of the total from 44% in 2021 to **61%** in 2030.

There are different types of batteries, each characterised by a **different raw material mix**, which influences their respective share of use in the various application sectors (mobility, energy storage, etc.)[17].

For example, in the mobility sector, as of 2021, NMC622[18] batteries have a **37%** market share, which is expected[19] to drop to 12% by 2030. The desire to reduce reliance on cobalt in battery manufacturing will lead to a growth in the market share of high-nickel batteries. Not surprisingly, therefore, the market share of NMC811+ batteries (including NMC955) is expected to rise from 15% in 2021 to **48%** in 2030. At the same time, LFP (Lithium-Iron-Phosphate) batteries are expected to maintain their market share at around 25% of the total.

15
Reference is made here to both grid-scale and behind-the-meter.
16
Considering that 89.5% (2,127 GWh out of 2,376 GWh) of the forecast battery capacity installed worldwide in 2030 is expected to be mobility-related, an in-depth analysis has been conducted on this sector.
17
It should be pointed out that the electrochemistry of lithium batteries is – precisely – based on lithium, even if the name of the latter material is not included in the battery nomenclature. In particular, NMC (Nickel-Manganese-Cobalt) and NCA (Nickel-Cobalt-Aluminium) batteries are named after the raw materials that make up the cathode.
18
The three numbers following the battery designation refer to the ratio of the different materials that make up the cathode. For example, in the case of the NMC622, 60% of the cathode is made up of nickel, while manganese and cobalt account for a share of 20% each.
19
Source: BloombergNEF, 2022.

Figure 48 → **Market share of different types of EV batteries worldwide, 2021-2030E**
(% values)



Source → Elaboration The European House - Ambrosetti and Enel Foundation on European Commission data, 2023.

As regards grid-scale and behind-the-meter applications, LFP batteries are the most widely used: **50%** in the case of grid-scale storage (this figure is expected to grow up to 72% by 2030) and **37%** for behind-the-meter (expected to grow up to 57% by 2030)[20].

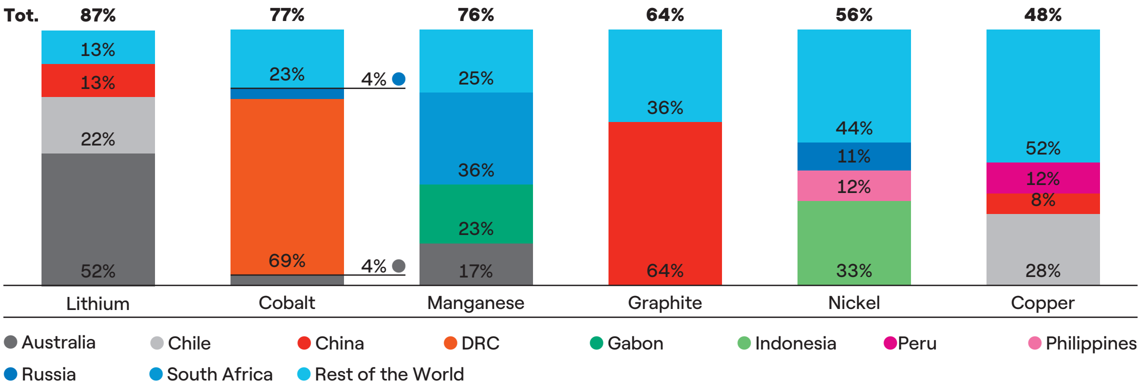
→ State of the art and bottlenecks in the battery value chain stages: raw materials

Access to raw materials is heavily influenced by extraction and refining geographical concentration. **Australia** dominates lithium extraction (52% of the total), while the **Democratic Republic of Congo** extracts 69% of the world's cobalt. For nickel, on the other hand, extraction appears more fragmented, with **Indonesia** mining 33% of the world's total[21].

20
Lithium batteries account for 93% of batteries used for storage and 70% of those used for behind-the-meter.

21
In terms of reserves of these raw materials, Chile holds 35.8% of those of lithium; the Democratic Republic of Congo 48.2% of those of cobalt; Indonesia and Australia each hold 21% of those of nickel.

Figure 49 → **Share of top producing countries in extraction of selected minerals, 2021** (% values)

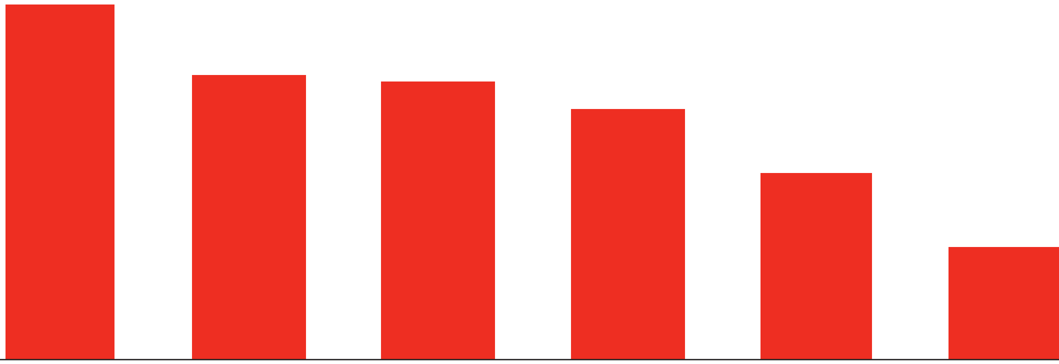


Source → Elaboration The European House – Ambrosetti and Enel Foundation on IEA and US Geological Survey data, 2023.

Despite having a primary role only in graphite mining (64%), **China** is undoubtedly the country where **most of the raw material refining and processing capacity is concentrated**: 95% for manganese, 72% for cobalt, 70% for graphite, 61% for lithium and 40% for copper. The only raw material where China does not play a dominant role is nickel[22], where it reports a refining capacity of 16%, lower than Russia (21%) and the European Union (18%).

22
Nickel sulphate C1, characterised by high purity (>99.8%), is considered.

Figure 50 → **Processing capacity of China for selected minerals, 2021 or latest available year** (% values on global capacity)



Manganese	Cobalt	Graphite	Lithium	Copper	Nickel
95%	**72%**	**70%**	**61%**	**40%**	**16%**

Source → Elaboration The European House - Ambrosetti and Enel Foundation on European Commission, IEA and US Department of Energy data, 2023.

China's dominance at this stage ties in well with the Chinese Foreign Direct Investments made over the past 15 years in those countries where the raw materials needed to make batteries are located. For example, in Australia, the main lithium-extracting country, China has invested **EUR 26.6 billion** between 2005 and 2021. In the Democratic Republic of Congo, the main cobalt extractor, China invested **EUR 13.7 billion** over the same period. Overall, in the past 15 years, China has invested **EUR 80.3 billion** in the main countries that extract raw materials to make batteries, about half of which in Australia and the Democratic Republic of Congo.

Considering their particular relevance and strategic importance for the battery supply chain, a focus on the extraction and refining stages of lithium, cobalt and nickel will be presented in the following paragraphs, in order to analyse the state of the art and possible criticalities with regard to each of these raw materials.

About **lithium**, the **European Union imports 81% of it as a raw material**, while the remainder is extracted in Portugal, which had a lithium production of 900 tonnes in 2021. However, despite the reserves in EU countries, several critical issues persist about the extraction of this material due to the high environmental impact of such processes. **Northern Portugal**, for example, is home to **Europe's largest lithium mine** (in the hands of the British company Savannah Resources), but extraction projects are continually delayed due to regulatory problems (e.g., obtaining extraction permits) and opposition from the local population regarding deforestation, air and noise pollution, and water contamination allegedly associated with extraction processes. Similarly, a **EUR 2.2 billion** lithium mining project in Serbia was suspended due to protests from the local population.

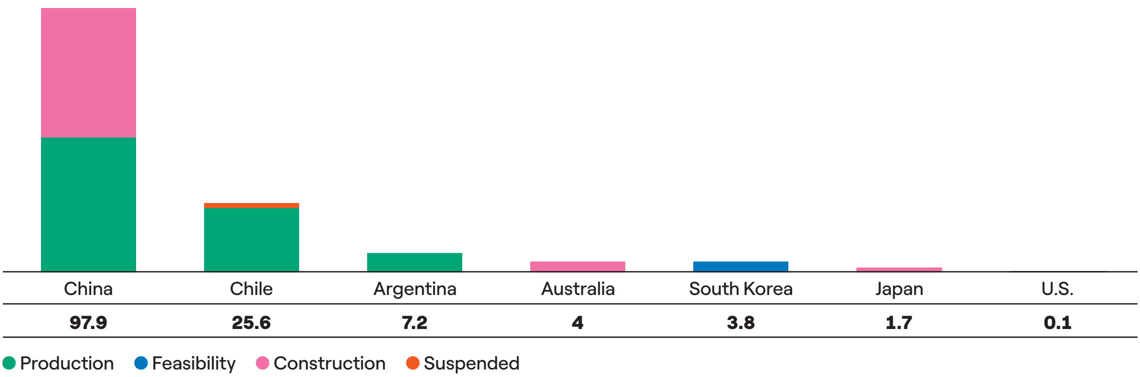
As regards the processing stage, according to a 2023 study on the critical raw materials for the EU realized by the **European Commission, the European Union imports 100% of refined lithium**. 79% **of processed lithium is imported from Chile**, 7% from Switzerland, 6% from Argentina, 5% from USA, 1% from China and the remaining 2% from other countries.

Also because of the difficulties related to the increased utilisation of its own mining capacity, the European Union is expected to play **a marginal role on lithium refining** in the coming years. Therefore, China – the world's 1st largest miner and 3rd largest refiner of lithium after Australia and Chile – is expected to maintain a dominant position in lithium refining in the coming years, **doubling its production capacity** to 97.9 thousand tonnes.

However, several companies in Australia are now seeking to move into refining, since going from ore to hydroxide allows them to take advantage of their high-quality reserves and make a higher value product. The partnership between Australian miners and experienced lithium conversion companies like Albemarle and Tianqi may help jump start this value chain.

Figure 51 →

Current and potential lithium refining nameplate capacity, 2021
(thousand metric tonnes lithium metal)



Source →

Elaboration The European House - Ambrosetti and Enel Foundation on BloombergNEF and IEA data, 2023.

China's predominant role is also linked to the fact that the chemistry selection in the battery market greatly impacts the production activities and prices across the two lithium chemicals (carbonates and hydroxides). Specifically, the synthesis of high-nickel cathode active materials such as NMC-811 and NCA requires lithium hydroxides, while lithium carbonates are mainly used in the processing of LFP and other low and middle nickel chemistries. The **increasing adoption of higher-nickel cathode chemistries**, particularly in passenger EV batteries, is pushing up demand for lithium hydroxide. Hydroxide does not travel well as it tends to absorb moisture. Compared to making carbonates, producing hydroxides thus requires **strong lithium chemical industry experience** and needs to be **close to battery-manufacturing centres**. This could represent a potential bottleneck both for EU and Italy, considering that currently **no refining capacity is available for lithium** within European countries and, as it will be reported in the section concerning the components' phase, 80% of current EU batteries manufacturing capacity is in the hands of Asian manufacturers.

About **cobalt**, on the other hand, the European Union reports a relatively better position than observed for lithium. In fact, the EU mines 2% of the world's cobalt, while there are an estimated 104 cobalt deposits in Europe (therefore not yet in production), mainly in Finland, Norway, and Sweden (79 estimated deposits, 76% of the total). However, despite the presence of actual mines and deposits, the EU still imports **81%** of its cobalt needs.

Concerning cobalt refining instead, the EU is **2nd in the world** (15%) for cobalt refining, with this capacity concentrated in Finland (10% of world total) and Belgium (5% of world total). Thus, European imports of refined cobalt only account for **9%** of total demand (compared to 81% for imports of cobalt as a raw material), with Finland and Belgium meeting, respectively, **62%** and **29%** of total European demand[23].

At the European level, however, a potential obstacle to increasing cobalt refining capacity could be the sourcing of a **reliable long-term supply of traceable raw material**. In fact, in DRC, **10-20%** of cobalt supply comes from Artisanal and Small-scale Mining (ASM), that is "informal" (and in some cases even illegal) extraction activities. This also raises concerns about human rights, health and safety protections, since here workers are typically paid only for what they produce and lack access to health care or compensation in the event of an accident. Also, surveys have found children present in about **30%** of the visited ASM sites in DRC.

To solve (at least partially) such concerns, the European Union is looking at **increasing traceability through digital "passports"** attached to individual batteries or metals. However, as of today, there are only few DRC mining operations which can claim to have **100% guaranteed traceable supply**, and several of these have already committed a substantial part their volume to long-term supply deals.

23
The rest is imported from the Democratic Republic of Congo (2%), China (2%), Norway (1%), the UK (1%), and other countries (3%).

Finally, even for **nickel**, despite having a low mining capacity (5% of world total), the EU ranks – again – **2nd** in the world in terms of refining (18%), higher than China (16%) and lower than Russia (21%). However, no expansion of refining capacity in Europe has been planned to date, whereas several Asian companies (such as CATL and Sumitomo Metal Mining) are investing in nickel refining through agreements with South-East Asian mining countries (such as Indonesia and the Philippines), with a view to shortening – as observed with Australia for lithium – the value chains and thus posing a possible threat to European competitiveness with regard to the supply of this material.

Finally, regarding the overall extraction capacity of raw materials in European countries, it is worth mentioning the problems related to the time required to obtain an extraction permit, which in Europe varies **between 15 and 17 years**, significantly longer than the 3 months required on average in China for the same activity[24].

With reference to Italy, on the other hand, an obstacle to the development of the country's mining capacity, particularly with reference to lithium in Lazio and cobalt in Piedmont, is represented by regulatory fragmentation, due to the fact that mining competences are devolved to the **Regions**, with the State instead retaining the power to set out guidelines on mining research, the collection and processing of mining data, and the determination of national mining policy guidelines. In fact, the transfer of competences to the Regions in the absence of a regulatory apparatus for guidance at the central level has generated a lack of homogeneity in the planning and control rules in information flows.

Finally, China's supremacy in raw material refining is matched by a significant **recycling capacity**. Approximately **81%** of the global lithium battery recycling capacity is concentrated in China, where more than **90%** of the expansion of this capacity in the coming years is also expected. China's dominance in recycling is due not only to its larger share of EVs, but also to **policies by the Chinese government regarding recycling**. China also has numerous policies promoting reuse.

As also reported regarding the PV value chain, the Chinese government has adopted a far-sighted vision concerning the recycling and second use of batteries. The recycling policies were **first implemented in 2015**, soon after subsidies were offered to develop the EV industry. More specifically, the first action was to explicit from a regulatory point of view the subject that – along the value chain – is responsible for recycling, also facilitating the establishment of a battery recycling and traceability system.

In 2018, recycling policies were released as the **National Guidance for NEV Battery Recycling**[25] the overall extraction capacity of raw materials in and included recycling industry standards and life-cycle management, with specifications

24
Source: Reuters, interview with Bernd Schaefer (Chief Executive of EU-funded EIT Raw Materials) "EU urged to speed up permits for critical mineral projects", 30 January 2023.

25
Source: Chinese Office of the State Council, 2020

that automakers and battery manufacturers are legally responsible for recycling EV batteries. Specifically, for automakers obligations were decided in terms of disclosing battery information and building battery recycling service outlets to collect and store scraped EV batteries, and hand over batteries to reliable battery-disposal enterprises; at the same time, battery manufacturers (in cooperation with automakers) were obliged to "code" batteries.

Other policies established a national battery coding and **tracking system**, as well as a **network of distributed and regional collection centres** for used batteries which must be built by automakers. Finally, on December 2019 recovery rates were fixed for nickel and cobalt (98% in both cases) and lithium (85%).

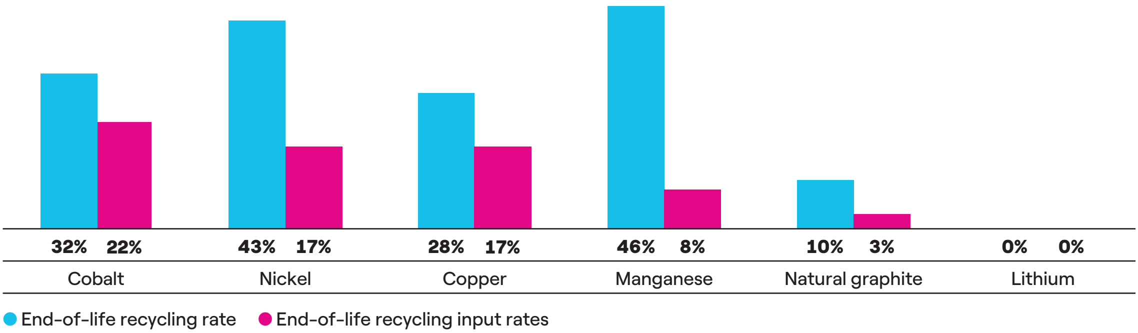
According to The European House – Ambrosetti and Enel Foundation estimates, as of today China's recycling rate of lithium batteries from EV cars could be around **60%**[26].

In Europe, on the other hand, as it will be further detailed in the next sections, the recycling of raw materials is still lagging behind, with the **end-of-life recycling rate**[27] that ranges from 32% in the case of cobalt to no capacity at all in the case of lithium.

26
This value has been calculated starting from the consideration that around 500 kg of batteries are present in each EV car. This value has been multiplied for the EV cars present in China as of 2022 (11 million according to IEA) in order to obtain the number of tonnes of batteries present in China as of today. However, as reported from Transport & Environment in the Report "A European response to IRA", until 2030 most of the batteries material to be recycled will come from scrap (about 7% of total batteries produced). Thus, the value previously computed has been multiplied for this share (the value of production scrap estimated by Transport & Environment). Finally, the recycling rate is represented by current recycling capacity of China (232,000 tonnes) divided by the value previously calculated.

27
It concerns the amount of (secondary) materials recovered at the end of life, compared to the amount of waste generated. The end-of-life input recycling rate concerns the amount of recycled materials used as input to the economy, compared to the total input.

Figure 52 → **End-of-life and end-of-life input recycling rate for raw materials of the battery chain in Europe, 2022** (% values)



N.B. The end-of-life recycling rate refers to the the amount of (secondary) materials recovered at the end of life, compared to the amount of waste generated. The end-of-life input recycling rate refers to the amount of recycled materials used as input to the economy, compared to the total input.

Source → Elaboration The European House – Ambrosetti and Enel Foundation on European Commission data, 2023.

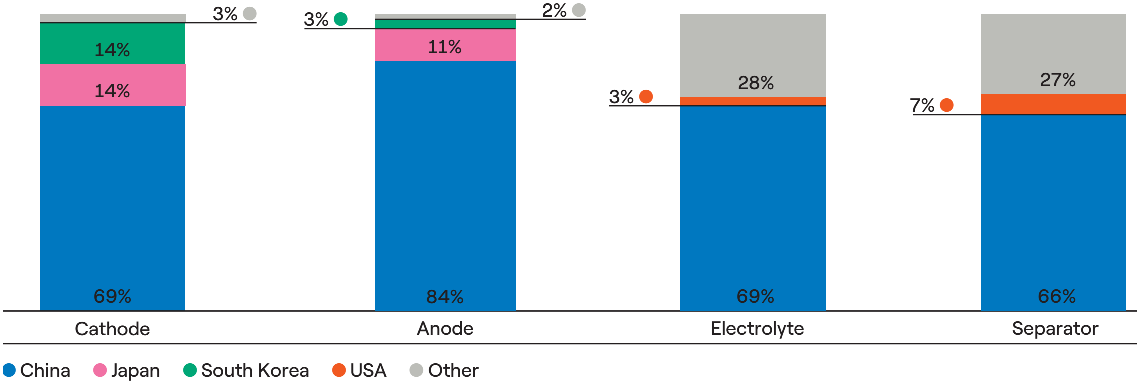
→ State of the art and bottlenecks in the battery value chain stages: the components

As reported for the raw materials stage, also the **component stage** shows China's predominance, with Japan and Korea also playing a relevant role. Overall, the components' stage likely represents the one in which the European Union and Italy report the worst competitive positioning across the batteries value chain.

In fact, Asian countries hold **between 66% and 98%** of the manufacturing capacity related to battery value chain components, with China reporting the highest production with reference to all components. The battery component stage is also concentrated with reference to companies:

- **7 companies** account for **55%** of global cathode production.
- **6 companies** (all Chinese) account for **66%** of global anode production.
- **1 Chinese company** (Jiangxi Tinci Central Advanced Materials) alone produces **35%** of electrolyte salt.
- **5 companies** account for **50%** of global separator production.

Figure 53 → **Manufacturing capacity of key lithium-ion battery components, 2021** (% values)



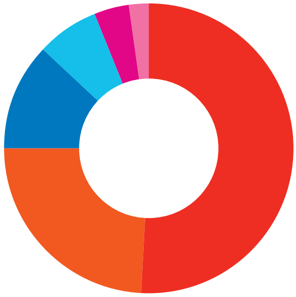
Source → Elaboration The European House - Ambrosetti and Enel Foundation on European Commission and IEA data, 2023.

The Asian advantage at the component stage is mainly due to the presence in these countries of a battery industry for devices such as smartphones and computers, which has allowed them to exploit and benefit from important **economies of scale**. In addition, the major Asian manufacturers are planning to increase their component production capacity in their home countries, where demand is currently higher and where cell and battery pack production is more concentrated, as illustrated in the next section.

Focusing on the individual components, the **cathode** is certainly the most critical element, both because its composition in terms of raw materials influences battery performance and because it is responsible for **more than half (51%) of the total cost of battery components**, followed by manufacturing (24%) and anode (12%).

Figure 54 →

Cost per EV battery cell component, 2021 (% values)



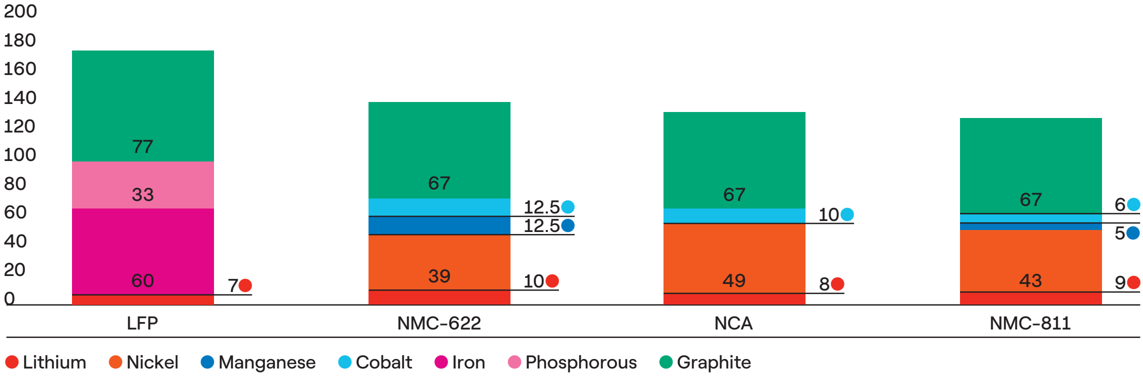
Source → Elaboration The European House - Ambrosetti and Enel Foundation on Bloomberg NEF data, 2023.

The high relevance of cathodes when looking at the cost of batteries is due to the fact that they are mainly made up of raw materials (lithium, cobalt, nickel, and manganese), and these are extremely volatile: at the end of 2022, the prices of such raw materials were USD 78,000 per tonne for lithium carbonate, USD 47,000 for refined cobalt, USD 27,000 for nickel, and USD 2,000 for manganese. At the same time, between December 2021 and December 2022, the price of lithium increased by **+128.8%**, the price of cobalt decreased by **-25.7%**, the price of nickel increased by **+44.8%**, and the price of manganese decreased by **-68.8%**[28].

As mentioned above, therefore, in addition to geopolitical instability, it is also the high cost that explains the desire to **reduce the use of cobalt in battery production by shifting towards higher nickel and manganese mixes**. For example, while 12.5 kg of cobalt is used in an NMC622 battery, this value drops to 6 kg for NMC811 batteries; at the same time, with reference to nickel, 39 kg are used in the former and up to 49 kg in the latter[29]. Looking at the different battery capacities, the NCA battery (that has the highest value of nickel) has the **highest specific energy range** (200–250 Wh/kg) in the current class of technologies as well as **high specific power**, combined with a lifetime of 1,000 to 1,500 full cycles. In contrast, NMC batteries can have longer cycle life (1,000-2,000 cycles) compared to NCA, but a lower energy density (140–200 Wh/kg).

28
Data expressed in USD per metric tonne.
29
Source: IEA, "*The Role of Critical Minerals in Clean Energy Transitions*", March 2022.

Figure 55 → **Raw materials for the production of lithium-ion batteries by battery type, 2022** (absolute values in kg per battery)



Source → Elaboration The European House - Ambrosetti and Enel Foundation on IEA data, 2023.

Anodes instead consist mainly of **graphite**, which is mined and refined primarily in China (64% and 70% of global capacity, respectively). Natural graphite can be used in EV batteries but is primarily employed in consumer batteries, whereas **artificial graphite** is increasingly popular for use in EV batteries since it enhances the rate capability and active capacity. Because artificial graphite processing is expensive, (the graphitising process accounts for about **50%** of the costs of refining artificial graphite), battery manufacturers are increasingly bringing it in-house, attempting to use in-house production to **ensure a stable and cost-competitive supply**.

The market for **separators** is characterised by high barriers to entry due to the high specialisation required for their production[30] and the tendency of manufacturers to operate near their customers, i.e., battery manufacturers. Finally, **electrolyte producers** tend, on the one hand, to internalise production capacity for salts and, on the other hand, to purchase solvents on the market, which are easily available in the petrochemical industry. Here, processes to shorten value chains are underway: given the liquid state of the electrolyte solution and the relative difficulties in transporting it, manufacturers prefer to set up electrolyte plants as close as possible to their battery-producing customers.

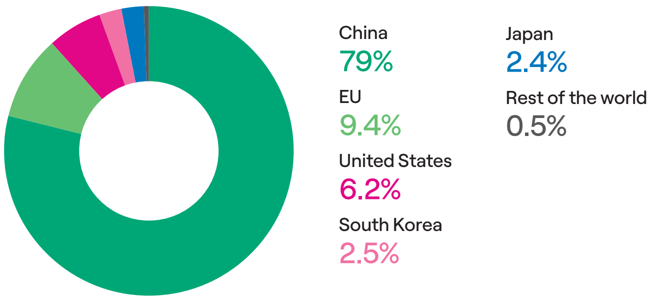
30
Source: Bloomberg NEF, Energy Storage Trade and Manufacturing, February 2021.

State of the art and bottlenecks in the battery value chain stages: assembly

Also in the assembly stage, **China** has the lion's share of the market, accounting for **79%** of the global capacity in 2021. European countries report a share of **9.4%**, which is associated with a production capacity of **66 GWh**[31].

Figure 56 →

Share of the lithium-ion battery production capacity worldwide by Country, 2021 (% values, GWh)



N.B. "Rest of the world" includes United Kingdom (0.3%), Australia (0.1%) and Thailand (0.1%).

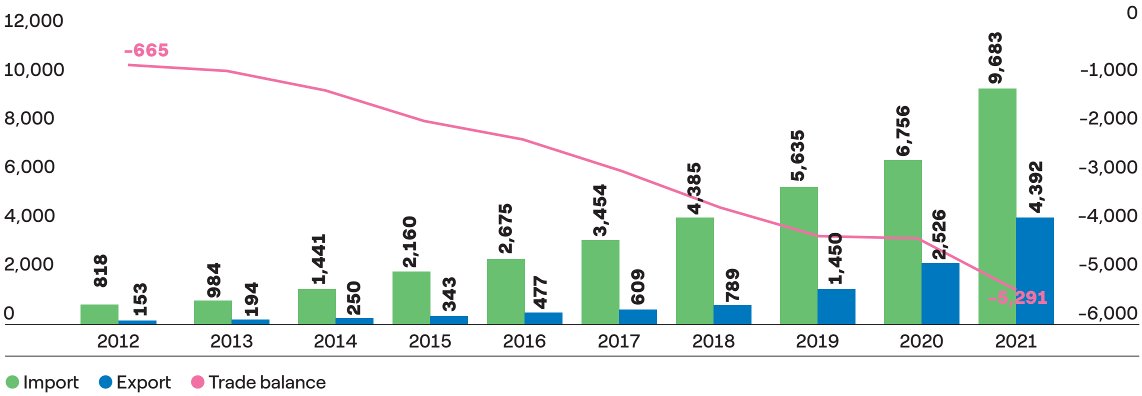
Source → Elaboration The European House - Ambrosetti and Enel Foundation on European Commission, S&P Global Market Intelligence data, 2023.

All the world's top ten battery manufacturers are Asian, with the exception of Svolt Energy, which is based in Germany but is still a subsidiary of a Chinese company. Asian manufacturers have a market share of **91.9%** of global production. In Europe, this figure is slightly lower at **78.5%**.

As a result, the European **trade deficit** for batteries is steadily increasing: whereas it amounted to EUR 665 million in 2012, this value has steadily increased up to **EUR 5.3 billion** in 2021 (almost 8x).

31
2021 is the last year available for a global comparison. In 2022, as will be shown later, European production was 75 GWh.

Figure 57 → **EU import, export and trade balance of batteries, 2012-2021** (EUR million)



Source → Elaboration The European House - Ambrosetti and Enel Foundation on Comext data, 2023.

The main importer of batteries in Europe is Germany, which is also the number one **importer of batteries at the global level**. Also, Germany is the **number two exporter of batteries** at EU level. In both import and export, Germany relies on a 50%-50% balance between EU and non-EU countries: 50% of import and export comes from and is directed towards EU countries whereas the other 50% concerns non-EU countries.

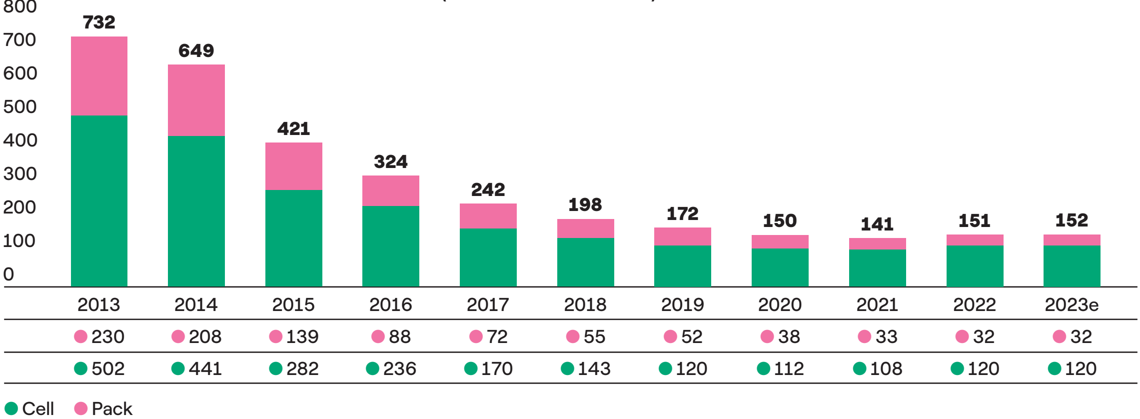
The largest EU exporter is **Poland**, supplying mainly the internal EU market: **88%** of Polish export is, in fact, within the EU. Poland is also the second largest battery exporter at the global level, after China. Finally, after Poland and Germany, Hungary is the third largest exporter of batteries in the EU.

As regards market destinations, most of EU-produced batteries exported outside EU reach the **United States**, followed by Mexico, China and the UK. On the other hand, the largest supplier of batteries to the EU is **China**, followed by South Korea and US.

Given the above, it is not surprising that in the EU in the period 2019-2021 only Poland and Hungary recorded a **positive trade balance**. In particular, the fast development of the positive trade balance in Poland and Hungary is the result of investments of **Korean subsidiaries**, which is LG Chem in Poland and SK Innovation and Samsung SDI in Hungary, which started production in 2017-2019 and are still scaling up.

In addition to the high concentration of the market in the hands of Asian manufacturers, another factor to monitor is the **production costs of batteries**, which, after a decreasing trend over the last decade, from USD 732 per kWh in 2013 to USD 141 per kWh in 2021, observed a slight increase to USD 151 per kWh in 2022 (due to rising raw materials and component prices).

Figure 58 → **Volume-weighted average lithium-ion battery pack and cell price split, 2013-2023E** (real 2022 USD/kWh)



Source → Elaboration The European House - Ambrosetti and Enel Foundation on Bloomberg NEF data, 2023.

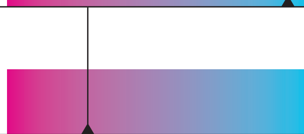
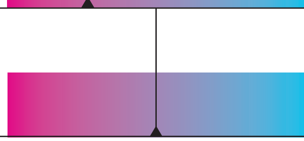
In 2023, this price is expected to remain stable (a price of USD 152 per kWh is estimated), while it is expected to decrease again from 2024 onwards and then fall **below USD 100 per kWh from 2026** onwards[32]. Reaching this threshold is particularly critical, as it is believed that at this value, automakers can sell electric vehicles at the same price (and with the same margins) as vehicles with internal combustion engines. However, to date, the cost of producing a battery in Europe is USD 169 per kWh, **33%** higher than in China (USD 127 per kWh).

This is mainly due to two factors: firstly, the diversification of battery production in China, which not only refers to mobility applications but also to other applications such as smartphones and laptops; secondly, the incentives made available by the Government lead the CAPEX for setting up a new gigafactory in China to be lower than in the United States and the EU. In China, it amounts to EUR 68 million per GWh and in the United States to EUR 94 million per GWh due to higher inflation and interest rates. Finally, in Europe, according to the "Net Zero Industry Act", CAPEX is around **EUR 100 million per GWh** (including buildings and machinery to produce the cells) and can go up to **EUR 150 million per GWh** considering also investments for the production of cathodes and anodes.

It should be remembered, in conclusion, how **gigafactories can take up to five years** to be built and become fully operational in Europe. This shows how dependence on Asian countries (primarily China) represents a potential obstacle to the transition to electric vehicles in the short term and a critical factor in terms of industrial and geopolitical competitiveness in the medium to long term.

32
Source: Bloomberg NEF, "BNEF's 2022 Battery Price Survey", 2022.

Figure 59 → **The main bottlenecks at European and Italian level along the battery supply chain**

Bottleneck	Bottleneck severity	Reasoning
	Low High	
Limited access to raw materials: import dependency and strong regulation constraints for mining		→ **100%** of lithium and **81%** of cobalt is imported in EU → **15-17 years** to get a permit for mining is in EU vs. **3 months in China** → In Italy competence for mining titles is in the hands of the **Regions**, generating a **lack of homogeneity**
Lack of recycling capacity		→ China holds **81%** of current global capacity for EV and stationary storage batteries → Europe has **low recycling rates** for batteries' raw materials (e.g., **0%** for lithium, **32%** for cobalt and **43%** for nickel)
Current limited production capacity to be scaled up		→ **Limited production capacity of EU and Italy** (**80**% of EU batteries production capacity in the hands of Asian manufacturers) → Gigafactories need about **5 years to build and fully ramp up in EU**
High costs for batteries manufacturing		→ The **manufacturing cost of batteries** in EU is **33%** higher than in China, with the CAPEX for setting up a new gigafactory that is **47%** higher

Source → Elaboration The European House - Ambrosetti and Enel Foundation on various sources, 2023.

→ The main opportunities and risks to be addressed for the development of the battery value chain in Europe and Italy

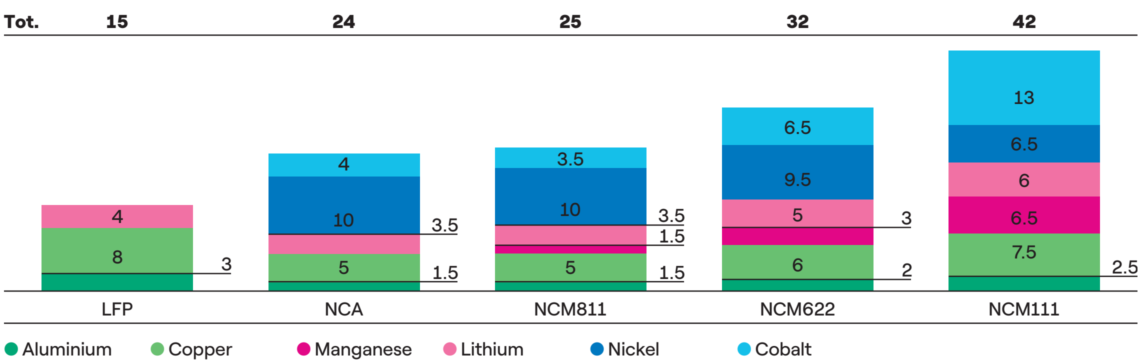
Following the analysis of the state of the art and bottlenecks of the batteries value chain, in this section we will provide an overview of the main opportunities and risks to overcome and face these bottlenecks and promote the development of the batteries value chain in Europe and Italy.

First, it should be noted that in 2017, aware of the dependency and bottlenecks in this value chain, the European Union founded the **European Battery Alliance** (EBA). In particular, the EBA set two main objectives: *i)* to create the conditions to produce, sell and export – by 2030 – a quantity of batteries equivalent to **one third of global demand**; *ii)* to enable – by 2030 – the EU able to cover **at least 90%** of its battery demand.

Following the creation of the EBA, two IPCEIs were promoted[33] in December 2019 and January 2021, respectively, to increase production and boost innovation in the batteries value chain. The first has a budget of **EUR 3.2 billion**, covers 7 countries[34] and is expected to generate EUR 5 billion in additional private investment by 2031. The second has a budget of **EUR 2.9 billion,** covers 12 countries[35] and is expected to generate **EUR 9 billion** in additional private investment by 2028. In both cases, **Italy** is among the countries involved and is estimated to receive about EUR 1 billion (of the total EUR 6.1 billion directly invested), as well as the resources of the PNNR, which has allocated EUR 1 billion to support, *inter alia*, the Italian storage industry and create a capacity of 11 **GWh**. In summary, therefore, significant resources have already been mobilised at EU level to promote the development of this supply chain (about EUR 100 billion), with the forecast to reach **EUR 600 billion** by 2030.

One development opportunity for Europe regarding the battery value chain is **recycling**, through which it is estimated that a value of between USD 15 per kWh can be extracted from LFP (lithium-iron-phosphate) batteries and up to USD 42 per kWh from NCM111 batteries (due to the higher cobalt content). Besides the obvious environmental benefits, the opportunity is made even more important considering the criticality of the access to raw materials in EU, making secondary raw material and essential resource to reduce dependency.

Figure 60 → **Value of recycled batteries by cathode chemistry, 2020** (USD per kilowatt hour)



Source → Elaboration The European House - Ambrosetti and Enel Foundation on various sources, 2023.

33
Important Projects of Common European Interest.
34
Belgium, Finland, France, Germany, Italy, Poland, and Sweden.
35
Austria, Belgium, Croatia, Finland, France, Germany, Greece, Italy, Poland, Slovakia, Spain and Sweden.

At the European level, several projects for recycling plants have already been developed: in **Germany**, for example, Primobius and Volkswagen have recently opened recycling plants with a capacity of 3,650 tonnes and 1,200 tonnes per year, respectively. In **France**, SNAM[36] has planned to expand its recycling capacity to 32,000 tonnes per year. Finally, in **Italy**, Enel-X (in partnership with Midac, an Italian company specialising in battery production) has recently started R&D activities to set up a lithium battery recycling plant. Further projects have been developed in Finland, Sweden and Hungary.

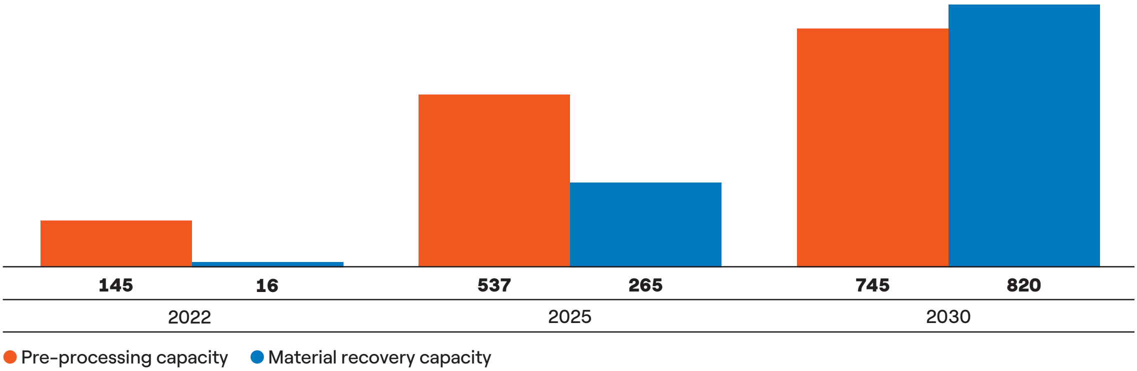
However, according to a recent analysis by Transport & Environment[37], Europe currently reports a **material recovery capacity** of only **16,600 tonnes**, whereas the **pre-processing capacity** goes up to 145,000 tonnes. These two stages of the recycling process require distinct capabilities and equipment, and for this reason they are usually addressed by different companies. Italy reports a context in line with the European one: currently there are no hydrometallurgy plants in the country to extract critical raw materials from dismissed technologies, meaning that it is possible only to pre-process them without actually recovering them[38].

In fact, the issue is that pre-processing consists only in collecting, discharging, and shredding the battery, implying that no material recovery takes place in this phase. If this capacity mismatch persists, valuable materials resulting from pre-processing, known as black mass, could leave Europe for further refining and cathode production in Asia. In 2022, it is estimated[39] that battery scrap available in the EU was equal to 92,700 tonnes, meaning that about 76,000 tonnes[40] of battery scrap was sent to other countries (primarily China for recycling). In this context, **integrating the recycling value chain remains essential to secure feedstock** and, eventually, to close the loop.

All in all, the current projects (announced or in the pipeline), according to Transport & Environment, could bring Europe to have a recycling capacity of more than **800,000 tonnes by 2030**, covering only **6%** of the lithium demand, **7%** of the nickel demand and **10%** of the cobalt demand[41] needed to meet the EBA's 2030 annual demand of 1,000 GWh by 2030.

36
The Snam Group holding company is a subsidiary of the Belgian group Floridienne.
37
Transport & Environment, "*A European response to US IRA*", January 2023.
38
For further details see The European House - Ambrosetti and Iren, "*Critical Raw Materials and Italian industrial production: the opportunities deriving from circular economy*".
39
Source: Bloomberg, Circular Energy Storage.
40
The value is calculated as the difference between 92,700 tonnes of battery scrap and 16,600 tonnes of material recovery capacity in the EU.
41
Source: Transport & Environment, "*A European response to US IRA*", January 2023.

Figure 61 → **Recycling capacities by processing stage in Europe, 2022-2030**
(thousand tonnes of battery cells)



Source → Elaboration The European House - Ambrosetti and Enel Foundation on Transport & Environment, 2023.

Moreover, as regards recycling, the proposed European Regulation 5469/23 of January 2023 set **minimum** (and increasing over time) **recycled content levels** for industrial batteries and batteries in electric vehicles. In parallel, specific rules were introduced in relation to **recycling efficiency**[42] and **material recovery targets**. Further obligations have been introduced about the declaration of the ecological footprint and the consequent labelling, as well as product characteristic knowledge duties for every economic operator placing batteries on the market. Specific provisions have been further stipulated for the collection of waste batteries.

42
Recycling efficiency is defined by the ratio of the mass of the output fractions that contribute to recycling to the mass of the input fraction of waste batteries that are reused.

The European recycling targets recently introduced to increase the circularity of the value chain

In January 2023, the proposed regulation 5469/23 introduced several recycled content requirements for batteries. It was stipulated that, starting **96 months** after the entry into force of the regulation, industrial batteries with a capacity of more than 2 kWh, batteries for electric vehicles and SLI (Starting, Lighting, and Ignition; it refers to lead-acid and rechargeable type of batteries mainly used in automobiles) batteries containing cobalt, lead, lithium or nickel among the active materials, will have to contain recycled material in the following percentages: **16%** cobalt; **6%** lithium; **6%** nickel. After **156 months** from the entry into force of the regulation, the recycled content will have to increase to **26%** in the case of cobalt, **12%** for lithium and **15%** for nickel.

Further specific targets have been set by the European Union for **recycling efficiency and material recovery**. In particular, the recycling efficiency for lithium batteries must be at least **65%** by the end of 2025 and **70%** by the end of 2030. Moreover, by 2027, **90%** of cobalt, copper and nickel will have to be reused, while for lithium the quota has been set at **50%**. Finally, by 2031, the percentage of recycled material must increase further: to **95%** in the case of cobalt, copper and nickel and **80%** in the case of lithium.

Finally, in December 2022, the European Parliament and the Council of the European Union reached an agreement on the introduction of **specific disclosure requirements**. Among other things, a "due diligence" policy was established for economic operators placing batteries on the European market, consisting in the assessment of environmental and social risks related to the sourcing, refining and trade of raw materials and recycled materials.

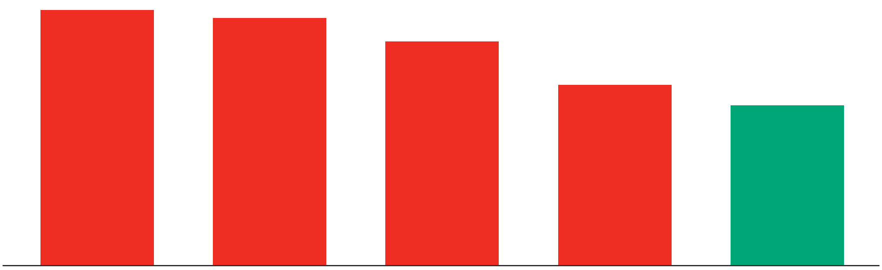
Source → Elaboration The European House - Ambrosetti and Enel Foundation on various sources, 2023.

In addition, Europe features better environmental **sustainability** in the batteries production process mainly **due to the lower GHG intensity of energy used**. Therefore, Europe reports 33% lower emissions compared to China, 31% compared to Japan and 25% compared to South Korea.

Figure 62 →

→ Production in the US and Europe tends to have the lowest GHG emissions, mainly **due to the lower GHG intensity of their electrical grids**

Emission intensity of battery production, 2020 (kg CO_2 per kWh)



China	Japan	Korea	US	Europe
100	**97**	**89**	**74**	**67**

Source → Elaboration The European House - Ambrosetti and Enel Foundation on "*Globally regional life cycle analysis of automotive lithium-ion nickel manganese cobalt batteries*", 2023.

Europe could also exploit the opportunities arising from **R&D investments**, particularly in **sodium battery** technology. The latter is a more than viable alternative to lithium batteries, as they do not require any critical raw materials, thus implying lower supply costs and risks. Also, they are safer and easier to transport, lowering transport costs. In addition, the possible future gains in **battery efficiency**, which may allow the same power to be delivered with smaller cells and packs, can be included among the opportunities arising from greater investment in R&D.

Potentially, sodium batteries could completely replace lithium batteries in the long run. If, in fact, one criticism to this technology was that it is characterised by a low energy density that makes it unsuitable for application in the mobility segment, recent developments are proving the opposite: in February 2023, **the first 100% electric vehicle powered by sodium batteries** was presented in China, the result of a joint venture between Volkswagen and the Chinese company JAC (Anhui Jianghuai Automobile Group Corp. Ltd.). The battery installed in the vehicle has an energy density of 120 Wh/kg, only slightly lower than the first LFP (Lithium Iron Phosphate) battery-powered Tesla launched in 2020 (125 Wh/kg).

However, for the time being, the relevance of sodium batteries is expected to experience limited growth in the coming years globally with regard to both grid-scale (**3%** of capacity in 2030 from 0% in 2021) and behind-the-meter applications (**8%** of capacity in 2030 from 0% in 2021). This could also be a consequence of the limited investments in this chemistry, which during the period 2014-2021 received only **EUR 10.2 million** in EU public funding out of the total **EUR 405 million** invested in the other battery chemistries[43].

This proves how the development of Na-ion batteries **has not been a priority for the EU** until now even though it relies neither on critical nor on expensive materials whereas **China is aiming to build its whole sodium-ion batteries supply chain by 2024**.

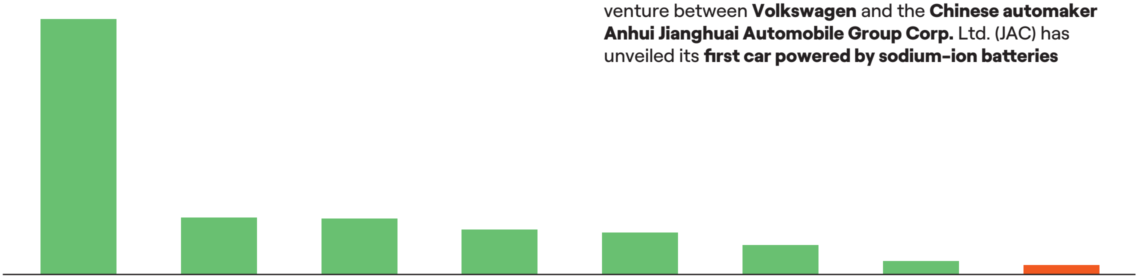
43
Projects focus on more than one chemistry/application and thus the sum of the funding of the single technology/application does not round up to the total in the graph below.

Figure 63 → **EU public funding of battery R&D, 2014-2021** (EUR million)

→ Total invested (projects focus on more than one chemistry/application and thus the sum of the funding of the single technology/application does not round up to the total): **EUR 405 million**

→ Development of Na-ion batteries **has not been a priority for the EU** until now despite the fact that it is neither relying on critical nor on expensive materials whereas **China is aiming to build its whole sodium-ion batteries supply chain by 2024**

→ At the end of February an electric vehicle (EV) brand of a joint venture between **Volkswagen** and the **Chinese automaker Anhui Jianghuai Automobile Group Corp.** Ltd. (JAC) has unveiled its **first car powered by sodium-ion batteries**



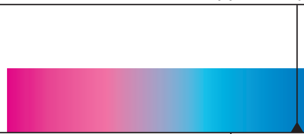
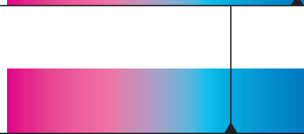
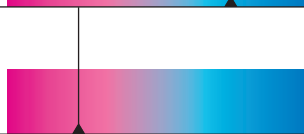
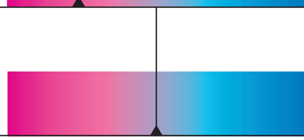
Li-ion	Li-ion with Si rich anode	Li-ion with metallic anode	Redox-flow	Solid state battery	Lithium-sulfur	Lead-acid	Na-ion
295.2	**65.1**	**64.3**	**51.4**	**47.6**	**33.3**	**15.2**	**10.2**

Source → Elaboration The European House - Ambrosetti and Enel Foundation on European Commission data, 2023.

A quick-win solution about R&D in the battery supply chain could be to promote more investment in **LFP batteries**, which – among lithium batteries – are the least dependent on raw materials and, therefore, in addition to cost advantages (around **30%** less per kWh than NMC batteries in 2021) also allow less exposure to geopolitical risks. In fact, the European Commission forecasts that – by 2030 compared to 2021 – the weight of LFP chemistry on overall lithium battery capacity will increase both concerning **grid-scale** (from 50% to 72%) and **behind-the-meter** applications (from 37% to 57%).

Finally, according to what previously reported, it is possible to underline that availability of funds represents a huge opportunity for EU and Italy, whereas sustainability and R&D can be leveraged, and recycling capacity still requires significant efforts to become a real opportunity for EU and Italy.

Figure 64 → **A summary view of the main opportunities and risks for the development of the battery industrial chain in Europe and Italy**

Risk/Opportunity	Risk/Opportunity severity	Reasoning
	Risk Opportunity	
Effective use of available funds		→ In EU and Italy, **funds are already available, but need to be effectively channeled** to expand and scale-up batteries manufacturing capacity, coordinating and integrating current capabilities across the EU
Environmental and social sustainability		→ **The manufacturing of batteries in Europe is more environmentally and socially sustainable** vs. China, even if the latter might **quickly catch up**
Development of recycling capacity		→ By 2030, recycling capacity is expected to increase by **x50** but will cover only **6%** of lithium demand, **7%** of nickel and **10%** of cobalt: further development of recycling capacity requires **higher investments and targeted R&D**
Research and Development		→ High opportunities related to **disruptive technologies** (e.g, Na-ion batteries) but **limited funds and coordination** across EU Institutions and Member States

Source → Elaboration The European House - Ambrosetti and Enel Foundation on various sources, 2023.

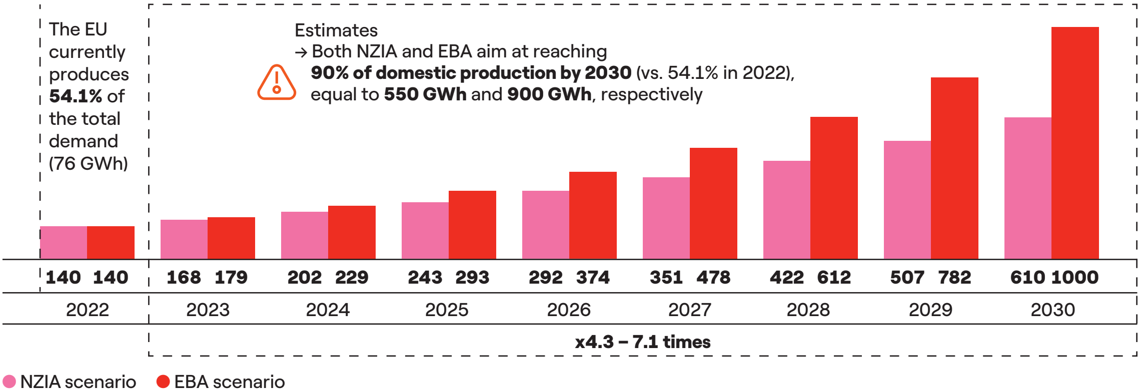
→ Evolution of expected demand, gap analysis and announcements for battery projects in Europe and Italy

With reference to the expected demand for batteries in 2030, the **European Battery Alliance estimates that demand for lithium batteries will reach 1,000 GWh in Europe by 2030**, while the NZIA estimates a demand of 610 GWh[44]. Based on these two scenarios, demand for Italy is estimated at 73 GWh (NZIA scenario) and 120 GWh (EBA scenario)[45].

44
Within the NZIA, the European Commission reports that the expected demand for lithium batteries in 2030 is the subject of several estimates, some of them very different. In particular, within its Market Analysis Report Q4 2021, VDI/VDE Innovation and Technik GmbH report how the expected demand in 2030 may vary between 362 GWh/year and 754 GWh/year; BNEF, on the other hand, reports an expected annual demand of 744 GWh in its dataset "*Localising clean energy supply chain comes at a cost*". Finally, in its "*European Battery Alliance Discussion Paper for the 7th High-Level Meeting of the European Battery Alliance*" the European Battery Alliance estimates an expected demand of 1,000 GWh/year.

45
As mentioned earlier, reference is made here to lithium batteries used in the 'mobility' segment.

Figure 65 → **Expected evolution of the demand for Li-on batteries in the European Union, 2022-2030E** (GWh)



Source → Elaboration The European House - Ambrosetti and Enel Foundation on European Commission data, 2023.

Taking these values to 2022, current demand in Europe is 140 GWh while in Italy it is estimated at 8.1 GWh. In summary, therefore, the gap to be bridged – by 2030 – is for Europe between 470 GWh (NZIA scenario) and 860 GWh (EBA scenario), while for Italy it is between 69 GWh (NZIA scenario) and 102 GWh (EBA scenario). Currently, however, Europe only produces **54.1%** of its demand internally (75.8 GWh), while Italy **41.1%** (3.3 GWh).

To date, several projects are underway in Europe covering all stages of the battery supply chain, with the primary goal of reducing dependence on foreign supplies (primarily from China and Asia). Regarding raw materials, many projects concern the **extraction and refining of lithium**, which could lead Europe to have a capacity by 2030 of 94 thousand tonnes, **74%** of which would be needed to meet demand by 2030 (126 thousand tonnes). Adding to this the recycling capacity that Europe could have by 2030 (around 8,000 tonnes), if all projects were to be implemented in time, the EU could be able to meet up to 81% of its needs.

Specifically, four of the projects will use the **Direct Lithium Extraction** (DLE) process, the **most environmentally friendly technology** for lithium production today, led by Vulcan Energy Resources (Germany), Eramet (France), Lithium de France (France) and Northern Lithium (UK). In fact, Europe could benefit from the application of lithium extraction processes that are more sustainable than traditional ones, such as those using **geothermal energy**. This method, besides being more sustainable and saving water and soil, is estimated to be 50% cheaper than conventional techniques. This process could be applied in the Rheingraben region on the German-French border, in the Pannonian Plain in Hungary and in Lazio in Italy.

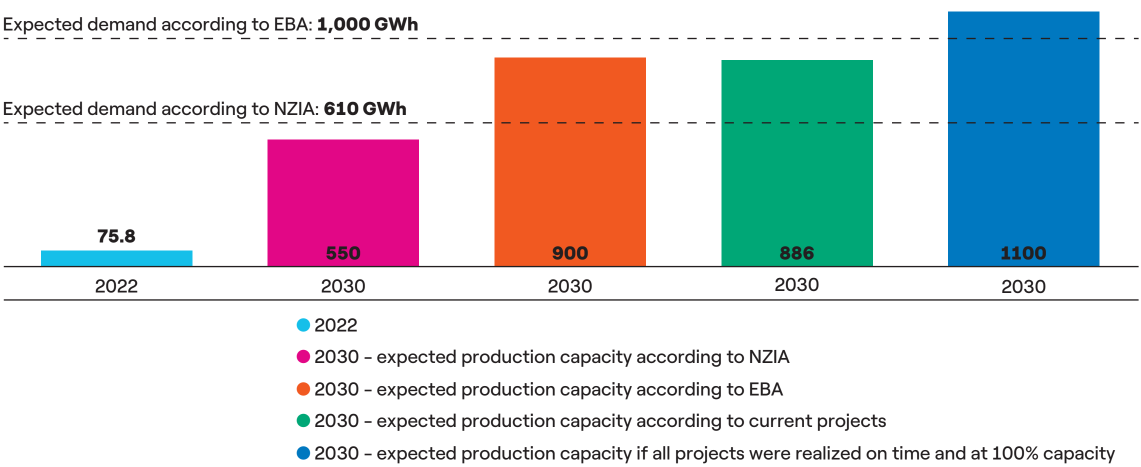
With reference to Italy, along with those in Lazio, further lithium deposits are estimated to be present in Calabria and Sardinia. In addition, permits were recently renewed for the exploration of cobalt, nickel, copper, and silver deposits in Piedmont: here, EUR 2.5 million have already been invested to date.

Other projects at European level concern the extraction of graphite (in Sweden) and manganese (in the Czech Republic), the refining of cobalt (in Finland) and the production of anodes (in Sweden).

Also, with regard to **components**, several projects are underway in Europe. In Finland, for example, three plants to produce active cathode material with a capacity of 100 thousand tonnes per year have been in operation since 2022. Also in Finland, production of cathode materials with a capacity of up to 100 thousand tonnes per year will start in 2024. Other important projects, also concerning cathode production, are planned in Germany, Poland, Sweden, and Hungary.

Finally, with reference to the assembly stage, **around 50 projects** are already operational/under construction, planned or announced. The full realisation of these gigafactories would allow Europe to reach a capacity of **1,100 GWh** by 2030, a 14.5-fold increase from 75.8 GWh in 2022. However, considering a 5-year ramp-up necessary until the gigafactory reaches full capacity, the European Commission estimates that 'only' **886 GWh** (**89%** of expected demand) will be ready by 2030, a gap of 114 GWh compared to the expected demand of 1,000 GWh estimated by the EBA.

Figure 66 → **Current and expected production capacity of Li-on batteries in the European Union, 2022-2030E** (GWh)

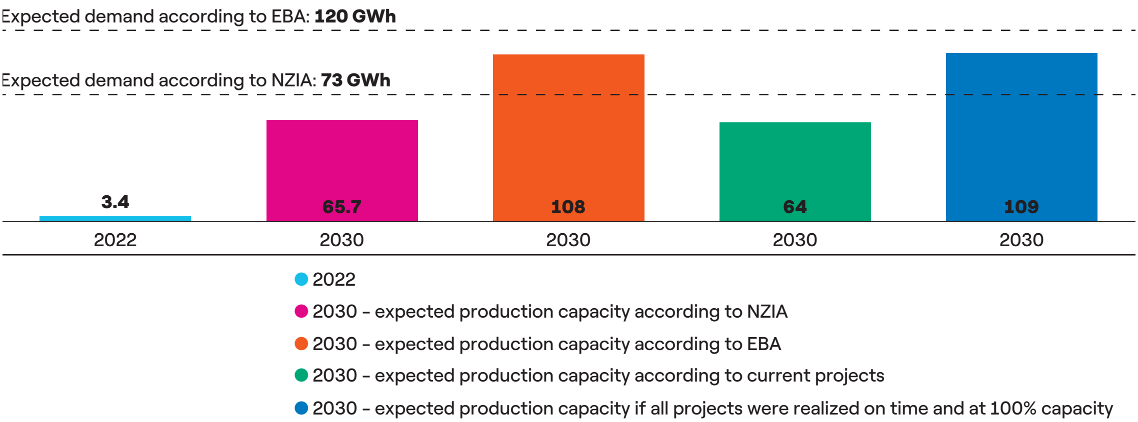


N.B. NZIA: “Net Zero Industry Act”. EBA: European Battery Alliance.

Source → Elaboration The European House - Ambrosetti and Enel Foundation on European Commission data, 2023.

Regarding Italy, **four investments** are currently planned: Italvolt (45 GWh), ACC Italy (40 GWh), FAAM/FIB (8 GWh), and Fincantieri (2 GWh). The complete implementation of these projects would make it possible to reach 109 GWh in production capacity by 2030, which is in line with the expected production capacity according to EBA. Uncertainty around the construction of the Italvolt gigafactory, however, may reduce the production capacity to 64 GW by the end of the decade.

Figure 67 → **Evolution of lithium-ion battery manufacturing capacity in Italy, 2021-2030E** (GWh)



Source → Elaboration The European House – Ambrosetti and Enel Foundation on European Commission data, 2023.

However, while both the EU and Italy seem to be relatively on track to reaching their 2030 targets according to the EBA scenario (estimates indicate a gap of 11% by 2030 for the EU and 8.5% for Italy), today the US IRA could represent a critical issue to be considered in the realisation of an Italian and European battery supply chain.

In fact, **68%** of European projects are considered to be at **"medium" or "high" risk of not being realised**[46], with highly strategic players such as Volkswagen and Northvolt considering redirecting their investments from Europe to the United States due to higher incentives. Critical issues in this sense are also emerging for Italy, where Italvolt (whose investment represents 41% of the total capacity planned in the country for 2030) is encountering problems in the construction of its gigafactory, both in terms of financing (EUR 3.4 billion in CAPEX is estimated) and the electricity grid needed to support production.

46
Source: Transport & Environment, "*Europe investments at risk: how not to lose it all: two-thirds of Europe's battery gigafactories at risk without further action*", March 2023.

In fact, Italvolt initially intended to build its gigafactory at the Scarmagno industrial site, but the electricity grid of the former Olivetti plant was decommissioned and has been abandoned for at least 30 years and Terna estimates that at least 4 years are needed to adapt it. Therefore, at the end of January 2023 the company started to evaluate the possibility of building the gigafactory in Termini Imerese, in Sicily.

Considering these critical issues, the **"Critical Raw Materials Act"**, published by the European Commission on March 2023, set the goal of creating **more resilient** supply chains, reducing the administrative burden, and simplifying permitting procedures for critical raw materials projects. 'Strategic Projects' will be identified, which will benefit from both increased support in obtaining funding and reduced permitting and authorisation times of around **24 months for extraction and 12 months for processing and recycling**.

The same programme has therefore provided support for access to financing and reduced authorisation times for selected strategic projects, as well as establishing that Member States will have to develop national programmes for the exploration of geological resources. Targets – as initial proposal from the European Commission to be discussed and agreed within the Trilogue – are set in terms of **domestic capacity** to be reached by 2030 with reference to each of the 'strategic' raw materials supply chains, i.e., those necessary to achieve decarbonisation:

- Extraction: at least **10%** of annual consumption in the EU.
- Refining: at least **40%** of annual consumption in the EU.
- Recycling: at least **15%** of annual consumption in the EU.
- **No more than 65%** of annual consumption of strategic raw materials in the EU (at any stage of the supply chain) must **depend on a single third country**.

Considering what has been reported so far, both with reference to the gaps that may persist by 2030, **recycling** is an essential tool. For Europe, recycling must be a real "mining" activity that can increase the circularity of the battery supply chain while ensuring less dependence on foreign countries for the supply of raw materials. The increased availability of materials would represent a significant starting point for the development of the supply chain, to be complemented by initiatives in favour of the construction of production plants, an aspect on which the European Union has recently shown greater awareness.

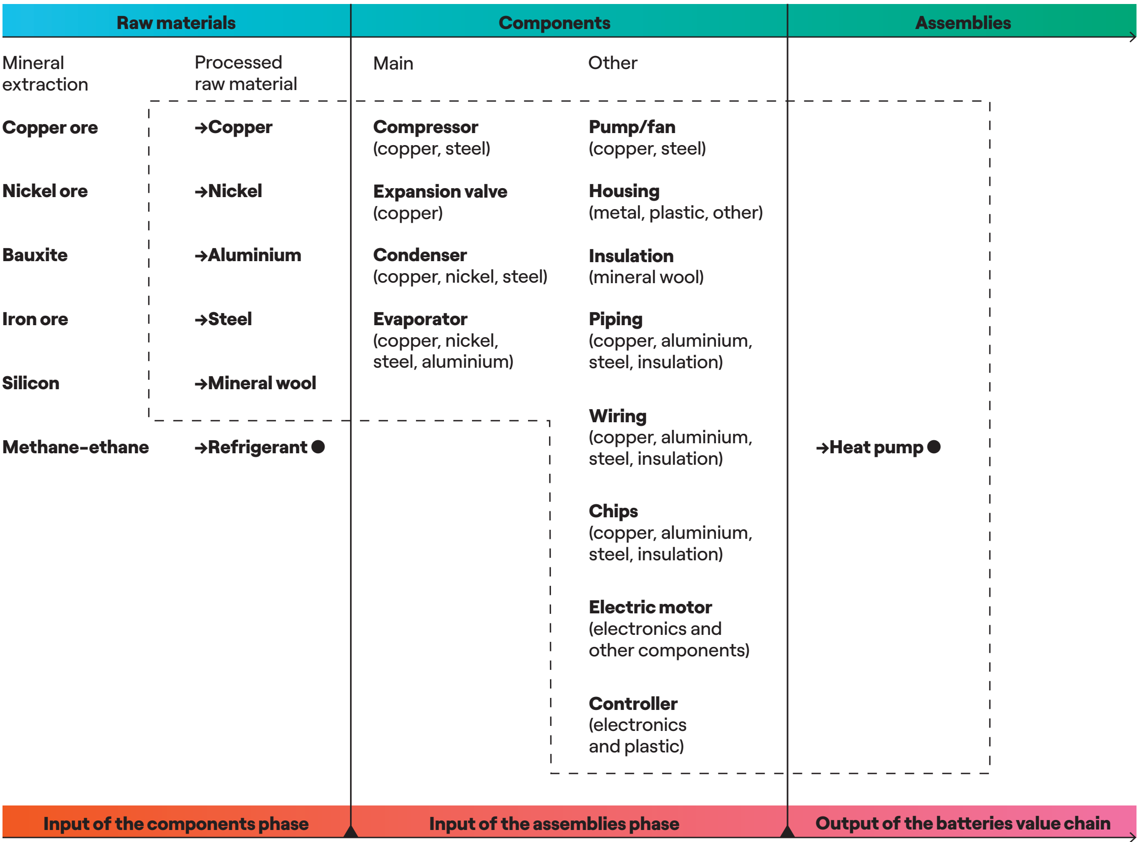
2.4

Heat pumps: mapping, quantification and analysis of the value chain in Europe and Italy

Heat pumps can be classified according to three dimensions: **input**, **heat transfer** and **energy source**. Regarding the first, a distinction is made between air-source heat pumps (extracting heat from the air), ground-source heat pumps (extracting heat from underground) and water-source heat pumps (utilising heat from watercourses). Of these, **air-source heat pumps are the most popular category** due to the relative ease of heat retrieval, lower investment costs and ease of installation. In relation to heat exchange, there are air-to-air, air-to-water, water-to-air or water-to-water heat pumps, depending on the destination of the extracted heat. Finally, heat pumps can be classified according to the type of energy source used to power them (e.g. electricity, thermal energy from gas or propane, dual-fuel). Finally, absorption heat pumps are a particular type not needing a compressor and operating on the energy provided by a source of heat, but are used only in some niche application.

Again, it is possible to divide the supply chain **into the three stages relating to raw materials, components, and assembly**. Raw materials relevant to the heat pump supply chain include copper, nickel, aluminium (obtained from bauxite), steel (obtained from raw iron), mineral wool (obtained from silicon) and refrigerant (obtained from alkanes such as methane and ethane). The main components include the compressor, condenser, expansion valve and evaporator. Other components include pumps and fans, cover materials, insulation, piping, wiring, chips, electric motor and control units. All these components are finally assembled into the finished product, the heat pump.

Figure 68 → **The heat pump industrial value chain: stages, processes and outputs**

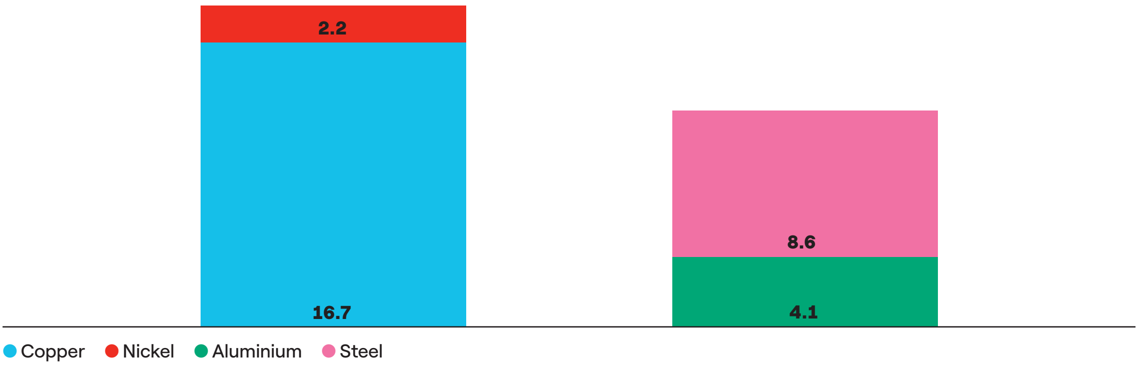


Source → Elaboration The European House – Ambrosetti and Enel Foundation on various sources, 2023.

→ State of the art and critical issues in the heat pump value chain stages: raw materials

The raw material provisioning does not represent a critical point of attention for the heat pump supply chain. However, it must be pointed out that heat pumps **are highly dependent on critical/strategic materials and bulk materials** in terms of cost, with manufacturing accounting for a small portion of the final value. In fact, **copper** alone is associated with a cost of **USD 16.7 per kW** along the heat pump supply chain, higher than the total cost of energy (USD 6.8/kW) in Europe. Steel (USD 8.6 /kW), **aluminium** (USD 4.1 /kW), and **nickel** (USD 2.2 /kW) are also particularly expensive. Overall, raw materials **account for 90% of the production costs** of heat pumps and are the main driver of the cost of all components.

Figure 69 → **Breakdown of average manufacturing costs of heat pumps, 2021** (USD/kW)



Source → Elaboration The European House - Ambrosetti and Enel Foundation on IEA data, 2023.

Considering the weight in terms of quantity of the main raw materials used, **reinforcing steel** accounts for 45% of the total, **copper** and **low-alloy steel** for 17.5%. The high incidence of these raw materials is reflected in the cost of the components: for example, compressors, with a high steel content, are the costliest, accounting for 30% of the total.

Looking at the production and processing of raw materials, there is a strong concentration in the latter phase. It is important to emphasise that while extraction activity depends on the geographical location of the raw materials, refining activity depends exclusively on the industrial dynamics of the country of reference. For example, copper mining is not particularly concentrated, **with Chile – the global main producer – accounting for 24% of the world total**. Peru and Congo follow (both with a 10% share), while China is in fourth place (9%). In contrast, **the copper refining market is more concentrated**, with China playing a dominant role with **a 41% market share**. Suffice it to say that Chile, the second largest country (and first in terms of extraction), is responsible for only 9% of refined copper production.

Figure 70 → **Left: Top 5 copper mining countries, 2022** (% values)
Right: Top 5 copper refining countries , 2022 (% values)

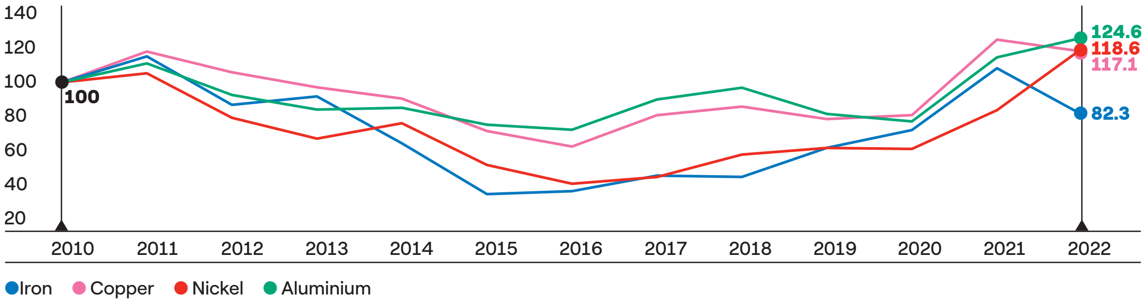
Source → Elaboration The European House - Ambrosetti and Enel Foundation on Statista data, 2023.

Similar results can be observed in the steel market. Here, **Australia has a mining share of 34%**, while China ranks third with 15%. However, **China accounts for most of the steel production** (53% market share), well above the other Asian countries[47], which are in second place with a total share of 8%.

Considering the relative importance of raw materials in heat pump production, **price volatility is a key element of attention**. From 2010, the prices of the main raw materials in the supply chain steadily decreased until the years 2015-2016, only to rise again in the following years. Taking 2010 as a reference, **the price of copper reached a negative peak in 2016** (when it was 64.5% of the value as of 2010), and then rose again until 2021 (when it was 123.7% of the value as of 2010). Similar considerations apply to the other heat pump raw materials, of which only nickel had a lower value in 2021 than in 2010 (84.7%).

47
Asian countries are considered here, with the exception of China, India (covering a 6% share of steel production), and Japan (5% share of production).

Figure 71 → **Evolution of the price of raw materials relevant to the heat pump industrial chain, 2010-2021** (indexed values, base year 2010=100)



Source → Elaboration The European House - Ambrosetti and Enel Foundation on IEA data, 2023.

The main critical issue regarding raw materials is represented by refrigerant policies. Most of the production of **refrigerants** used in heat pumps is concentrated in **China** (~40% of market share) and **the United States** (~38% of market share). Key factors facilitating production at this stage are the proximity of critical raw materials and the availability of cheap and skilled labour.

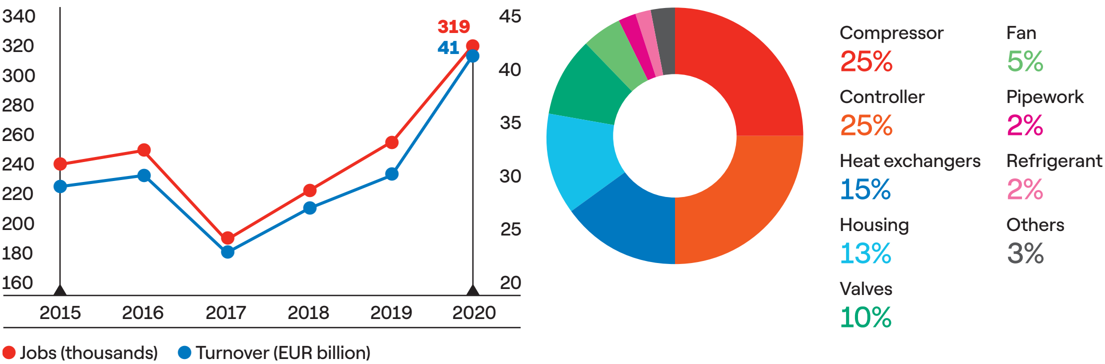
In Europe, recent refrigerant policies have led to increased costs. Heat pumps currently use a family of refrigerants called **fluorinated gases**. F-gases were developed in the 1990s to replace the ozone-killing chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) but have subsequently come under fire for their high global-warming potential. Much like CO_2, F-gases drive global warming and are very stable, meaning they will stick around in the atmosphere for a long period of time. F-gases made up 2.3% of total EU greenhouse gas emissions in 2019[48]. To address this, the EU decided a phase-down of HFCs in 2015, imposing annual production quotas on manufacturers to incentivise the use of alternatives, with a strong reduction by 2030. In addition, in 2023, the European Chemicals Agency (ECHA) proposed to ban the production, use, and sale of about 10,000 per- and polyfluoroalkyl substances (PFAS) in the European Union. According to the regulation, the amount of HFC currently present in the market must be less than half compared to 2015, implying a price growth for HFC and, specifically, R410A. These actions have led to **a sharp increase in their price** (from EUR 22 per litre in April 2021 to EUR 108 in April 2022). This containment activity has not been matched by a sustained growth of alternative refrigerants, due to the long lead times for the supply chain to adapt to a new type. Consequently, industry representatives are pointing out that the heat pump production chain could be affected by these policies, limiting its growth potential in the coming years.

48
In particular, fluorinated gases have a negative impact on the environment in the event of heat pump malfunctions and consequent leaks.

State of the art and critical issues in the heat pump value chain: the components

Within the EU, the heat pump market currently accounts for over **319,000 jobs** and EUR 41 billion in turnover[49], with a steady increase between 2017 and 2020 of both variables. Compressors and controllers are responsible for most of the added value of this market, **each covering a share of 25%**. This is followed by heat exchangers (15%) and housing (13%).

Figure 72 → **Left: Heat pumps turnover** (EUR billion) **and direct and indirect jobs in EU** (thousands)**, 2015-2020. Right: Heat pump value added by component, 2020** (% values)

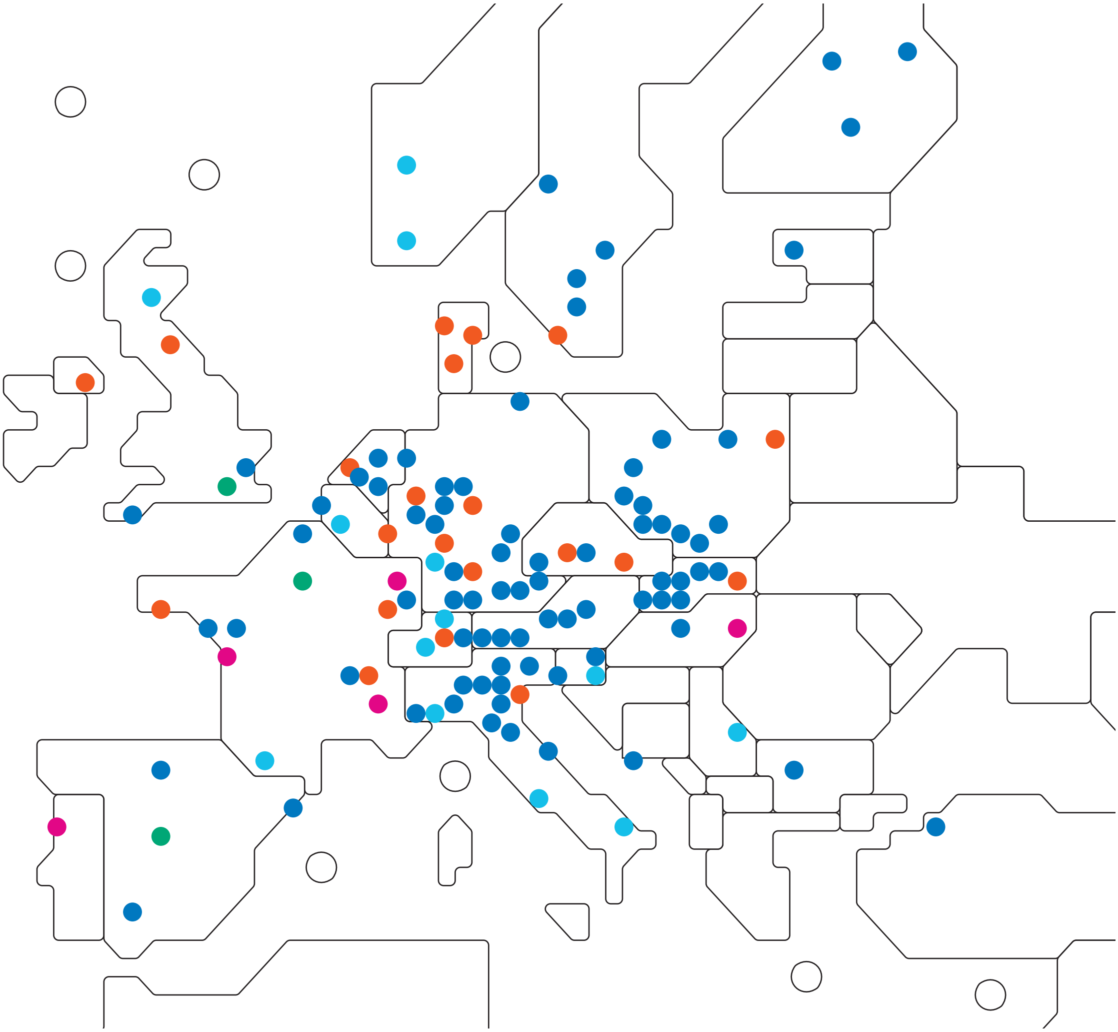


Source → Elaboration The European House - Ambrosetti and Enel Foundation on European Commission and EurObserv'ER data, 2023.

The heat pumps market is still at an initial stage globally. However, European heat pumps appear to be a **stronghold on the market** in terms of production, although there has been an **increasing trend of imports from Asia** over the years. Both heat pumps and their components are produced in Europe thanks to the presence of numerous **small and medium-sized companies**. Despite the presence of some large companies, none of them dominates the entire European market. There are European manufacturers of compressors, fans, pumps, and heat exchangers, as well as enclosure and control systems. In Italy in particular, **CAREL** is a leading manufacturer in the market for electronic control systems.

49
Source: elaboration The European House - Ambrosetti on data from the European Commission and EurObserv'ER, 2023.

Figure 73 → **Heat pumps manufacturing locations in Europe, 2021** (illustrative)



● Components ● Heat pump water heater ● Heat pumps ● Importer ● Large heat pumps

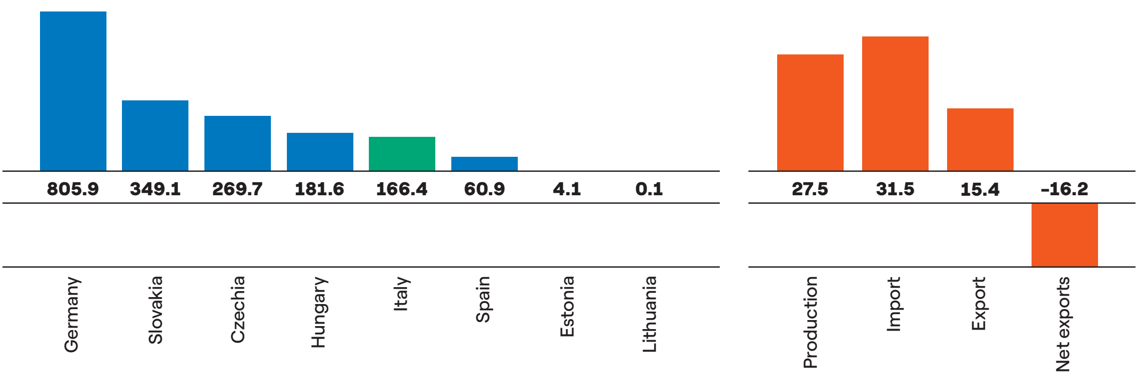
Source → Elaboration The European House – Ambrosetti and Enel Foundation on Enel data, 2023.

However, for some components, the design and production phase are characterised by higher specialisation. One example is the **compressor market**, which is dominated by a small number of global suppliers (e.g. Mitsubishi, Panasonic, LG Electronics, Toshiba, Danfoss, Bitzer, Emerson Copeland), with foreign companies characterized by higher market share compared to European ones. Some of the leading heat pump manufacturers, such as Hitachi and Daikin, also manufacture their own compressors. The compressor is linked to the heat exchangers via pipework which can be complex, as designers try to fit components into smaller packages. Although the pipework itself is conventional, the process of shaping and brazing is hard to automate, so it tends to require **skilled labour**. The shaping and brazing process is mostly conducted in the same facility as heat pump manufacture, the issue being that the complex pipework often has to be made around other components. In this context, manufacturers of compressors may face challenges in **scaling up their production**. These challenges arise due to cost competition, which is influenced by the dominance of a small number of global manufacturers operating on a massive scale.

Regarding compressors, Europe has a **negative trade balance**. In 2021, the trade balance reached **-16.2 million units** of compressors, a **decrease of 30% compared to 2008**. Italy is Europe's fifth largest producer of compressors, with a value of EUR 166.4 million (compared to EUR 805.9 million for Germany, Europe's largest producer).

Figure 74 →

Left: Compressors production value for the main European producers, 2021 (EUR million)
Right: Production, import, export and net export of compressors in UE, 2021 (million units)



Source → Elaboration The European House - Ambrosetti and Enel Foundation on Prodcom data, 2023.

Unlike compressors, the manufacture of the rest of the mechanical components such as **fans, housings, control systems, pumps, heat exchanger and expansion valves is less specialized and distributed among a wider range of companies worldwide**. In particular:

- **Control systems** are mostly custom-made, and the large manufacturers tend to make these themselves. Manufacturers of control systems include Carel (Italy), Parker Hanifin (USA), Alco and Dixell (owned by Emerson Copeland and manufactured in Italy).
- For **pumps**, the most important companies include Grundfos and Wile (Denmark), but there are also a large number of suppliers available.
- This is also the same for **heat exchangers** where Alfa Laval and Swep (Sweden) are only some of the leading suppliers.

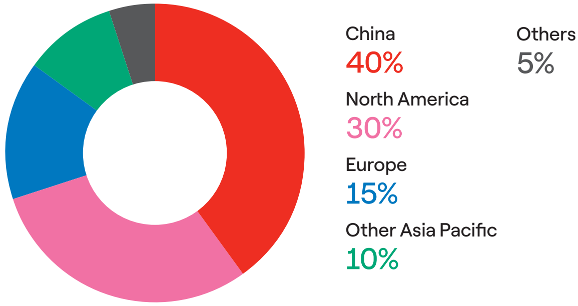
→ State of the art and critical issues in the heat pump value chain stages: assembly

The heat pump market is currently in an **early stage of development** and is not yet fully mature. As a result, there are several **uncertainties regarding the future evolution of demand** for heat pumps (in terms of technology solutions, materials, requirements, …), complicating the investment planning process of companies.

Factors such as technological advancements, changes in government policies or incentives, environmental concerns, and consumer preferences can significantly influence the demand for heat pumps. These uncertainties make it difficult for industry players to gauge the potential growth and market size in the coming years. The uncertainties surrounding the heat pump market can **discourage established industries**, such as the gas boiler industry, from investing in the conversion or integration of heat pumps into their existing infrastructure. These industries may already have significant investments in their current technologies, manufacturing processes, and supply chains. The lack of clear demand projections and market stability may deter them from taking risks or making large-scale changes in their operations. Companies may be hesitant to allocate significant financial resources towards heat pump research, development, and production if they are unsure about the market's future growth and profitability. This can slow down the pace of innovation, investment in infrastructure, and expansion of production capacity in the heat pump industry.

To date, production of heat pumps, considered as a finished product, is heavily concentrated in China and the United States. In fact, **China** accounted for **40% of production** in 2021, the **United States** for **30%**, with **Europe** coming in third with a value of **15%**.

Figure 75 → **Global heat pump manufacturing capacity, 2021** (% values)

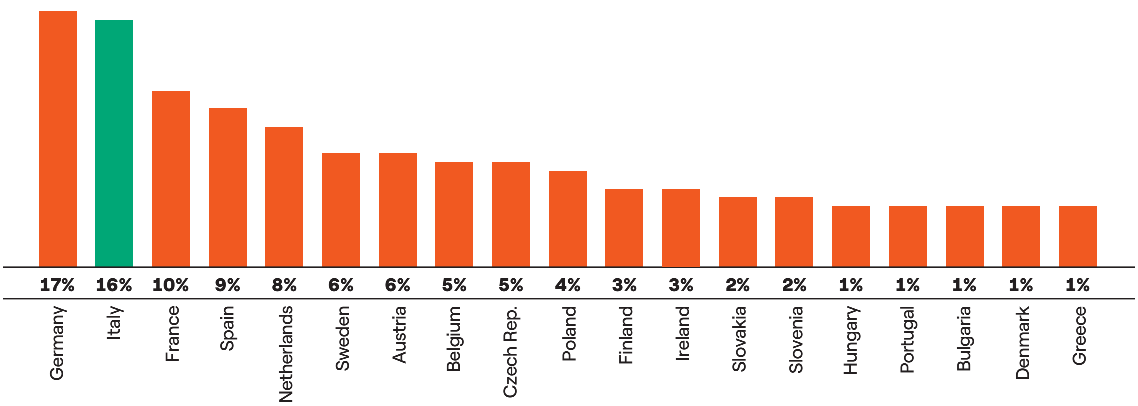


N.B. The data include manufacturing of air conditioning.

Source → Elaboration The European House – Ambrosetti and Enel Foundation on EHPA and IEA data, 2023.

In Europe, **Germany and Italy** are the top two countries for heat pump **manufacturing**, with shares of **17% and 16%**, respectively, which cumulatively represent one third of total European manufacturing companies. France follows with 10%. There are currently **about 170 companies** manufacturing heat pumps in Europe. Among those operating in Italy, there are Italian-owned companies, Italian companies belonging to a foreign group, and foreign companies. Chinese companies also operate in Italy: in 2016, **Midea** (China) **acquired** a majority holding in the Italian **Clivet group**, with manufacturing of domestic hot water heat pumps being relocated from Asia to Italy in 2017.

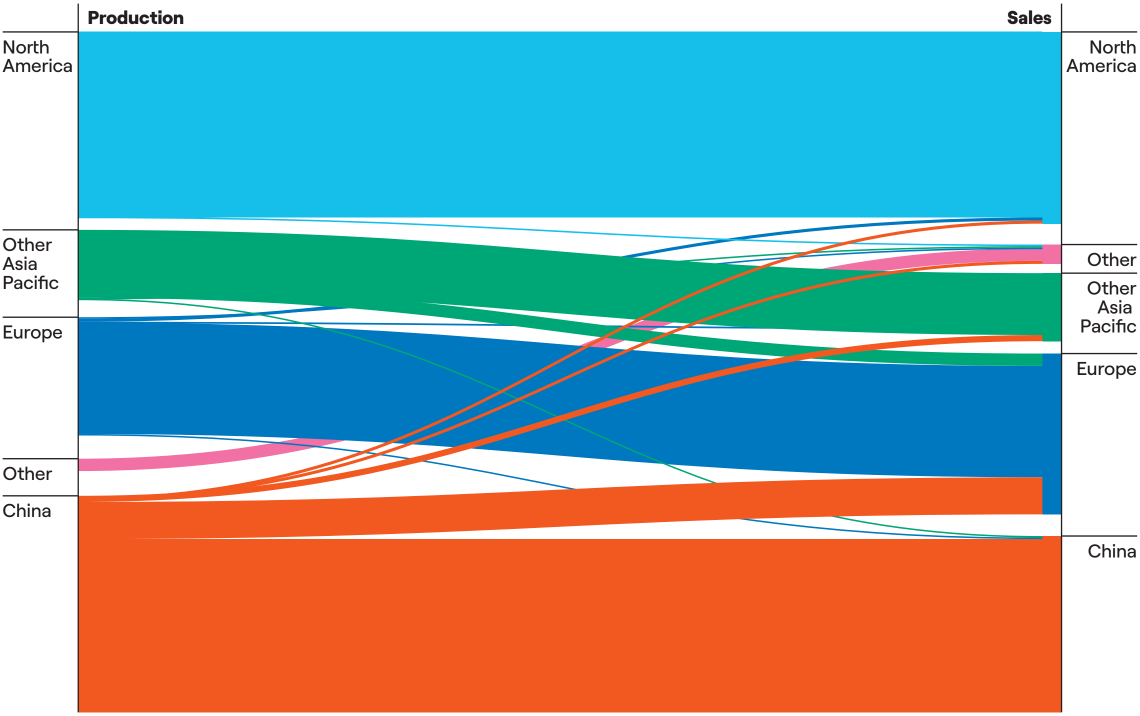
Figure 76 → **Number of heat pumps manufacturing companies in Europe, 2021** (share of the total)



Source → Elaboration The European House – Ambrosetti and Enel Foundation on European Commission data, 2023.

Trade between different geographical areas is, in the case of heat pumps, rather low, at less than 10% (compared to around 60% for photovoltaics). At the root of this lies the **high cost of transport** (due to the large volume of the product, shipping, export, and import costs are 6-12% of the unit's cost), their specificity in relation to **regional climatic conditions**, and the need for heat pumps to comply with **local legal requirements in terms of recyclability, efficiency, safety, and cooling materials**. In 2021, Europe and North America were net importers of heat pumps, while China, Japan and Korea were net exporters.

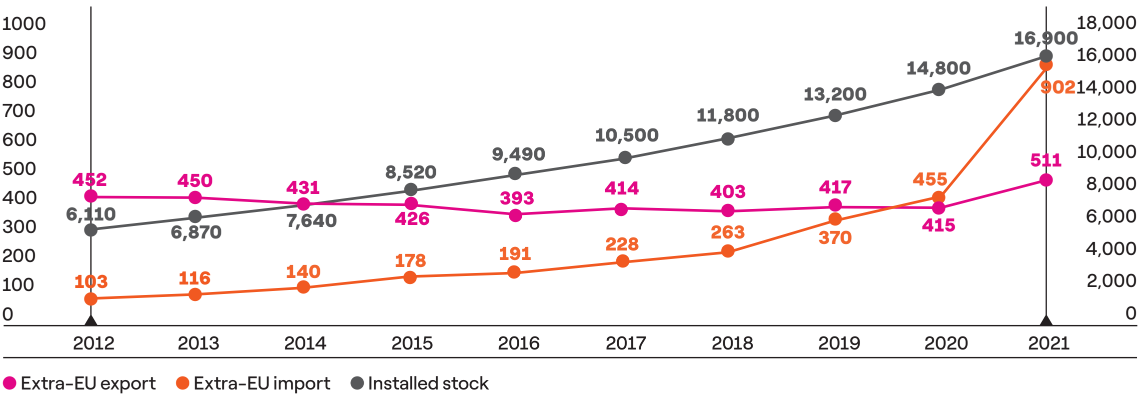
Figure 77 → **Global interregional heat pump trade flows, 2021** (units)



Source → Elaboration The European House - Ambrosetti and Enel Foundation on IEA data, 2023.

The **European Union** accounts for almost a **quarter of global trade (24%)**, while **intra-European flows** amount to **32%** of total heat pump imports from EU countries. With these figures, domestic production has been unable to meet growing demand over the past 10 years. In fact, **demand has grown steadily** from EUR 6.1 billion in 2012 to **EUR 16.9 billion** in 2021. This demand **has been met mainly through the growth of imports**, which amounted to EUR 103 million in 2012 and reached **EUR 902 million** in 2021. On the contrary, **EU exports declined** between 2012 and 2018 and have recorded a weak recovery in the last few years, still remaining below import levels (in 2021, export amounted to EUR 511 million).

Figure 78 → **Extra-EU imports and exports, 2012 - 2021**
(left axis: EUR million, right axis: thousands)

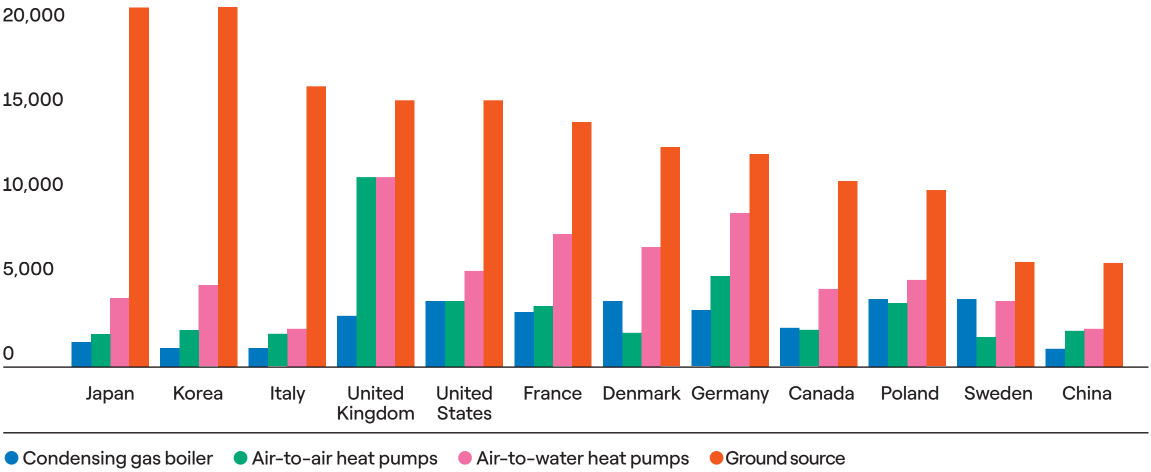


Source → Elaboration The European House - Ambrosetti and Enel Foundation on European Commission data, 2023.

For this analysis, the entire industrial heat pump value chain was considered. However, in addition to the production activity of the finished product, the heat pump value chain suffers from other structural weaknesses associated with the **system design and installation stage**, which has several points of concern that impact the industrial dimension of the supply chain.

Looking at installation, this stage has a significant impact on the final cost of the system. In particular, the installation of an air source heat pump alone can cost around **EUR 6,000 per unit**, while the installation of a geothermal heat pump, due to the complexity of its ground extraction systems, can cost around **EUR 14,000**. It can also be noted that installation costs vary between countries, with a particularly positive performance in China also due to lower costs of labour. In this context, the cost incurred for installation in Italy is relatively lower than that of other countries; however, there is a considerable gap between the cost of installing a gas boiler and that of a heat pump (the installation of the former technology costs less than half that of a heat pump), which limits its diffusion.

Figure 79 → **Installation and equipment costs of the main residential heating technologies in selected countries**



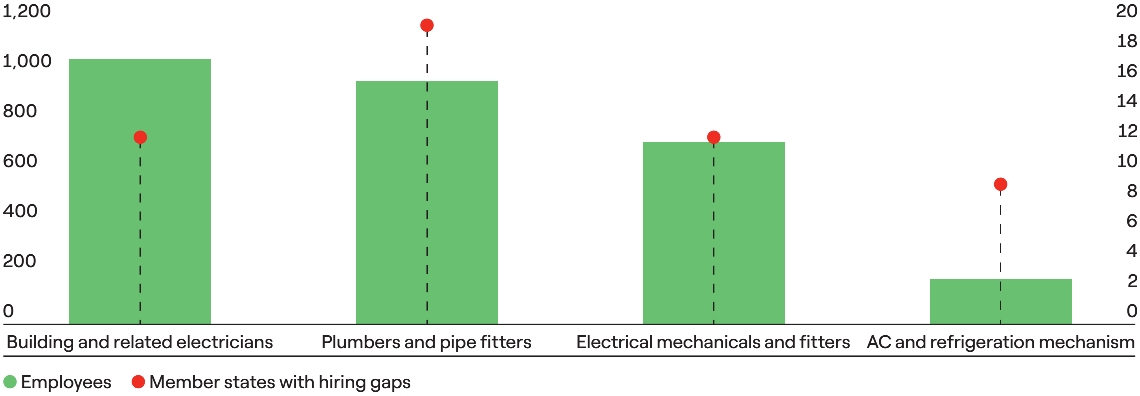
Source → Elaboration The European House - Ambrosetti and Enel Foundation on IEA data, 2023.

In addition to difficulties on the manufacturing front, the EU and its Member States currently suffer from a **shortage** of heat pump **installers**. Currently, there are about **1.5 million** installers in Europe of all kinds of heating appliances, most of them small companies and 85 thousand in Italy[50]. The European Heating Industry, however, estimates that the **number of installers** needs to **increase by 50%** to reach the "REPowerEU" targets, in addition to the need for **50% of existing installers to upgrade their skills**. This shortfall is mainly explained by the high requirements associated with this work.

50
For the analysis the following ATECO code has been considered: 43.22.01. Installation of plumbing, heating and air conditioning (including maintenance and repair) in buildings or other construction works.

Figure 80 →

Number of employees in occupations related to heat pumps installation and number of Member States with labour shortage in EU, 2020
(left axis: thousands, right axis: number of countries)



Source → Elaboration The European House - Ambrosetti and Enel Foundation on IEA and European Commission data, 2023.

All heat pumps, whether imported or domestically produced, need to be installed on site. It takes **more than twice** as long **to install a heat pump** as it does to install a boiler, especially when that heat pump is replacing an existing boiler. **Ground- or water-source heat pumps take far longer to install** than air-source heat pump because they require drilling or digging. The skills needed to install heat pumps are similar to those of many standard occupations in construction but require **additional specialisations**.

Furthermore, to install a heat pump, certain conditions must be met within the building. These conditions pertain to different aspects:

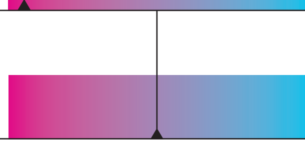
- **Space**: sufficient space needs to be available within the building to accommodate the installation of the heat pump. Heat pumps can vary in size but are usually larger than a gas boiler, so there must be an appropriate area to house the unit, including any required ventilation or clearance around it.
- **Distribution system**: the building must have a suitable distribution system in place to facilitate the functioning of the heat pump. This typically involves having a network of pipes or ducts that can carry the heated or cooled air generated by the heat pump to different areas of the building.
- **Electricity**: the building must have an electrical system capable of supplying the necessary power for the heat pump to operate efficiently. Heat pumps require electricity to run various components, such as compressors and fans, which are essential for heat exchange and proper operation.
- **Insulation**: adequate insulation is important to maximize the efficiency of the heat pump system. Good insulation helps retaining the heated or cooled air within the building, preventing unnecessary heat loss or gain. It ensures that the heat pump doesn't have to work harder than necessary to maintain the desired temperature, leading to energy savings.

The lack of these requirements within the building might represent an obstacle to the diffusion of heat pumps, compromising the performance of this technology.

The Renewable Energy Directive (**RED**) requires installers to have a **specific certification** to install heat pumps. Also, the **F-Gas Regulation** requires anyone who installs, services, repairs or decommissions heat pumps with HFCs to do **leak checks** or to reclaim HFCs to be certified. The Commission proposal for a new F-Gas Regulation also includes a certification based on **mandatory training in climate-friendly refrigerants**, but the obligation will not apply retrospectively to existing installers. Therefore, installers of heat pump and other experts **need to be trained specifically in relation to refrigerants and dimensioning of the system**.

On the one hand, **specific skills** are required for the installation and handling of certain materials such as refrigerants. On the other hand, specific **certifications** and **training courses** are often required for regulatory reasons.

Figure 81 → **The main bottlenecks at European and Italian level along the heat pump supply chain**

Bottleneck	Bottleneck severity	Reasoning
	Low — High	
Heterogeneous installation requirements		→ Several building **requirements** (space, distribution system, electricity and insulation), high cost of installation (**~€6,000 for air-source** HP) and lack of installers (need to increase by **50%**) and **50% of existing ones need reskilling**
Market immaturity and high uncertainties regarding future demand		→ **Immature market**, implying **uncertainties** about future demand evolution, disincentivizing the conversion of existing structured industries (e.g. gas boiler) and companies' investment plans
Restricting refrigerant regulation		→ **EU HFC's phase-down plan** can obstacle the development of HP market while **increasing the cost of refrigerants** (+394% between April 2021-April 2022) without relevant environmental benefits
Lack of EU specialization in strategic components		→ **63% of EU compressors' demand** is **imported** and their market is **concentrated**. Manufacturers might not be able to **scale up** their production due to **cost competition** and the massive scale of the few existing global manufacturers

Source → Elaboration The European House - Ambrosetti and Enel Foundation on various sources, 2023.

→

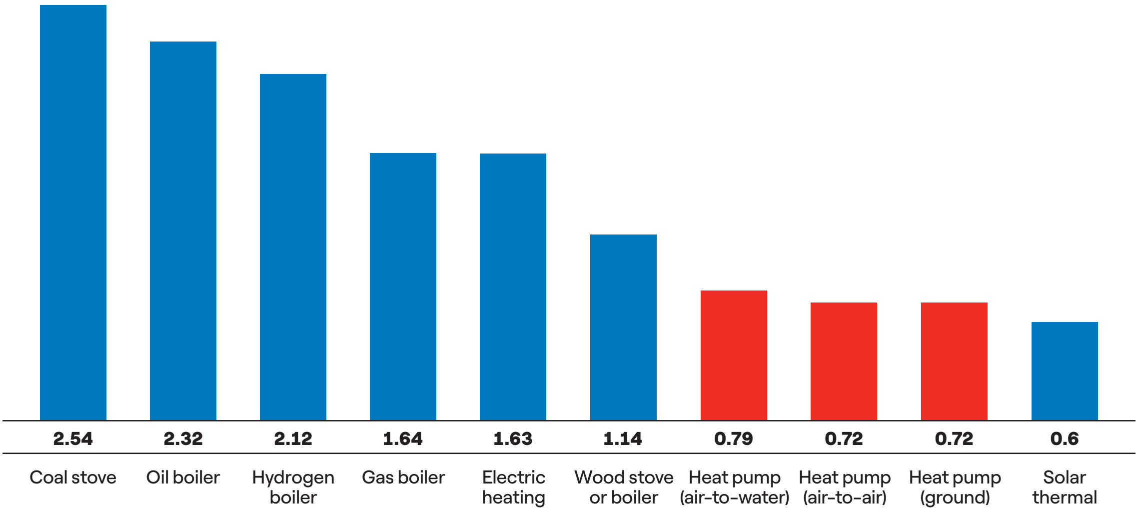
The main opportunities and risks to be addressed for the development of the heat pump value chain in Europe and Italy

If on one hand the early stage of development might be an obstacle for investments 'planning of companies due to its high uncertainty regarding the future, on the other hand there is **significant room for growth and expansion in this industry**. With respect to the current market size, the EU accounts for 15% of global heat pumps production, indicating the region's manufacturing capabilities and market presence. Moreover, the EU covers 77% of domestic demand for heat pumps, implying that the EU has a relatively strong market for heat pumps within its borders, indicating a growing adoption of heat pumps as a heating solution by consumers and businesses. Finally, there is an opportunity for the EU to shift away from traditional gas boiler systems and transition towards heat pumps. This conversion could involve various aspects, such as manufacturing, distribution, installation, and maintenance of heat pumps, replacing the existing infrastructure and practices related to gas boilers.

Despite the challenges that Europe and Italy face in developing a domestic heat pump supply chain, this technology represents a cost-effective solution to decarbonise heating systems. Although the up-front investment for heat pump is high, the lifetime cost of a heating technology is dominated by its operating costs. In fact, the **Total Cost of Ownership** is estimated to be **EUR 0.72 per kWh** for geothermal and air-to-air heat pumps, and EUR **0.79 per kWh** for air-to-water heat pumps[51]. These values are far lower than for other heating technologies: coal-fired stoves, for example, are associated with a cost of EUR 2.54 per kWh, while that of oil-fired boilers is, on average, EUR 2.32 per kWh, and gas-fired boilers cost EUR 1.64 per kWh. The Levelised Cost of Heating is decreasing for heat pumps, with the possibility of being further reduced by up to 50% through building renovation and efficiency improvements. Although solar thermal has the lowest cost of ownership, its efficiency strongly depends on the weather, whereas **heat pumps work well in a variety of climates**. In addition, heat pumps offer both **heating and cooling services**, whereas other heating technologies must be integrated with cooling, thus further increasing their total cost of ownership.

51
These values refer to estimates by the European Commission.

Figure 82 → **Total cost of ownership by heating technology, 2030-2040**
(EUR/kWh heat delivered)



Source → Elaboration The European House - Ambrosetti and Enel Foundation on European Commission, 2023.

For these reasons, heat pumps are a crucial element in the energy transition. **European policies** have recognised the role of this technology, aiming to install **an additional 60 million heat pumps** by 2030. This European target has been complemented by national policies in favour of more energy consumption from heat pumps and more installations. In **Italy**, it is expected to install **10 million additional heat pumps** by 2030.

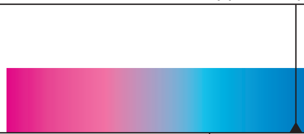
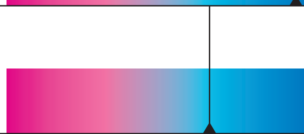
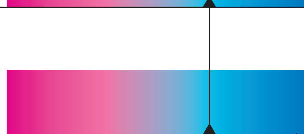
Figure 83 → **Selected European policy targets for heat pump deployment, 2022** (illustrative)

Country	Year	Target
European Union	**2030**	**60 million additional Heat Pumps installed**
Belgium	2030	Final energy consumption by Heat Pumps to increase five-fold over 2018
Germany	2024 2030	Install 500,000 Heat Pumps per year Reach a heat pump stock of 6 million
Hungary	2030	Final energy consumption by Heat Pumps to increase six-fold over 2020
Italy	**2030**	**10 million additional Heat Pumps installed**
Poland	2030	Final energy consumption by Heat Pumps to increase three-fold over 2020
Spain	2030	Final energy consumption by Heat Pumps to increase six-fold over 2020
United Kingdom	2028	600,000 annual heat pump installations

Source → Elaboration The European House – Ambrosetti and Enel Foundation on BloombergNEF data, 2023.

Despite the relevance of a plurality of raw materials for the heat pump supply chain and the associated costs, most materials are characterised by **high recycling and substitution rates**. In fact, the recycling rate in 2022 was **90%** for **steel**, **80%** for **cooling materials**, **75%** for **aluminium** and **70%** for **copper**. The ability to reuse materials can solve the problems of price volatility and raw material scarcity, providing a significant stimulus for the heat pump industry.

Figure 84 → **A summary view of the main opportunities and risks for the development of the heat pump industrial chain in Europe and Italy**

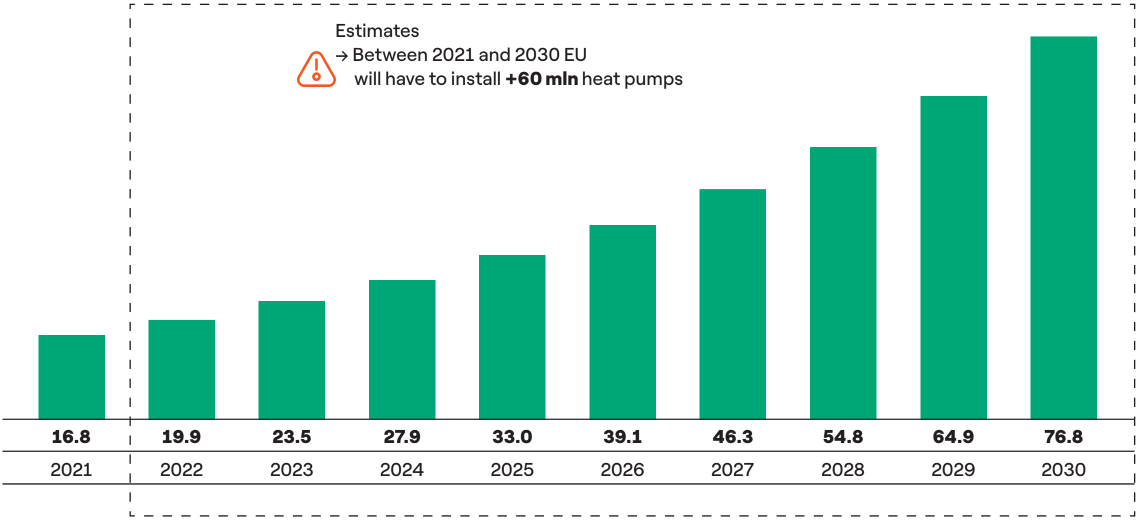
Risk/Opportunity	Risk/Opportunity severity (Risk – Opportunity)	Reasoning
Relevance of European industry		→ With respect to the current market size (still at an early stage of development), the EU accounts for **15% of global HP production** and covers **77% of domestic demand**, with great potential to **convert the boiler gas value chain**
Economic and environmental convenience		→ Despite high initial investment costs (installation, cost of the machine), HP is the best technology in terms of **total cost of ownership and adaptability to a variety of climates**, minimizing the impact on the environment
Recycling capacity		→ In the longer term, recycling can be an **effective strategy to solve the price volatility and scarcity problems**
European policies		→ The growth of heat pumps market is boosted by **European policies** aimed at reducing gas dependence

Source → Elaboration The European House - Ambrosetti and Enel Foundation on various sources, 2023.

→ Expected demand trends, gap analysis and announcements for heat pump projects in Europe and Italy

Based on the policy targets, the EU will have to reach a level of **76.8 million installed heat pumps by 2030**, i.e., +60 million compared to 2021, when 16.8 million heat pump units were installed in Europe.

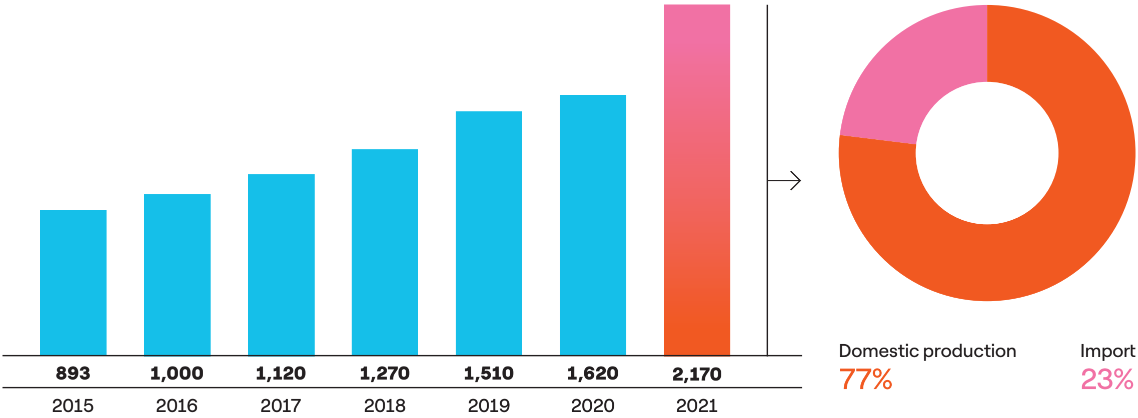
Figure 85 → **Evolution of heat pumps in EU, 2021-2030E** (million units)



Source → Elaboration The European House – Ambrosetti and Enel Foundation on European Commission and EHPA data, 2023.

In recent years, Europe has seen a **steady growth in heat pump sales**, from 893 thousand units sold in 2015 to **2.17 million units sold in 2021**. Currently, Europe produces enough heat pumps in-house to satisfy the majority (77%) of its demand. According to the recent targets set by the NZIA, the EU must be able to **satisfy 60% of its demand domestically**. Even though this target represents a lower quota compared to the share in 2021, it must be underlined that the heat pump market is still in its early days and is expected to grow substantially over the next decades. This will imply that the European market will have to scale up its production in order to match the 60% domestic production by 2030.

Figure 86 → **Left: heat pump units sales in EU, 2015-2021** (thousand units)
Right: European heat pumps domestic production*, 2021 (% values)



* Production value of heat pumps other than air conditioning machines of HS 8415

Source → Elaboration The European House - Ambrosetti and Enel Foundation on EHPA and Prodcom data, 2023.

At the European level, several investments are already planned or underway to meet heat pump demand. Overall, there are **EUR 5 billion in investments** in the heat pumps market in Europe to 2025. Among others[52]:

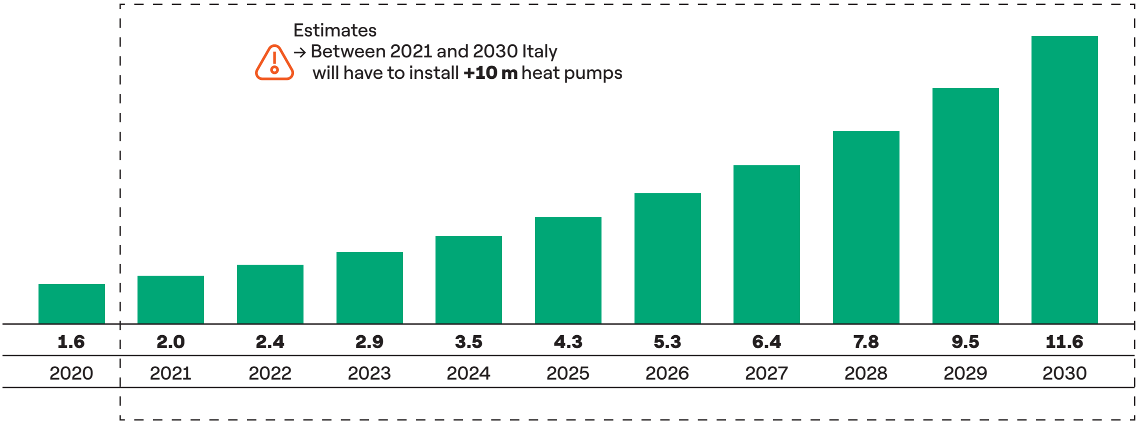
- Saunier Duval is investing EUR 10 million in France to increase its production capacity from 35,000 Heat Pumps in 2020 to 130,000 units by 2023.
- Vaillant is doubling its production capacity in Germany and France, including EUR 120 million in investments in Slovakia.
- Daikin planned a further expansion in Poland, where a new EUR 300 million factory is to open in 2024, employing 1,000 people by 2025.
- Stiebel Eltron aims to double its production capacity by 2026, investing EUR 120 million and creating 400 new jobs.
- Bosch is planning to invest EUR 355 million in heat pumps by mid-2025.
- Viessmann planned an investment in Poland of EUR 1 billion over the next 3 years, including EUR 200 million in propane-based heat pump manufacturing.
- Panasonic announced investment of EUR 145 million at its factory in Czech Republic to increase capacity to 500,000 air-water units by March 2026.
- Hoval planned to invest EUR 40 million in Slovakia.

If all these investments are implemented, the EU will have very good chances of meeting the **60%** NZIA goal of domestic production by 2030.

52
Source: EHPA, 2023.

Also in **Italy**, according to scenarios elaborated by Enel and Agici, a strong growth of installed heat pump units is expected in the coming years. In particular, the country is expected to reach a level of **11.6 million heat pumps by 2030**, +10 million compared to 1.6 million units in 2020.

Figure 87 → **Evolution of heat pumps in Italy, 2020-2030E** (million units)



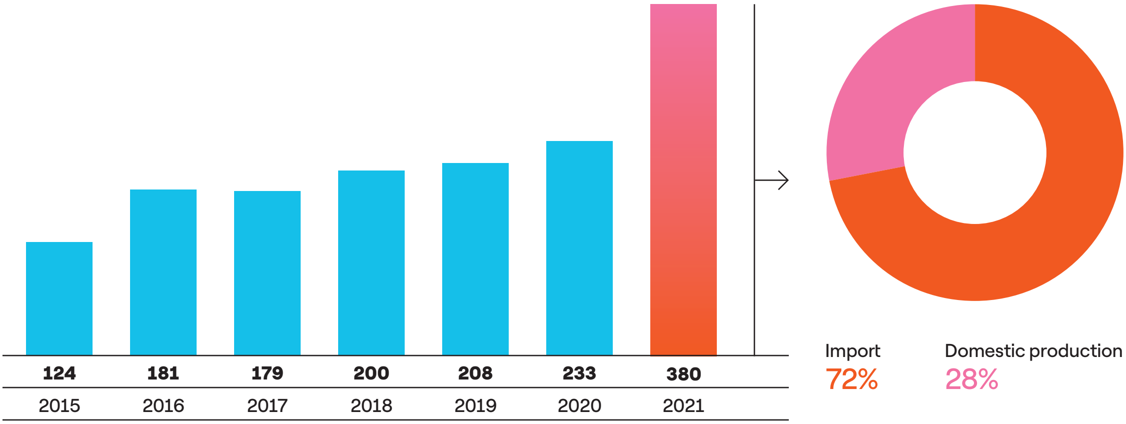
* Data on production and imports were collected using the following Prodcom code: production value of heat pumps other than air-conditioning machines of HS 8415.

Source → Elaboration The European House - Ambrosetti and Enel Foundation on Assoclina, Enel and Agici data, 2023.

Italy has also seen a growing trend in the sale of heat pumps in recent years, so much so that between 2015 and 2021 the number of heat pumps sold in in Italy increased from 124,000 units to 380,000 units. Contrary to Europe as a whole, Italy covers a low share of domestic demand through its own domestic production, which was 28% in 2021[53].

53
Source: Prodcom, 2023. The following Prodcom code was considered: production value of heat pumps other than air-conditioning machines from HS 8415.

Figure 88 → **Left: heat pumps units sales in Italy, 2015-2021** (thousand units)
Right: Italian heat pumps domestic production*, 2021 (% values)



* Production value of heat pumps other than air conditioning machines of HS 8415.

Source → Elaboration The European House - Ambrosetti and Enel Foundation on EHPA and Prodcom data, 2023.

In conclusion, the targets highlighted in this section require a **strong development of** European and national **production capacity**. In an inertial scenario, in which the same percentage of heat pumps would continue to be produced as today's installed total, there would be a gap of **13.8 million heat pumps in Europe** and **5.4 million in Italy** that would have to be imported from third countries by 2030.

Policy proposals and guidelines for the development of key decarbonization-related industrial value chains in Europe and Italy

3.1 → The rising global competition on green industrial value chains

3.2 → The proposals to develop industrial value chains in Europe and Italy

Key Messages

1 → The European Union has been slow in recognising the relevance of **promoting a strategic vision** for the development or creation of a competitive green industry at the European level. The **European share** of global manufacturing capacity of the 17 strategic components of the main clean technologies is equal to **14%** on average compared to **65%** of China, which achieved this level also because of a long-term industrial vision dating back to 1992.

2 → The EU is trying to fill these gaps: in March 2023 the NZIA was issued, with the goal of achieving domestic production of at least **40%** of the annual demand for green technologies by 2030. At the same time, if all the existing funds were redirected to finance net zero technologies (**EUR 695.1 billion between 2021 and 2027**) – the European Union would have a significant amount of funds to develop local green value chain, even though still **far from Chinese support**.

3 → Nevertheless, to fully reap the benefits of the current energy transition and reduce the risk associated to the supply chain, **green industrial supply chains must be created, develo-**

ped and strengthened to support the growth that is expected in the coming years and to **reduce the dependence on third countries**, hence increasing the geostrategic resilience. In this process it will be crucial to **avoid moving from energy dependence to technological dependence**, to decrease the reliance on countries with low political stability and reduce the risk of weaponization of technology trade by third party suppliers.

4 →

This requires action on 2 main fields: **1) reducing the cost** of European products (**through import reduction and investments along the value chains development to exploit economies of scale**); **2)** creating a **level playing field** in global production conditions to smooth the structural differences between the European market and the Chinese market. Overall, adding the **net benefit of reduced imports** and the **direct, indirect and induced economic benefits** coming from investments needed to reach the NZIA targets for the creation of local supply chains in the three technologies under analysis, the **overall return on the investments would be equal up to EUR 642 billion**, with a corresponding **multiplier between 4 and 7 times the initial investment**. This **huge amount of financial resources** could be able to level out the final cost for the final consumer, making European value chain **even more competitive**.

5 → To this extent, the Study proposes a **strategic vision**, aimed at developing a competitive European-wide decarbonization industry, implementing **integrated and coordinated European value chains** and promoting **greater diversification in the supply of technology** components and **critical raw materials**, also leveraging on the already existing partnerships and complementarities with countries outside the EU. To achieve the strategic vision identified, the Study proposes **11 policy actions (7 at the Italian level and 4 at the EU level)**.

6 → Policy actions at the **Italian level**:

1. Applying **streamlined and predictable permitting procedures.**
2. Favouring the **realization of gigafactories** through financial support in terms of CAPEX and OPEX.
3. Promoting decarbonization through **efficient electric technologies** such as heat pumps
4. Supporting measures to ease the gas **boiler value chain conversion**
5. Implementing a clear strategy to **ensure critical raw materials supply.**
6. Creating dedicated **green finance mechanisms** to develop value chains.
7. Facilitating **upskilling/reskilling**.

7 →

Policy actions at the **European level**:

1. Favoring the **distribution to companies and citizens of the strategic value** generated by the development of local supply chains.
2. Promoting EU Member States coordination on **R&D and industrial innovation**.
3. Providing **specific financial tools** to ensure that all the clean technology products installed and imported comply with **ESG criteria**.
4. Establishing a **common frame for the governance** by creating mechanisms for **guaranteeing coordination and integration** in the realization and implementation of European and Member States policy actions.

3.1

The rising global competition on green industrial value chains

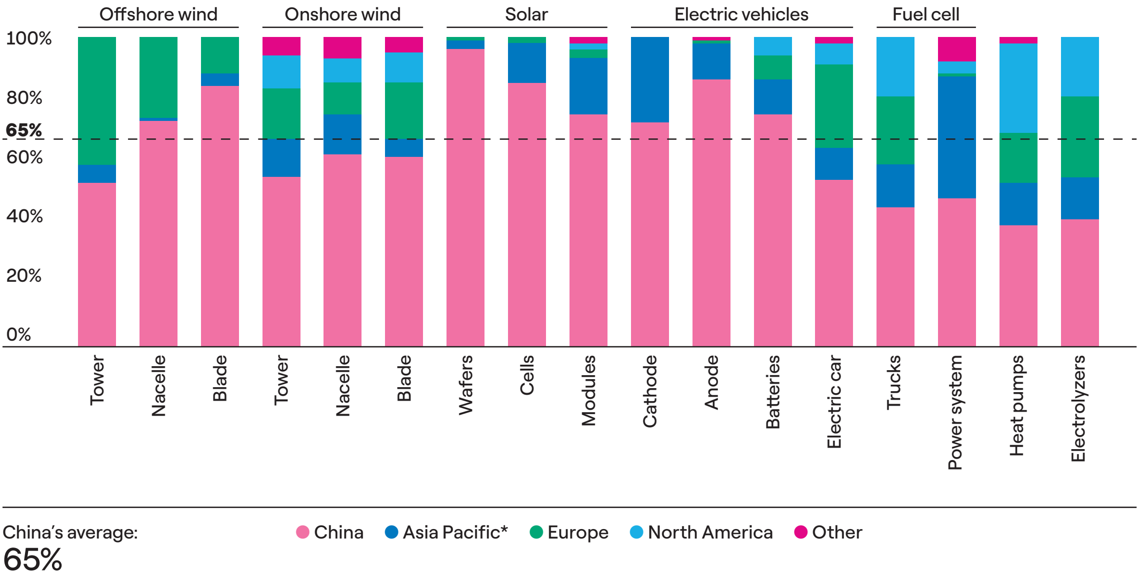
The previous chapters of the Report explain why the EU and Italy should develop industrial value chains to **manufacture key technologies for the energy transition** to meet a more relevant part of their internal demand, therefore boosting economic growth and strategic resilience.

In particular, the analysis of the photovoltaic, battery and storage, and heat pump value chains in the second Chapter of the Report highlighted how Europe and Italy lag significantly behind China in adopting **integrated approaches** along key supply chains for decarbonization. Moreover, the European Union has also been slow in recognising the relevance of **promoting a strategic vision** for the development or creation of a competitive industry at the European level. The **European share** of global manufacturing capacity of the 17 strategic components of the main clean technologies is equal to **14%** on average compared to **65%** of China, which achieved this level also because of a long-term industrial vision dating back to 1992[1].

1
In 1992 Deng Xiaoping, former Chinese leader said: "*The Middle East has oil, China has rare earths*".

Figure 89 →

Share of clean-energy technologies' manufacturing global capacity by region, 2021 (% values)



* Excluding China.

Source → Elaboration The European House - Ambrosetti and Enel Foundation on IEA data, 2023.

To overcome — at least partially — these issues, in March 2023 the European Union issued the "**Net Zero Industry Act**" (NZIA). This plan was created with the goal of achieving domestic production of at least **40%** of EU annual demand for green technologies by 2030, and also provided projections for individual technologies to be reached by the same year: Europe should reach a yearly production capacity of **30 GW** for all stages of the photovoltaic chain, as well as at least **550 GWh** (or 900 GWh according to EBA projections) for the battery and storage value chain[2] and **31 GW** for heat pumps.

More specifically, the European NZIA was developed after the **US Inflation Reduction Act** (IRA), which aims to increase the manufacturing capacity of green technology supply chains in the United States. In the case of photovoltaics, for example, IRA provides **tax credits** throughout the supply chain to reach the target of **50 GW** of manufacturing capacity in each segment by the end of the decade (+20 GW compared to the NZIA target).

2
It is worth to notice that the installation of decarbonization technologies will require significant investments on the grid to integrate them in the power system. Grid technologies are in fact included among the strategic net zero technologies in the NZIA, but in this case Italy and Europe can rely on a well structured supply chain.

Some examples of manufacturing incentives in green technologies at global level

In the **Unites States**, the **Inflation Reduction Act** (IRA) grants its clean-tech manufacturing subsidies in a simple way, via incentives and **tax credits covering 10 years and without competitive process**, while EU support is more **fragmented, requiring more red tape, and slower**, consisting of a competitive process that can take **up to 1 year** from the application to the official award. With regards to the photovoltaics value chain, manufacturers can choose between the **Investment Tax Credit** (ITC) and **Manufacturing Tax Credit** (MTC). The ITC is a 30% credit for eligible investments costs in facilities and equipment and USD 10 billion are allocated to this measure. To receive the **full 30% credit**, a project **must meet prevailing wage and apprenticeship requirements**. Otherwise, the credit will be 6%. On the other hand, the MTC is for certain components based on the **volume of product manufactured** (polysilicon, wafers, cells, modules, backsheets, inverters and trackers). For instance: USD 3/kg for solar grade polysilicon, USD 12/m^2 for wafers, USD 4/W for solar cells, USD 7/W for solar modules. Manufacturers must choose one, since **two credits cannot be cumulated**.

In **India**, the **Production Linked Incentive** (PLI) **Scheme** managed by the Ministry of Heavy Industries provides subsidies and incentives under several national programmes to local industries to support the development of local supply chains. Local governments participate by **providing land and facilitating permitting for the benefiting companies**. Benefitting industries have included the battery ecosystem (under the 'National Programme on Advanced Chemistry Cell Battery Storage') with **USD 2.49 billion over 5 years** in subsidies to **develop 50 GWh of battery capacity in India**. Beneficiaries must ensure **60% domestic value addition within 5 years**. An additional PLI scheme was launched to **boost solar panel production** in India as well, with a budget of **USD 600 million**. The goal is to attract USD 2.30 billion in private financing and to **reach an additional 10 GW solar electricity production capacity in India**. This project is managed by the Ministry of Renewable Energy.

Canada has announced **two clean energy tax credits to match U.S. subsidies** of the IRA and ensure that Canadian companies remain competitive: a **30%** refundable tax credit for capital investments in low-carbon energy generation and technology (USD 6.7 billion over 5 years) and a **tax credit for hydrogen production**. The design of the hydrogen tax credit has yet to be determined, but the government has suggested it will be modelled on tax credits in the IRA.

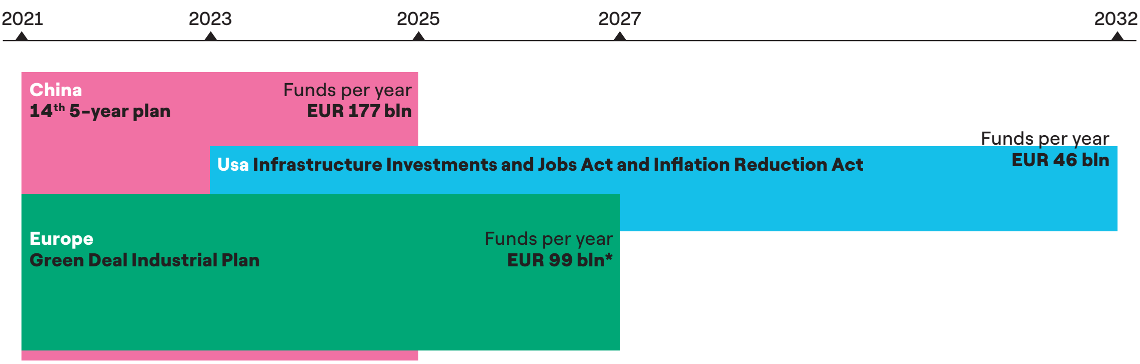
Source → Elaboration The European House - Ambrosetti and Enel Foundation on various sources, 2023.

Another fundamental and synergic element for the implementation of the NZIA is the "**Critical Raw Materials Act**" (CRMA) which defines the strategy, objectives, and instruments to ensure EU **security of supplies of critical raw materials** necessary for technologies related to the energy transition.

The implementation of the NZIA requires, however, a **change of pace at European level**. To this end, the Plan itself has set out initiatives aimed at, *inter alia*, **reducing administrative burdens** and **streamlining authorisation processes, facilitating market access**, and developing a **skilled workforce**.

At the same time, it is important to highlight that – if all the existing funds were redirected to finance net zero technologies (**EUR 695.1 billion between 2021 and 2027**[3]) – the European Union would have a significant amount of funds to develop local green value chains, even though still **far from Chinese support**. However, the EU funds **focus predominantly on the early stages of technological development** and on the uptake stage of these technologies by **downstream users**. Among the existing EU funds, **only a few can currently cater for support to strengthen manufacturing capacities**[4]. Indeed, the issue of public funds is a case in point: against the common rhetoric about European institution underspending compared to the international competitors, public money is available, but that it needs to be managed in a more straightforward and effective way to ensure it unlocks industrial renaissance in the green domain within a reasonable time frame. In addition, better coordination of research activities currently scattered across the continent and an enhanced effort to develop an industry-wide circular approach based on higher recycling and substitution rates, would help exploiting and maximizing the sustainability advantage of the European supply chains in the international context.

Figure 90 → **Measures implemented in the major economies for green industrial development, 2023** (illustrative)



N.B. The funds for China and US are based on official sources of the Governments, even though they are not fully comparable with European funds since the underlying mechanism is different. Therefore, it is a purely illustrative representation intended to highlight how, although the underlying mechanisms are different, there is an intensifying global competition for green industrial leadership.
* As reported in the "Net Zero Industry Act". These are existing funds that could be redirected to finance net zero technologies.

Source → Elaboration The European House - Ambrosetti and Enel Foundation on Net Zero Industry Act Staff Working Document, Eurostat and Istat, 2023.

Within this context, Europe and Italy need to develop programmes that **favour the development of integrated domestic supply chains** and **greater diversification of supply sources**.

3
As reported in the "Net Zero Industry Act" Staff Working Document. Programmes implemented by the Commission at the central level: Innovation Fund (ETS proceed based), Horizon Europe, LIFE Clean Energy Transition, InvestEU. EU Programmes implemented by the Member States: Recovery and Resilience Facility (RRF), "REPowerEU" package and RRF remaining loans, ERDF/Cohesion Fund/Just Transition Fund, Modernisation Fund (ETS proceeds based), Social Climate Fund (ETS proceeds based).

4
A comparison between NZIA and IRA is not fully appropriate since the two mechanisms are different (IRA is based on tax credits, unlike the European mechanism).

3.2

The proposals to develop industrial value chains in Europe and Italy

→ An introduction to the strategic vision

As of today, **China has the lowest manufacturing costs for all segments of the supply chains analyzed**. As explained in detail in the second Chapter of the Study, **China built its industrial capacity leveraging on policies specifically aimed at achieving global leadership in green technologies**.

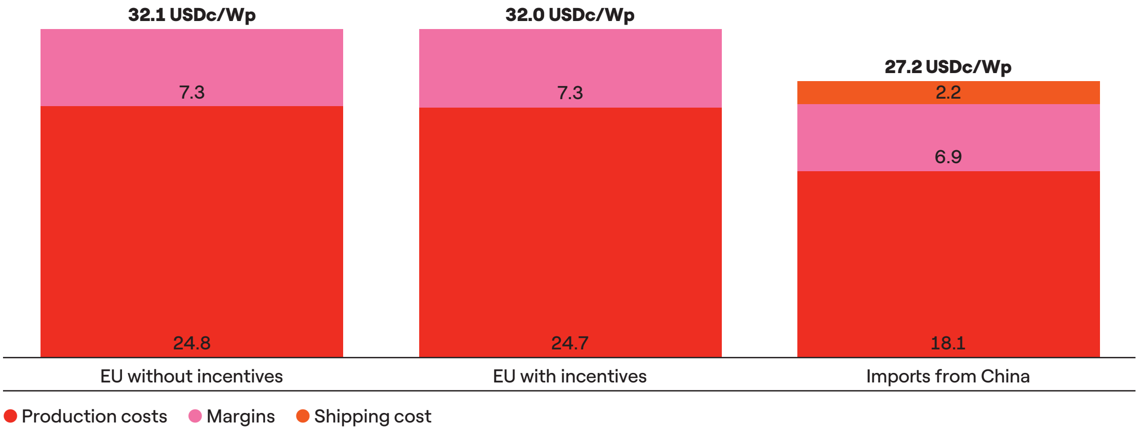
On the other hand, Europe's strategy focused on **industrial delocalization** and reliance on **global value chains**. This situation generated a **competitive gap** with China, which appears to have a more attractive business model: even if Europe had the same initial investments (CAPEX) and operating expenses (OPEX) as China, **economies of scale, labour costs, social and environmental standards**[5] **and incentives** would make the Chinese product cheaper. Nevertheless, to fully reap the benefits of the current energy transition and reduce the risk associated to the supply chain, **green industrial supply chains must be created, developed and strengthened** to support the growth that is expected in the coming years and to **reduce the dependence on third countries**, hence increasing the geostrategic resilience. In this process it will be crucial to **avoid moving from energy dependence to technological dependence**, to decrease the reliance on countries with low political stability and reduce the risk of weaponization of technology trade by third party suppliers[6].

However, when it comes to the photovoltaic value chain – as of today – the European competitiveness along the value chain is weak. **Without incentives**, the cost to produce a PV module in Europe is equal to **32.1 USDc/Wp** (**18% higher** than the corresponding cost in China). Also considering the current EU incentives, the European solar manufacturing cost would decrease only by **0.1 USDc/Wp**, not enough to make the European value chain competitive compared to China. Thus, as represented in Figure 92, it is cheaper today for Europe to **import PV modules, already assembled, directly from China**.

5
China has been accused to adopt forced labor in its polysilicon facilities, especially in Xinjiang.

6
The European energy dependence was evident in 2022, with extra-EU imports of energy products (solid fuels, natural gas and petroleum oils) rising to EUR 52 billion (+122% vs 2021), due to the higher prices of these commodities following the Russian invasion of Ukraine.

Figure 91 → **The European solar manufacturing costs, 2023** (USDc/Wp)



N.B. Shipping cost is assumed equal to 0 for locally manufactured solar modules.

Source → Elaboration The European House - Ambrosetti and Enel Foundation on J. Lindahl, ESMC and WCPEC Milano, 2023.

The same is true for both batteries and heat pumps value chains. In fact, to date, the cost of producing a battery in Europe is USD 169 per kWh, **33%** higher than in China (USD 127 per kWh). Concerning the **heat pump market**, in Europe the average cost of a heat pump is USD 2,000, whereas it can be purchased for around **USD 1,200 by importing it from China** (USD 800 less, equal to -40% of the cost).

Besides the development of a European (and Italian) value chain along these three sectors, the EU needs to make sure that the domestic products are fairly competitive on the market. This requires action on **2 main fields**:

- **Reducing the cost** of European products.
- Creating a **level playing field** in global production conditions to smooth the structural differences between the European market and the Chinese market.

→ Reducing the cost of European products

As already discussed, at current costs, domestic production of the key technologies for decarbonization in Europe **is more expensive than in China** and the US. **Pursuing a strategy of domestic industry development will of course come at a cost**. If specific actions are not taken to **redistribute the economic and strategic benefits generated by the strategy itself**, this cost will, in the short to medium term, turn into a higher price for final users. Nevertheless, **several implicit or explicit benefits and economic savings can be accounted for at country level, thus reducing the cost that countries, companies, and citizens will have to bear**. In this sense, the main task of policymakers will be to **revert toward citizens the benefits and economic savings** that the domestic production of key technologies for decarbonization can bring.

Within this context, the EU can take advantage of some levers that can be favourable for European-based companies and citizens, such as:

- **Reducing imports** from third countries.
- **Economic and social benefits** of investing in local value chains.
- **Achieving economies of scale**.

→ **Import reduction**[7]: Investing in local value chains can significantly reduce the exposure on third countries, **mitigating the possibility of value chains disruptions**. At the same time, creating a local value chain will significantly **decrease the cost of imports**, given the high dependence on third countries. In the case of the photovoltaic value chain, for instance, in 2022 only the European Union **imported PV modules** for a value equal to **EUR 22.7 billion** (**53%** of the Chinese modules exports). These costs – associated to the imports of photovoltaic modules from non-EU countries – if not properly addressed are likely to **weight even more on European budgets between now and 2030**. In fact, if European dependence on module imports remains the same as today (**78%**), Europe would import about **334 GW** of photovoltaic modules to reach the photovoltaics' installed capacity target by 2030, resulting in a cumulated cost of **EUR 90 billion**. On the other hand, **reaching a production capacity of 30 GW** (as envisaged by the "Net Zero Industry Act") by 2030, the European Union would import **254 GW** (**80 GW less** than in the former scenario), incurring in a cost of **EUR 69 billion**. In summary, **reaching the "Net Zero Industry Act" target in the photovoltaic value chain would guarantee a cumulated net benefit of EUR 21 billion from reduced imports**.

Concerning batteries, as of 2022, Europe imported **45.9%** of its domestic demand, equal to an economic value of **EUR 9.6 billion**. If European Union will maintain this level of import, this situation could undermine both the **resilience in strategic value chains** and the **economic competitiveness**, given the need to increase the annual deployment rate to reach decarbonization targets by 2030. In fact, with a 45.9% import rate, under the EBA scenario (European expected demand of 1,000 GWh) Europe would import by 2030 a total value of **EUR 663 billion**. At the same time, reaching the target of 90% of battery demand by 2030 through domestic production could allow Europe to import up to EUR 382 billion, thus enabling savings equal to around **EUR 281 billion**. Under the NZIA scenario instead (European expected demand of 611 GWh) Europe would import by 2030 a total value of **EUR 355 billion**. At the same time, reaching the target of 90% of battery demand by 2030 through domestic production could allow Europe to import up to EUR 177 billion, thus enabling savings equal to around **EUR 178 billion**.

7
To calculate the cumulative import reduction from now until 2030 for photovoltaics and batteries, two opposite scenarios were considered. In the first scenario, the target set by the "Net Zero Industry Act" by 2030 is reached linearly from current European manufacturing production. In the second scenario, a constant import level, equal to today's value is considered, which therefore considers a more limited growth of European industry, maintaining current shares. The savings due to the import reduction is thus the difference between the first and the second scenario. With reference to heat pumps, the first scenario considers a 60% domestic production target of the additional 60 million units by 2030. The second scenario assumes a constant domestic production, equal to the 2021 value (77% of 2.12 million units). Also in this case, the savings due to the import reduction is the difference between the first and the second scenario. The conversion from units to economic value has been estimated by applying the 2021 import share of domestic and import production to the number of sold units in 2021.

In the case of the **heat pumps** value chain, in 2021 the European Union imported **23% of its domestic demand**, equal to an economic value of **EUR 902 million**. Even though this value chain is characterized by a lower import dependence, the rising domestic demand of heat pumps has been met mainly by the growth of imports (+775% imports between 2013 and 2021), due to a stagnant domestic production. Assuming a fixed level of production, equal to around 1.7 million units in 2021, between 2022 and 2030 the EU will be able to cover only **25% of domestic demand** (around 15 million units), resulting in a cumulated cost of import of **EUR 81.3 billion**. On the other hand, if the 60% NZIA domestic production target will be met, the cumulated cost of import in 2030 will be of **EUR 43.4 billion**, thus enabling savings equal to around **EUR 38 billion**.

Therefore, as a result, the cumulative net benefit at 2030 of meeting NZIA (and EBA for batteries) targets in the selected supply chains in terms of import reduction would be between EUR 237 and 340 billion[8].

→ **Investments along the value chains development and economic and social benefits**: From an economic point of view, **investments in local value chains** can, on the one hand, reduce the exposure on third countries, and, on the other hand, create **systemic effect on the whole economy** while achieving the yearly domestic production capacity set by the "Net Zero Industry Act". Regarding the photovoltaic value chain, to reach the NZIA target along all the phases of the value chains, the total capital expenditure is estimated to be between **EUR 10 and 15 billion**. Concerning batteries, investments needed to reach the target of 90% of battery demand (in the NZIA and EBA scenarios) by 2030 domestically produced are expected to be between **EUR 80 and 130 billion** along the overall value chain. Regarding the heat pumps value chain, manufacturing capacity investments needs to reach NZIA target are expected to be around **EUR 6 billion**. These investments can have a **huge systemic effect on the whole economy**, considering both the **direct** and the **indirect** and induced components, linked to the activation of new local value chains; as analyzed in the Study "*Net Zero E-conomy 2050*[9]", the economic multiplier linked to the development of RES and electrification technologies is equal to **2.64**[10]. Hence, **investments in the photovoltaic, batteries and heat pumps value chains can have a massive impact into the economy, generating up to EUR 302 billion, around 2.0% of the EU Gross Domestic Product in 2022**[11].

8
The cumulative net benefits at 2030 are the sum of the estimated net benefits in the three supply chains under analysis. The range of values arises from the two different assumptions (EBA vs. NZIA) used to calculate the cumulative import reduction for batteries.

9
Source: "*Net Zero E-conomy 2050. Decarbonization roadmaps for Europe: focus on Italy and Spain*", by The European House – Ambrosetti and Enel Foundation, 2022.

10
Economic multiplier of the "Net Zero" scenario, which envisages a more ambitious decarbonization path. This economic multiplier is taken from the Study "*Net Zero E-conomy 2050. Decarbonization roadmaps for Europe: focus on Italy and Spain*" by The European House – Ambrosetti and Enel Foundation, and refers to Italy. It is used as a proxy to estimate the possible spillover effects generated at the European level.

11
Source: Eurostat. EU27 Gross Domestic Product is equal to EUR 15,810.3 trillion in 2022.

→ **Economies of scale**: Lastly, European companies – or companies that expect to set up manufacturing capacity in Europe – **will only succeed if they are able to grow fast to reach large scale** and to exploit synergies across manufacturing plants. A key factor in scaling up the industry is also to build a viable ecosystem of equipment suppliers, in a context in which **equipment suppliers are scarce in upstream segments.** As explained earlier in this Study, in Italy **there are no suppliers of production equipment necessary to process polysilicon**, while there are **2 companies** supplying production equipment for the modules stage, the market segment in which Italy is most present. **Without sufficient scale, the industry will not spur the necessary investments and competition among equipment suppliers**. This is true especially for the heat pump value chain and, in particular, to produce **compressors** that require large economies of scale to reduce costs and remain competitive in the market. Concerning batteries instead, it should be noted that gigafactories need **5 years** to ramp up in EU, thus highlighting a possible weakness in the short-term to increase domestic demand. As for the photovoltaic value chain, even though detecting the exact scale thresholds is difficult, on plant level the leading players typically have **3 to 5 GW at the cell and module level**, and **around 10 GW for ingot and wafer, and polysilicon**[12]. The scale levels have consistently increased over time as the industry has matured. In other terms, without large scale, European players will have a hard time to succeed in being competitive: about **4 USDc/Wp can be reduced by achieving a sufficient scale**[13].

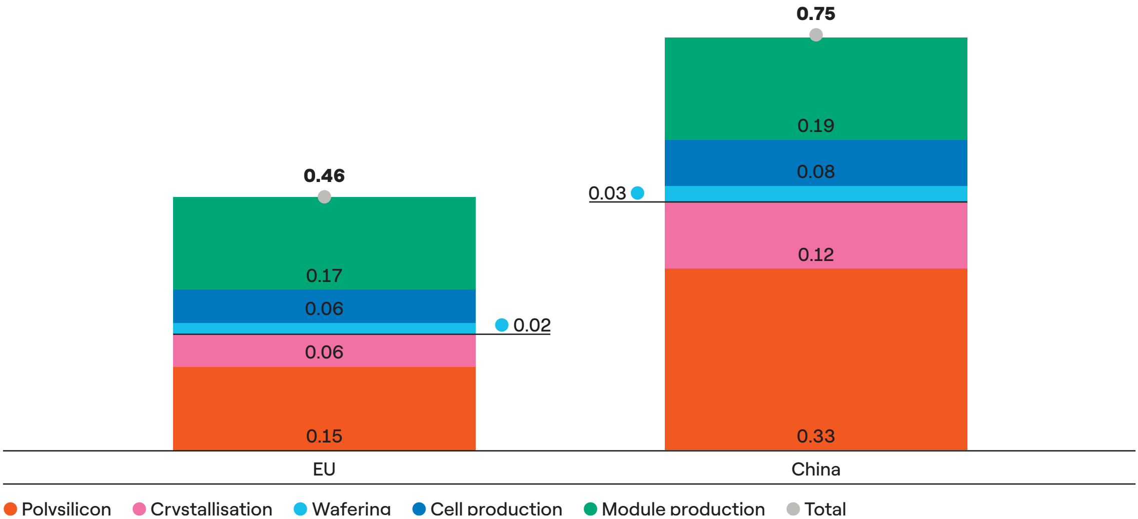
→ Creating a level playing field

As of today, the emission intensity of the manufacturing production is **significantly lower in Europe than in China in all the value chains analysed**, especially regarding photovoltaics and batteries. For instance, when it comes to the production of a PV module, the EU has a lower carbon footprint (0.46 kg CO_2-eq./Wp) compared to PV produced in China (0.75 kg CO_2-eq./Wp), which relies heavily on **coal for power**. Within this context, the **Carbon Border Adjustment Mechanism** (CBAM) **might slightly reduce the Chinese competitive advantage in the manufacturing of PV modules**. In fact, **CBAM might reduce the cost differential between European and Chinese made PV by 3.3 EURc/Wp**[14].

12
Source: Wood MacKenzie, March 2022.
13
Source: "*Building a competitive solar-PV supply chain in Europe*", McKinsey & Company; December 13, 2022.

14
Source: Professor Andreas W. Bett, Fraunhofer ISE, University Freiburg, "*The Promise Towards Terawatt Photovoltaics*". The difference between the cost of modules produced in EU with respect to the ones produced in China is equal to 4.8 EURct/Wp (the cost of Chinese modules is 85% the cost of EU modules).

Figure 92 → **Emissions produced along the PV value chain in EU and China** (kg CO_2-eq./Wp)



Source → Elaboration The European House - Ambrosetti and Enel Foundation on Fraunhofer data, 2023.

Concerning batteries, instead, Europe reports **33%** lower emissions compared to China, 31% compared to Japan and 25% compared to South Korea. In fact, the emission intensity of battery production in Europe is equal to 67 kg CO_2 per kWh, whereas in China is equal to 100 kg CO_2 per kWh.

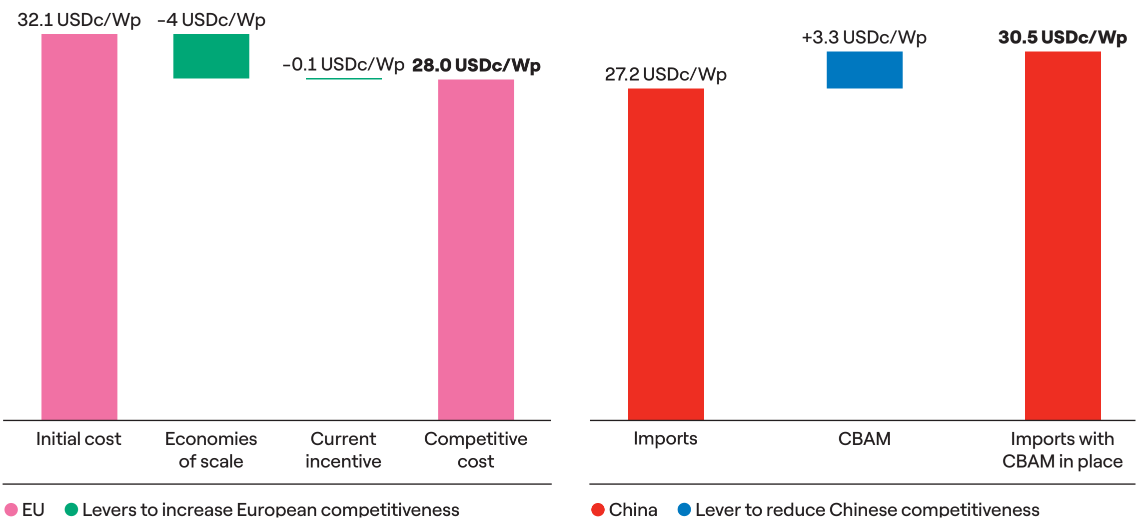
Regarding heat pumps, the total lifetime GHG emissions per MWh of annual useful heat output for heat pump in Germany is around **44% lower than China** (approx. 0.9 tCO_2-eq. vs. 1.3 tCO_2-eq.). Considering the lower inter-regional trade in the market due to transport costs, regional conditions, and local legal requirements, it can be deduced that the **heat pumps produced in Europe are characterized by lower levels of CO_2 emissions**.

European policies should be directed, on the one hand, to **develop the domestic manufacturing industry** (by defining investment incentives through support for CAPEX and OPEX and adjusting the regulatory framework) and, on the other hand, to protect its structure and development through the **establishment of virtuous production criteria** (such as non-price-related ESG criteria).

Overall, **creating a level playing field** (i.e. with the introduction of the Carbon Border Adjustment Mechanism) while, at the same time, **establishing large-scale local value chains** might **reduce or eventually close the gap** between European and Chinese manufacturing costs, also in those value chains which - as of today - are not competitive from an economic point of view. For example, **economies of scale, short term incentives and CBAM mechanism** could even reverse the European Chinese PV cost gap[15]. In fact, taking in consideration **photovoltaics** as a reference, there are some **potential levers** which – if properly exploited – can make European PV companies extremely competitive. On the one hand, there are levers able to increase European competitiveness both in the **medium-long term**, such as the **economies of scale** (about **4 USDc/Wp** can be reduced by achieving a sufficient scale), and in the **short term**, for instance looking at **current European incentive** (**0.1 USDc/Wp**). On the other hand, there is a **further lever to increase European competitiveness by reducing Chinese one**: in fact, the implementation of the **CBAM** might be able to increase the manufacturing cost up to **3.3 USDc/Wp**. **All these measures could reverse**[16] **the European-Chinese cost differential, reducing the European solar manufacturing cost by 13%** (reaching a value of **28.0 USDc/Wp**), and **increase the Chinese one by 12%** (reaching a value of **30.5 USDc/Wp**).

However, it is important to underline that **this is an illustrative estimate**, since it does not take into account neither **time constraints** (it takes time to reach economies of scale) nor a **possible Chinese reaction** to a significant reduction in imports from Europe (further reducing its production costs). However, this representation shows that **it is possible to carry out a clear pathway to improve competitiveness in Europe**.

Figure 93 → **The potential levers to increase European solar companies' competitiveness** (solar manufacturing costs, USDc/Wp)



Source → Elaboration The European House – Ambrosetti and Enel Foundation on Fraunhofer data and various sources, 2023.

15
This estimation does not consider the improvement in Chinese costs.

16
This calculation doesn't take into account the evolution of Chinese manufacturing markets, which could of course improve its economic performance.

In addition to this, as explained earlier, there is a significant benefit coming from the **investments in local value chains**, which could **reduce dramatically the imports** from third countries and create **systemic effect on the whole economy** while achieving the yearly domestic production capacity set by the "Net Zero Industry Act", as represented in Figure 94. As a matter of fact, adding the **net benefit of reduced imports** and the **direct, indirect and induced economic benefits** coming from **investments** needed to reach the NZIA targets for the creation of local supply chains in the three technologies under analysis, the overall return on the investments would be equal up to **EUR 642 billion**, with a corresponding **multiplier between 4 and 7 times the initial investment**[17]. This **huge amount of financial resources** could be able to level out the final cost for the consumer, making European value chains **even more competitive**.

Figure 94 →

Summary view of investments to reach NZIA 2030 targets of domestic production and levers that can reduce the cost of EU products and bring benefits to European-based companies and citizens by value chains (EUR billion)

	Photovoltaic	Batteries	Heat Pumps
Investments to reach the NZIA 2030 targets of domestic production	EUR 10-15 bln	EUR 80-130 bln	EUR 6 bln
↓ Levers that can reduce cost of EU products and bring benefits to European-based companies and citizens			
Import reduction	EUR 21 bln	EUR 178-281 bln	EUR 38 bln
Direct, indirect and induced economic benefits	EUR 16-25 bln	EUR 131-215 bln	EUR 62 bln
Total return on investments		EUR 446-642 bln	

Source → Elaboration The European House - Ambrosettii and Enel Foundation on "Net Zero Industry Act" Staff Working Document of the European Commission, Eurostat and Istat, 2023.

17
The multiplier is obtained dividing the overall return on the investment by the estimated minimum and maximum investments in the 3 decarbonization-related industrial value chains.

The possibility to achieve these significant benefits again suggests the importance of developing these crucial supply chains at sufficient scale. Further targeted measures may be required to trigger and sustain the large-scale investments needed. To this extent, in the following paragraphs the Study proposes **a strategic vision and a set of policy actions at Italian and EU level** aiming at this goal.

→ The prerequisite: a new strategic vision

In the last 30 years, China has implemented a strategy **aimed at achieving global leadership** in a few key value chains, setting out specific policies aimed at creating a robust industrial base. On the contrary, European industries have focused on **industrial delocalization** and **global value chains**, thus lacking a strong unitary industrial and commercial policy and vision. This led Europe to lose competitiveness and know-how in key industrial domains. Only recently the EU and its Member States, including Italy, have slowly started to shift their strategic posture to address this issue.

This Report suggests that Europe and its Member States should adopt a **new strategic vision** aimed at developing a competitive European-wide decarbonization industry, implementing **integrated and coordinated European value chains** and promoting **greater diversification in the supply of technology** components and **critical raw materials**, also leveraging on the already existing partnerships and complementarities with countries outside the EU.

In particular, the term "**European-wide**" refers to the fact that key decarbonization-related industrial value chains should leverage **full integration and coordination** among Member States, meaning that the specific know-how present in some countries concerning – for instance – the components phase of the value chain should be complemented with other countries' skills and technologies related to the assembly phase of the value chain.

In this sense, the creation of **specific hubs and knowledge-sharing mechanisms** at the European and national level for individual components and technologies is proposed. As a result, the development or strengthening of identified key decarbonization-related industrial value chains would be fostered. Indeed, **sharing knowledge and skills** between different countries would lead to greater opportunities and production capacities for European companies active in the supply chain stages.

Along the way to a greater degree of self-sufficiency, it will initially be necessary to continue importing a large share of both finished products, components, and critical raw materials. Therefore, it is first and foremost important to pursue a **greater diversification in the supply of both technology components and critical raw materials**, avoiding technological and material dependence on a single country. In this sense, the EU and Italy should leverage on the already existing geostrategic partnerships with countries outside Europe.

Also, the achievement of a greater degree of self-sufficiency in terms of materials dependence should leverage on the role that **R&D** can have in finding new solutions involving largely available and sustainable materials in the EU (as it is the case with LFP and Na-ion batteries).

Furthermore, **the relocation of production activities of European companies** (which currently produce abroad) to Europe should be **encouraged (re-shoring**) with appropriate incentive mechanisms (for instance through VAT exemptions). Similarly, with the same instruments, it is possible to adopt **friend-shoring** strategies, promoting the relocation of production activities in countries where the risk of supply is relatively lower thanks to strategic alliances.

To achieve the strategic vision identified, the Study proposes **7 policy actions at the Italian level and 4 at the EU level** that aim both at addressing the bottlenecks and reaping the benefits of the opportunities analysed in the Report. Each of these policies refers to one or more (or all) of the key decarbonization-related industrial value chains analysed in the Study.

Figure 95 → **Policy actions to develop key decarbonization-related industrial value chains in EU and Italy**

Policy level		Policy actions	Photovoltaic	Batteries	Heat pumps	Implemented: No	Implemented: Partially	Implemented: Yes
Italian level	1	Applying **streamlined and predictable permitting procedures for factories' realization**	✓	✓			●	
Italian level	2	Favoring the **realization of gigafactories** through **financial support** in terms of **CAPEX and OPEX**	✓	✓		●		
Italian level	3	Promoting decarbonization through **efficient electric technologies** such as heat pumps			✓	●		
Italian level	4	Supporting measures to ease the gas **boiler value chain conversion**			✓	●		
Italian level	5	Implementing a **clear strategy** to ensure **critical raw materials supply**	✓	✓	✓	●		
Italian level	6	Creating dedicated **green finance** mechanisms to develop value chains	✓	✓	✓		●	
Italian level	7	Facilitating **upskilling/reskilling**	✓	✓	✓	●		

Policy level	Policy actions	Photovoltaic	Batteries	Heat pumps	Implemented: No	Implemented: Partially	Implemented: Yes
European level	**1** Favoring the **distribution to companies and citizens of the strategic value** generated by the development of local supply chains	✓	✓	✓	●		
European level	**2** Promoting EU Member States coordination on **R&D** and **industrial innovation**	✓	✓	✓	●		
European level	**3** Providing **specific financial tools** to ensure that all the clean technology products installed and imported comply with **ESG criteria**	✓	✓	✓		●	
European level	**4** Establishing a **common frame for the governance** to **guarantee coordination and integration** in policy actions implementation in EU and in its Member States	✓	✓	✓	●		

Source → Elaboration The European House – Ambrosetti and Enel Foundation on various sources, 2023.

→

The proposals for action at the Italian level

1 → **Applying streamlined and predictable permitting procedures**

Policy proposal

Applying streamlined and predictable permitting procedures at all levels of the value chains, through the following actions:

- Giving **priority status** at national level.
- Relying on a **more competent Public Administration**.
- Addressing **public acceptance**.

Industrial value chain of application:
This proposal is mainly applicable to the p**hotovoltaic and battery value chains**.

Concerning the first action, it is suggested to give **priority status** at the national level to ensure rapid administrative handling and **strengthening** the offices in charge of authorization procedures. In this sense, Italy should overcome the lack of homogeneity generated by the fact that competence for mining is devolved to the **Regions**, with the central government retaining the power to set out guidelines on mining research, the collection and processing of mining data, and to determine national mining policy.

Second, streamlining and predictable permitting must leverage a **more competent Public Administration**, provided with qualified and independent structures. It must also be better supported by private actors and be able to engage in constructive dialogue with the relevant stakeholders, be they companies or citizens. It also appears necessary to overcome the current presence of **multi-level governance**, which today causes a proliferation of bodies that further 'weigh down' procedures.

Finally, in addition to the procedural and administrative problems, the "**NIMBY ("Not In My Back Yard") Syndrome**" blocks or slows down the realisation of public works at a local level. To face this problem, there is the **need to involve citizens**, within a **structured process of consultation and deliberation**. This factor represents a key point in raising awareness about the importance of bridging the gaps in facilities, an enabling factor which is necessary in the medium to long term to enhance the role of the circular economy and the green transition in the country.

Overall, despite the "Critical Raw Materials Act" has provided with the possibility to obtain faster authorization procedures for strategic projects, all the other issues identified need to be addressed specifically at the Italian level.

2 → Favouring the realization of gigafactories

Policy proposal

Favouring the realization of gigafactories at all levels of the value chains, through the following action:

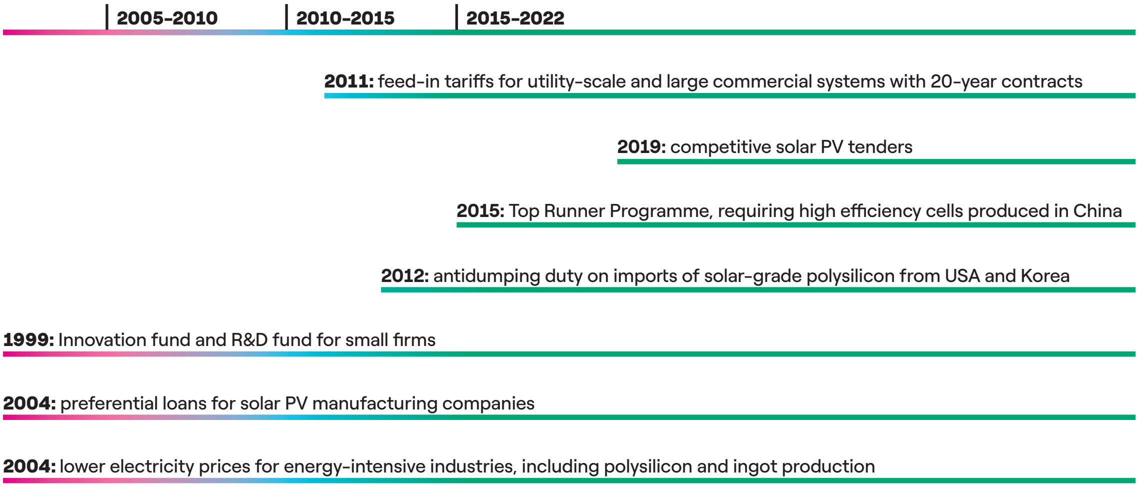
- Providing **competitive incentives** and additional resources both in terms of **CAPEX (e.g., tax exemption on investments) and OPEX (e.g., energy costs)**.

Industrial value chain of application:
This proposal is mainly applicable to the **photovoltaic and battery value chains**.

When it comes to **competitive incentives** - as highlighted in the previous chapters of the Report - China's competitive advantage in the green value chains is the result of **targeted industrial policies** carried out by the Chinese government throughout the years. Suffice it to say that Chinese **capital subsidies** can cover **34%** of the investment cost, whilst European subsidies cover only 3%. At the same time, Chinese industrial **policies have targeted also operating costs** (covering **27%** of the investment cost through utility subsidies and relaxed labour laws, whilst **in the European Union there are currently no subsidies on operating costs**), thus creating a more attractive environment. Over the years, the Chinese government directly or indirectly funnels credits and investment into strategic sectors, through so-called **government guidance funds** that combine public and private investment as well as lending by **state-owned banks**: it is estimated that, in the last 10 years, Chinese industry has received **more than EUR 170 billion in subsidies**[18].

18
Source: Enel internal data.

Figure 96 → **The supply and demand policies targeting solar PV manufacturing in China** (illustrative)



Source → Elaboration The European House - Ambrosetti and Enel Foundation on IEA data, 2023.

In this context, it is crucial to favour the construction of gigafactories for photovoltaic and batteries[19] by providing **competitive incentives** both in terms of **CAPEX** (i.e., tax exemption on investments) and **OPEX** (e.g., energy costs and labour costs) for the entire value chains, to reduce the competitiveness gap between Europe and China and proving additional resources that can cover **100%** of the **funding gap**[20]. This would allow to complement national resources with **additional resources from the EU**, promoting the development and enhancement of manufacturing plants. In this regard, the European Commission aims to give a structural answer to investments and incentives needs by proposing a **European Sovereignty Fund** as part of the review of the multi-annual financial framework.

19
Heat pumps represent a less mature market in which Europe already can count on a relatively good positioning.

20
It corresponds to the difference between the costs and revenues of an activity that contributes to climate objectives compared to the costs and revenues of a similar, but less environmentally friendly activity.

3 → **Promoting decarbonization through efficient electric technologies such as heat pumps, and guaranteed contracts for heat pumps installation**

Policy proposal

Promoting decarbonization through efficient electric technologies such as heat pumps and guaranteed contracts for the installation of heat pumps, through the following actions:

- Establishing **guaranteed contracts**.
- Creating targeted incentives for building renovations.

Industrial value chain of application: This proposal is mainly applicable to the **heat pumps value chain**.

To promote the development of the heat pump value chain, it is crucial to establish **guaranteed contracts** that ensure the proper performance and installation of heat pumps. These contracts would provide customers with the assurance that their heat pump systems will be installed correctly and meet the expected efficiency and performance standards. By implementing such contracts, the Italian government can instil confidence in consumers, encourage the adoption of heat pump technologies, and drive the growth of the value chain. Moreover, these contracts would also facilitate the monitoring and maintenance of heat pump systems, ensuring their long-term effectiveness and minimizing potential issues.

In addition to guaranteed contracts, it is essential to implement policies that support the **construction and renovation of buildings** in a way that favours the transition to heat pump technologies. This can be achieved through **targeted incentives** aimed at gradually phasing out fossil fuel boilers. By offering **tax deductions** for the replacement of heating systems (covering both the equipment and building adjustments) until at least 2030, the government can alleviate the financial burden associated with the transition. Furthermore, additional support, such as **cost reductions for increasing the power capacity of the electric meter**, can be provided to further incentivize the adoption of heat pumps. Additionally, offering enhanced incentives for **smart heat pump systems**, which can interact with the electric grid in real-time, would encourage the deployment of advanced and efficient heat pump solutions.

4 → **Supporting measures to ease the gas boiler value chain conversion**

Policy proposal

Easing the gas boiler value chain conversion, through the following action:

- Implementing **support mechanisms in terms** of upskilling/reskilling programmes and system of **incentives and financial schemes**.

Industrial value chain of application:
This proposal is mainly applicable to the **heat pumps value chain**.

To ensure effective decarbonization of heating, the fuel switch to **solutions based on efficient electrification** (e.g., heat pumps) appears to be the solution with the **highest benefits with respect to the costs**. Therefore, there is a need to facilitate the **transition of the gas boiler manufacturing sector** to new technologies, in order to **enhance Italian leadership and excellence** at the international level.

The development of the heat pump value chain in Italy requires a strategic **shift towards the production of heat pump** components and assemblies. Currently, the **gas boiler value chain** dominates the national and European markets. To ensure a successful transition, it is imperative for the Italian government to implement proactive policies that incentivize and support the conversion process. By favouring the transformation of the mature gas boiler value chain into a robust heat pump value chain, Italy can lead the way in sustainable heating technologies and contribute to the reduction of greenhouse gas emissions.

To effectively achieve this goal, it is essential to establish **appropriate mechanisms and tools** that provide guidance and support for the value chain conversion. The mechanisms should encompass specific measures aimed at **facilitating the adoption of heat pump technologies** and the production of associated components and assemblies. Furthermore, the programmes should also address any potential barriers or challenges associated with the transition, such as **workforce training and technical standards**. Such tools for **training and updating** with respect to new technological and regulatory standards (also in view of the evolutions on the F-Gas issue), represent an opportunity to facilitate a **fair transition particularly for small and medium-sized installation companies**. To drive the necessary transition towards the adoption of more sustainable heating systems, the policy proposal must address the dual goals of **supporting gas boiler producers** during their transition to heat pump production, while simultaneously fostering the development of the heat pump value chain. This approach **ensures a just and equitable transition for existing industry stakeholders** while creating a conducive environment for the growth and advancement of heat pump technology.

Finally, the implementation of a **system of incentives and financial schemes** will play a crucial role in driving the conversion of the gas boiler value chain towards the production of heat pump components and assemblies, providing support in terms of CAPEX (e.g., tax exemption on investments) and OPEX (e.g., energy costs and labour costs), reducing the upfront costs associated with adopting heat pump technologies.

5 → **Implementing a clear strategy to ensure critical raw materials supply**

Policy proposal

Implementing a clear strategy to ensure critical raw materials supply, through the following actions:

- Achieving **greater diversification of supply**.
- Building a **robust recycling capacity**.

Industrial value chain of application:
This proposal is applicable to **photovoltaic, battery and heat pumps value chains**.

To ensure the supply of critical raw materials it is essential the implementation of a **clear strategy**. In fact, to date, Europe has a **limited extraction and refining capacity** concerning the raw materials needed for the energy transition and this is due – and linked – at least in part to the lack of a high-level vision promoting the development of an integrated European supply chain. The policy proposals identified aim to fill these gaps and, as mentioned at the beginning of this Chapter, should be considered in a synergic and complementary perspective with the NZIA and the "Critical Raw Materials Act" proposed by the European Commission.

An initial policy area identified concerns the achievement of **greater diversification and security in the supply of critical raw materials** needed for the energy transition. To achieve this objective, it is necessary in the short-term to facilitate agreements with supplier countries with which economic, commercial and geopolitical relations are already in place, and in the medium- to long-term, to make greater use of the resources available in Europe, as also set out in the "Critical Raw Materials Act".

At the same time, it is essential for Italy to set up a **recycling capacity** adequate for the amount of end-of-life key components of decarbonization-related industrial value chains that will be present in Italy in the coming years. Recycling must represent a real mining industry for the country, helping to reduce reliance on third countries.

Consequently, an incentive system could be put in place that also takes into account the **environmental and social sustainability** of the entire life cycle of key components of decarbonization-related industrial value chains. In this sense, both concerning the opening of new mines and the construction of new recycling plants, a possible problem could relate to the NIMBY syndrome as indicated in the first policy action.

6 → **Creating dedicated green finance mechanisms**

Policy proposal

Creating dedicated green finance mechanisms, through the following action:

- Defining a premium mechanism based on **criteria other than price**.

Industrial value chain of application:
This proposal is applicable to **photovoltaic, battery and heat pumps value chains**.

To ensure that the energy transition is sustainable, it is essential that **all production outputs along the value chains** (photovoltaic, batteries and heat pumps) installed in Italy should be designed, produced and even delivered according to **clear and binding ESG criteria**. In this sense, another lever to increase the manufacturing capacity at the Italian level is to create dedicated green finance mechanisms (i.e., **SACE green guarantees**[21]) – to develop key decarbonization-related industrial value chains – that provide funds also with **premium mechanisms based on criteria other than price, facilitating access for national firms that follow ESG criteria** in designing and manufacturing components: the importance of ESG is picking up, especially when banks are involved.

The role of SACE in supporting the development of green domestic value chains

The 'Simplification' Decree Law (76/2020) gave **SACE a central role in supporting the Italian Green New Deal.**

Through the Green Guarantee instrument, issued at market conditions, counter-guaranteed by the State to a **maximum extent of 80%**, SACE can finance projects in the country aimed at **facilitating the transition to an economy with a lower environmental impact**, integrating production cycles with low-emission technologies for the production of sustainable goods and services, and promoting a new mobility with lower polluting emissions.

The **eligibility** of initiatives is assessed through due diligence on the basis of the **taxonomy** defined by the European Union. Projects must produce a **significant benefit** in at least one of the following environmental objectives, without harming any of the others:

- Climate change mitigation and adaptation.
- Sustainable use and protection of water and marine resources.
- Transition to the circular economy.
- Pollution prevention and reduction.
- Protection and restoration of biodiversity and ecosystems.

The guarantee allows sustainable companies to have **easier access to medium- and long-term finance**, with **more favorable conditions**.

Source → Elaboration The European House – Ambrosetti and Enel Foundation on SACE and various sources, 2023.

21
Additional information can be found here: https://www.sace.it/soluzioni/dettaglio-categoria/dettaglio prodotto/garanzie-green.

This would further stimulate Italian companies to develop **compelling value propositions** that include **sustainability** and **low-carbon footprint**, **full value-chain traceability**, as well as **excellent product quality**, **output performance**, and **bankability**. All these factors will contribute, on the one hand, to **develop sustainable local manufacturing capacity** and, on the other hand, to support those projects that have **the lowest GHG emissions**.

Overall, it is worthy of note to underline that Italy is already moving in this direction: a prime example, which has to be extended on a larger scale, is given by the **SACE green guarantees**, which aim at supporting the development of green domestic value chain.

7 → Facilitating upskilling and reskilling

Policy proposal

Facilitating upskilling and reskilling, through the following actions:

- Promoting high-quality programs for upskilling and reskilling.
- Creating a system of incentives to promote training activities and new hires.
- Promoting awareness about potential careers in decarbonization-related industries.

Industrial value chain of application:
This proposal is applicable to **photovoltaic, battery and heat pumps value chains**.

To enhance the domestic manufacturing production and promote the growth of the decarbonization-related industrial value chains, a key area of intervention lies in the **training of operators**. Upskilling and reskilling activities are essential to meet the increasing demand for skilled workers in these sectors. Particularly in the heat pump value chain, it is crucial to address the skill gap, as approximately 50% of current installers require reskilling to meet the ambitious "REPowerEU" installation targets. To tackle this challenge effectively, it is necessary to prioritize the promotion of **high-quality training programs** that offer both quantitative and qualitative improvements in skills. By collaborating with professional institutes, the government can foster the development of professionalization courses that equip workers with the necessary competences to thrive in these evolving industries.

To incentivize the acquisition of new competences in the decarbonization-related industrial value chains, various measures can be implemented. One approach is to utilize **tax credits**, enabling businesses to invest in training activities and obtain certifications. By offering tax incentives, the government encourages companies to allocate resources towards the development of their workforce, fostering a culture of continuous learning and skill enhancement. Additionally, **tax breaks for new hires** can further incentivize businesses to recruit and train individuals with the required expertise. These incentives can effectively stimulate the growth of skilled professionals in the decarbonization sectors, contributing to the overall development of the value chains.

Collaboration between the government, educational institutions, and industrial stakeholders is crucial for the success of training initiatives. By establishing **partnerships with professional institutes and vocational training centres**, the government can ensure that the training programs align with industry needs and standards. Furthermore, it is essential to **promote awareness** about the available training opportunities and the potential career prospects in the decarbonization-related industries. Public campaigns and information dissemination can help individuals understand the value of acquiring skills in these sectors and encourage them to pursue training and employment in the evolving value chains. By fostering a supportive ecosystem that nurtures and empowers skilled workers, Italy can strengthen its domestic manufacturing production and establish itself as a leader in the transition towards a sustainable future.

→ Proposals for action at European level

1 → Favoring the distribution to companies and citizens of the strategic value generated by the development of local supply chains

Policy proposal

Favoring the distribution to companies and citizens of the strategic value generated by the development of local supply chains, through the following action:

- Defining suitable mechanisms (e.g., fiscal) that reduce the price of domestic products.

Industrial value chain of application:
This proposal is applicable to **photovoltaic, battery and heat pumps value chains.**

As seen above, the EU can create a level playing field (e.g., by introducing CBAM) and, together with economies of scale, **reduce the competitive gap** with Chinese manufacturing products. Although not directly related to reducing product costs, there are significant benefits coming from the investments in local value chains, which could dramatically reduce the imports from third countries and create systemic effect on the whole economy while achieving the yearly domestic production capacity set by the "Net Zero Industry Act". According to The European House – Ambrosetti and Enel Foundation's estimate, the **return on investments** in industrial supply chain development to meet NZIA targets to 2030 could be as much as **EUR 640 billion**. However, these benefits **are not directly associated and linked with companies or citizens**. To be properly valued, these benefits should be transferred from the economic system to companies or citizens. It is then possible to define **financial mechanisms**, such as, for example, **VAT exemption on technologies produced in Europe**, that would make domestic products cheaper precisely because of the benefits they generate.

2 → **Promoting EU Member States coordination on R&D and industrial innovation**

Policy proposal

Promoting EU Member States coordination on R&D and industrial innovation, through the following actions:
- Fostering greater cooperation among Member States.
- Providing additional resources.
- Investing both in existing and most disruptive technologies.

Industrial value chain of application:
This proposal is applicable to **photovoltaic, battery and heat pumps value chains**.

At European level, the **policy proposal** concerns fostering greater cooperation among EU Member States on **R&D** and **industrial innovation**, to consolidate a coordinated approach in these areas and promote higher competitiveness of European industries. In addition, it is essential, on the one hand, to invest more in existing and more widespread technologies (as in the case of lithium batteries and in particular LFP batteries) and, on the other hand, to launch pilot projects on the most disruptive technologies (for example, sodium batteries) that present the benefit of being largely available in the EU.

3 → **Providing specific financial tools for green value chain development**

Policy proposal

Providing specific financial tools for the development of the green value chains, through the following action:
- Defining **binding ESG criteria**.

Industrial value chain of application:
This proposal is applicable to **photovoltaic, battery and heat pumps value chains**.

Also, as proposed for Italy, it would be desirable to **provide specific financial tools** to ensure that all the clean technology products (photovoltaic, batteries and heat pumps) installed and imported in the EU are **designed, manufactured and delivered following binding ESG criteria**. This mechanism would allow European companies to have a **more attractive environment**, hence stimulating investments in green domestic value chains through an easier access to financial capital.

Overall, despite some national governments are already implementing **non-price criteria** when selecting projects in renewables (RES) auction winners, at the European level there is no such a similar approach, creating differences among Member States.

Non-Price criteria in renewables auctions

An additional instrument to serve the purpose of establishing a robust EU and Italian value chains in the major green technologies, **while not decreasing the speed of decarbonization**, is the introduction of **non-price-based criteria in renewable auctions**.

National Governments have the possibility to apply **up to 30%** of non-price criteria when selecting projects in renewables (RES) auction winners. Non-price criteria can refer, for instance, to sustainable and innovative manufactured PV panels.

A recent interesting example of an EU country that has applied such criteria in renewable tenders is **France**. The French **competitive contracts for difference** system used the minimum amount of price criteria for allocation set by CEEAG (Guidelines on State Aid for Climate, Environmental Protection) at **70%**, to include **30%** non-price-based criteria in the final score for a bid. "**Local content**" was also comprised in the remaining 30% of the scoring criteria.

A similar approach can be pursued at the European level to ensure that in every Member State part of those non-price criteria will be dedicated to the support of the domestic green value chains.

Source → Elaboration The European House - Ambrosetti and Enel Foundation on various sources, 2023.

4 → **Establishing a common frame for the governance innovation at EU level**

Policy proposal

Establishing a common frame for the governance, through the following actions:

- Creating platforms for collaboration, knowledge exchange, and joint decision-making.
- Fostering communication channels and promoting transparency.
- Monitoring and evaluating the effects of policy actions.

Industrial value chain of application:
This policy is applicable to **photovoltaic, battery and heat pumps value chains**.

To ensure a cohesive and synchronized approach to the development of domestic decarbonization-related industrial value chains, it is essential to establish a **common governance framework** at both the European and Member State levels. This framework should encompass mechanisms that promote **coordination and integration among stakeholders** involved in policy actions. By creating **platforms for collaboration, knowledge exchange, and joint decision-making**, Europe can leverage collective expertise and resources to drive the development of key value chains. Additionally, the governance framework should facilitate the **alignment of national policies** with European objectives, ensuring a coherent and unified approach towards achieving decarbonization goals.

The establishment of mechanisms for coordination and integration within the governance framework is crucial to streamline policy actions across different levels of governance. This includes creating platforms for regular dialogue and information sharing among relevant stakeholders, such as policymakers, industry representatives, research institutions, and civil society organizations. By **fostering communication channels and promoting transparency**, Europe can facilitate the exchange of best practices, identify synergies, and address potential conflicts or gaps in policy implementation. Moreover, the governance framework should enable the integration of policy measures, funding mechanisms, and regulatory frameworks, ensuring a comprehensive and consistent approach to developing domestic decarbonization-related industrial value chains.

A common governance framework should also support the **monitoring and evaluation of policy actions**, providing a basis for evidence-based decision-making and iterative improvements. By establishing clear metrics, targets, and indicators, Europe can assess the progress and effectiveness of policy actions in developing key value chains. This includes tracking investment levels, technological advancements, job creation, environmental impacts, and social benefits. Additionally, the governance framework should facilitate periodic reviews and assessments to identify areas of improvement and recalibrate strategies as needed. By adopting a systematic and iterative approach to policy implementation and evaluation, Europe can enhance the overall effectiveness and efficiency of measures aimed at developing domestic decarbonization-related industrial value chains.

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