IAPI: ItaliAn network
for Photovoltaic R&I

A Strategic Plan for Research and Innovation to Relaunch the Italian Photovoltaic Sector and Contribute to the Targets of the National Energy and Climate Plan

This document is the result of a joint effort of the Italian R&I community operating in the photovoltaic sector. Senior Italian researchers and innovation managers with an active role in European and international organisations (EERA, PV-ETIP, IEA) have worked with the rest of the community to translate the priorities of the PV Implementation Plan of the SET Plan, into a comprehensive action plan with clear objectives and expected economic and strategic impact. This initiative goes hand in hand with the plans of the European PV industry to relaunch large-scale manufacturing in Europe along the whole value chain and is inspired by the R&I “missions” of Horizon Europe.

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Executive Summary

At the dawn of an imminent global economic crisis triggered by the coronavirus pandemic and in the middle of an even deeper environmental and social crisis due to the manifold effects of climate change and its causes, Research and Innovation (R&I) should be at the forefront of a coordinated action to find solutions for the benefit of the common good.

Energy transition from fossil fuels to renewable energy is one of the most urgent and effective actions to cut Carbon emissions and curb global warming. Photovoltaics (PV) is key part of the solution as recognised also by the Italian Integrated Energy and Climate Plan, where solar electricity generation in Italy is set to treble by 2030 and play the most important role in the Energy Transition process.

The Italian Photovoltaic R&I Community believe that tackling climate change and the connected social and environmental problems, requires a paradigm change in terms of ambition, strategy, organisation as well as public and private investments. A concerted and cooperative approach in line with the spirit of the "Missions" of Horizon Europe is essential to achieve solutions on the same scale of the problems we are facing.

During the last three years this concept has been developed by the whole community, into a collaborative programme whose structure and priorities formed the basis of the Italian contribution to the SET Plan implementation plan of the photovoltaic sector in late 2017.

The work was coordinated by a team of senior academics and researchers representing Italian public research organisations in the European Energy Research Alliance (EERA) and by the Italian member of the SET Plan Working Group on Photovoltaics, under the supervision of the Italian Representatives in the SET Plan Steering Committee.

The Italian contribution to the **PV Implementation Plan** was the **result of a three-stage consultation** process and was organised around **two national "flagship activities"**, that is "Innovative Technologies for Modern Utility-Scale PV" and "Italian BIPV/PIPV value chain", each containing 9 tasks connected to the expertise and to the specific plans of each R&I organisation.

The SET Plan is now in its actual implementation phase when **Member States** are **urged to translate the priorities contained in the Implementation plans**, including Photovoltaics, **into National projects and investments**. The implementation effort is also supported and monitored by the European Commission who is funding the **Horizon 2020** CSA Project "**PV IMPACT**" fully devoted to the PV Implementation Plan.

For Member States like Italy, who subscribed to Mission Innovation and to the commitment to double public spending on clean energy innovation, the scale of the actions is also expected to be coherent with this commitment. **Italy still does not have a specific scheme to fund R&I in the field of Photovoltaics within a clear strategic programme linked to technological, economic and environmental objectives and targets**.

As a follow-up of the coordinated effort, put forward to support the preparation of the PV Implementation Plan of the SET Plan, the Italian R&I community has discussed with the main industrial stakeholders of the PV sector, over the last three years, in order to **identity a coherent set of actions** which could **trigger and sustain** the rebirth of an **Italian PV value chain** and **contribute to** the objectives of the **Italian Integrated Energy and Climate Plan**. Most of these initiatives have been supported by PV IMPACT.

Over the last few months, after the outbreak of the COVID-19 pandemic, the discussion has been focussed on the **impact** a coherent and ambitious R&I plan for the PV sector, can have on the **economic and social recovery from the effects of the lockdown**.

The following are the **key objectives** of the actions proposed by the Italian R&I network of the PV sector:

1) Relaunch innovation-based PV industry in Italy and in Europe for utility-scale applications, both in the upper part of the value chain (the first priority being solar cell manufacturing) down to the very bottom of the value chain (operation, management and upgrade of existing PV plants)
2) Develop new and multisectoral value-chains for the development and manufacturing of innovative products with an integrated PV function (building components, vehicles, greenhouses, etc)
3) Develop solutions for the intelligent use of photovoltaics in distributed generation and Energy Communities
4) Maximise the coordination and the synergy across the network of Italian R&I organisations operating in the PV sector, in order to foster collaborative actions all along the TRL scale, make technology transfer more effective and strengthen the R&D effort towards high priority and high impact targets

The proposed programme is articulated in **three types of synergic actions**:

1) Strategic R&I projects, where the best of know-how and lab facilities throughout the country participate in a collaborative effort to meet the R&I targets set for each of the two flagship sectors. These projects should be based on a cooperative, rather than competitive, approach as proposed for the missions of Horizon Europe.
2) A national “distributed laboratory” of R&I, that is a strong coordination scheme among public research organisations, private industrial research laboratories, regional technopoles and others, to achieve the necessary critical mass required by the national strategic projects, to reduce redundancies, optimise the use of the lab infrastructures and to stimulate synergies among the different organisations.
3) National facilities for industrial prototyping, to be created as independent industrial-grade centres, fully devoted to the pre-production development of product prototypes or novel manufacturing processes.

The **strategic projects** are meant to maximise the effort towards the key scientific, technological and innovation targets which are expected to foster the competitiveness of the national and the European PV sector and provide industries with efficient, sustainable and environmentally-friendly technological solutions.

The nationwide “**distributed laboratory**” and the new **national industrial-prototyping facilities** should **complement each other** to operate as an organic infrastructure linking R&D all the way to industrial implementation and scale-up with a shared effort to overcome the so called “valley of death” of innovation. The national distributed laboratory should enable the transformation of proof-of-concepts (TRL 3) into validated or demonstrated technologies (TRL 5-6), while the national prototyping facilities should be exclusively involved for the last steps of the TRL ladder starting from the prototypisation phase (TRL 7) to the final demonstration of competitive manufacturing (TRL 9).

The following table summarises the **key strategic actions of the proposed programme**, divided between the two flagship activities of the SET Plan Implementation Plan which have been renamed to reflect the evolution of the PV sector over the last three years.

<table>
<tr><th></th><th>Utility-scale Photovoltaics</th><th>Integrated PV for distributed generation</th></tr>
<tr><td>Strategic Projects
(same approach as Horizon Europe's mission projects)</td><td>1) Incremental Innovation from Solar Cells to O&M of PV plants, to relaunch of the Italian PV industry and meet the objectives of the NECP (pulled by industry)

2) Radical Innovation in manufacturing processes, PV technologies, products and systems to maximise the penetration of Photovoltaic Power Generation (pushed by R&D)</td><td>1) 3D solar cadastre for Italy to assess the full potential of distributed PV energy generation

2) 100 virtually-connected renewable energy communities enabled by Photovoltaics</td></tr>
<tr><td rowspan="2">National Distributed R&I Laboratory
(existing public and private R&I labs working as an organized network)</td><td>The network of R&I organisations works cooperatively towards the objectives (TRL5-6) of the strategic projects.</td><td>• Five national working groups coordinate the activities of the strategic projects
• Cooperative development of key technologies for integrated PV
• R&D support to the industrial projects carried out at the national prototyping facility</td></tr>
<tr><td colspan="2">National Facility F3:

Connecting the key R&D hubs of the national distributed lab, this multi-site facility acts as a primary interface between industry and research and enables technology transfer projects to be carried out at the two industrial prototyping facilities</td></tr>
<tr><td>Industrial Prototyping facilities
(to be created to fill the gap between R&D and market)</td><td>National Facility F1:

New PV products and processes are developed from prototype stage (TRL6-7) to final demonstration of competitive manufacturing (TRL9).

Most appropriate site: Catania next to EGP</td><td>National Facility F2:

Industries and other R&I stakeholders from multiple sectors, design and develop products with embedded PV

Most appropriate site: Bolzano next to EURAC Research</td></tr>
</table>

For “**Utility-scale PV**”, the following strategic project proposals have been identified as the most effective R&I actions to support the renewed industrial effort to make Italy and the E.U., No 1 in Renewables as stated by the SET Plan.

1) Incremental Innovation from Solar Cells to O&M of PV plants, to relaunch of the Italian PV industry and meet the objectives of the NECP (pulled by industry)
2) Radical Innovation in manufacturing processes, PV technologies, products and systems to maximise the penetration of Photovoltaic Power Generation (pushed by R&D)

The first project is essentially a collective and immediate effort of the R&I community to support the Italian and the European PV manufacturing industry and its implementation in the downstream sector in its current effort to make their new products and manufacturing processes more competitive based on innovation, quality, reliability, lifetime and environmental impact in addition to efficiency. The second is a medium to long term research effort to validate and demonstrate the most promising results generated by the network of public research labs and fast-track them towards industrial applications with a significant return to research organisations in terms of funding for basic research.

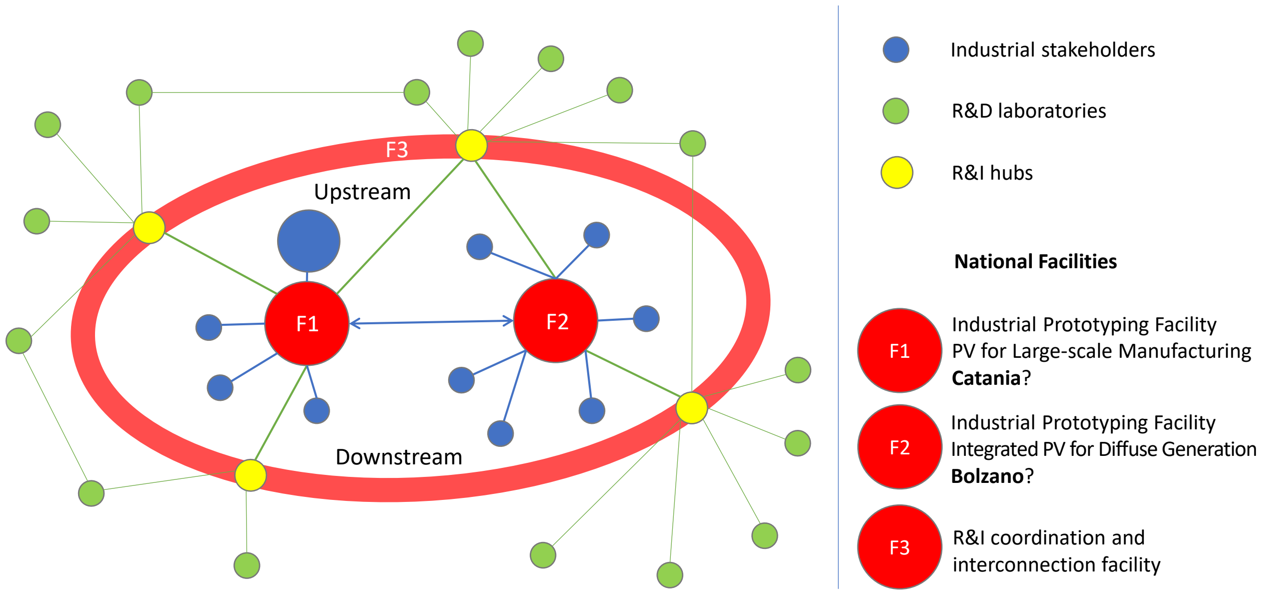
There is no doubt about the most appropriate location of a national prototyping facility for this sector (F1). Enel Green Power’s (EGP’s) solar cell and module manufacturing facility in Catania is the most rapidly expanding in Europe, it is based on an innovative technology and, most of all, on an aggressive technological roadmap aiming to achieve 28% efficiency in production by 2025. An independent prototyping facility located next to EGP’s manufacturing plans and to its own Innovation Hub & Lab would create a highly productive ecosystem similar to other cases of successful partnership between PV industry and research institutions throughout the world.

In the case of “**Integrated PV for distributed generation**”, the strategic projects proposed in this document aim at creating the conditions for the take-off of a completely new industrial value chain involving not only manufacturers of PV components like solar-cells, modules, power and control electronics, but also industries from other sectors like building construction, curtain wall, window and tile manufacturers, utilities, building services and many others:

1) 3D solar cadastre for Italy to assess the full potential of distributed PV energy generation
2) 100 virtually-connected renewable energy communities enabled by Photovoltaics

Deep integration of PV in the built environment can contribute to a significant share of the electricity demand from residential, public and commercial buildings but requires a systematic assessment of the viability as well as the productivity of potential PV installations based on technologies currently under development or still to be developed. This the is objective of the first strategic project. The second is a proposal for a nationwide deep experimentation of Energy Communities based on appropriate PV technologies fitting the needs of each specific community as well as the specifications suggested by the solar cadastre design tools.

The national industrial prototyping facility for “Integrated PV for distributed generation” (F2) requires a radically different approach compared to a conventional PV prototyping facility. The tasks of integrating a PV component in products like a window, a façade element or a roof tile, such as developing electrical interconnections and thermal management solutions, developing an acceptable aesthetic design, ensuring safe and easy installation and O&M can be more important than developing the bare PV module. EURAC Research in Bolzano has pioneered this multi-technological approach together with industrial partners of the building sector at a regional level. This experience can be effectively scaled up to the national level to become one of the first large-scale industrial prototyping facilities of this kind.



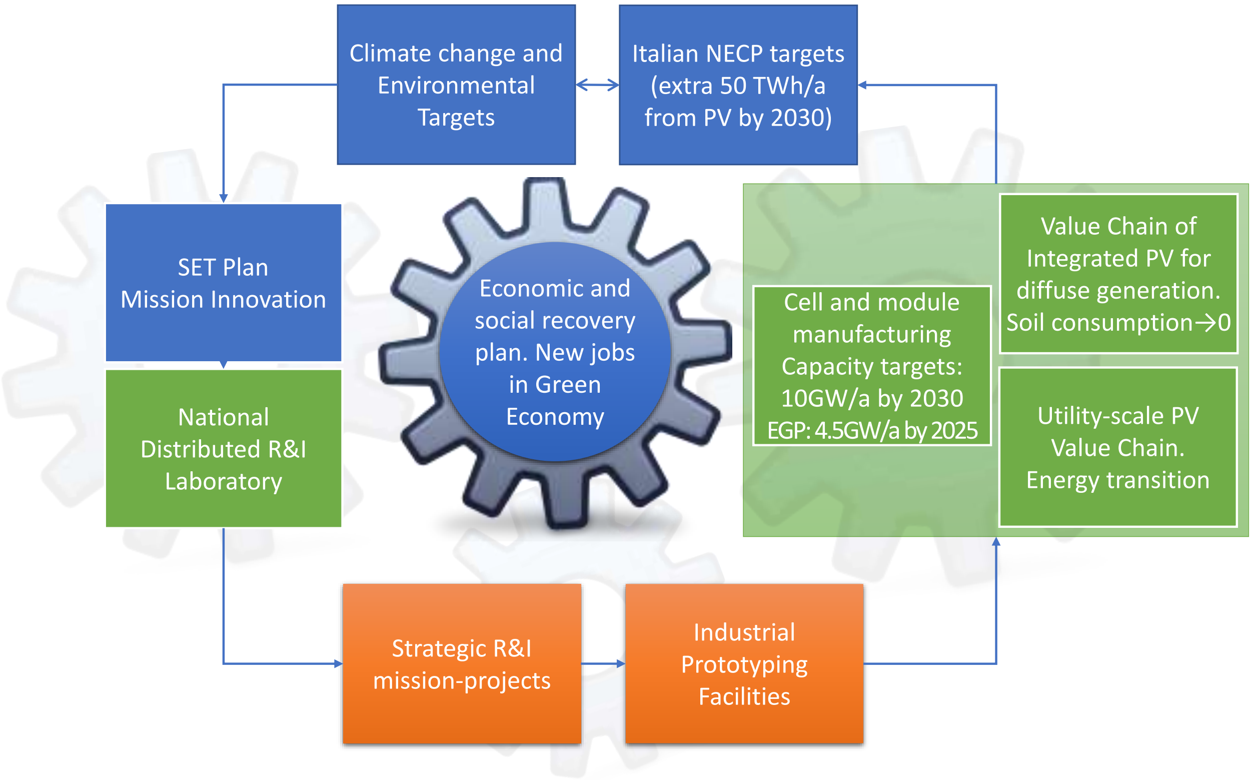
The establishment, endowment and operation of the **National Distributed Lab** (green and yellow dots in the previous graph) is an essential component of this programme. The Distributed PV Lab is expected to become the key infrastructure for the execution of the high-impact strategic R&I projects but it has also been conceived to be a unified and organised R&D partner for the PV industry, whose product-development roadmaps require quick responses, coordination and critical mass. The Distributed PV Lab should be able to accompany the industrial partners all the way to the final steps of the TRL ladder where they are expected to be joint users of the **Industrial Prototyping Facilities** (**F1** and **F2**).

In order to accomplish these tasks the Italian R&I community have created a **detailed map of the R&D facilities installed in public and private laboratories throughout Italy**. The map includes information about the main PV applications each facility is devoted to, the TRL of the current R&I activities and the **unique-selling-points of each facility** in terms of expertise, technological capabilities and innovation. This information is a solid foundation for the organisation of the **National Distributed Lab** which will enable the National **R&I Community to act synergically** towards the objectives of the SET Plan.

The map clearly reveals the potentials and the weak points of the Network where a small subset of the R&I labs (yellow dots in the graph) have the potential to act as **specialised hubs** for key topics like “technologies for high-efficiency PV”, “Perovskite, DSSC and other thin-film PV technologies”, “PV integration in products and building components”, “PV systems for distributed generation”, “advanced O&M and upgrade of PV plants”. These “yellow dots”, run by different organisations, could be transformed into a **highly coordinated R&I facility** (**F3**, red strip) acting as primary interface between the R&I network and the industrial stakeholders (blue dots) and managing the technology transfer projects to be carried out at the two industrial prototyping facilities (F1 and F2).

The Italian Photovoltaic R&I Community believes that the actions proposed in this document can stimulate a **virtuous circle** where industry, institutions and R&I community can effectively support each other towards a **“green” recovery of the national economy** from the severe effects of the COVID-19 pandemic. The rapid increase of the national installed PV capacity required to meet the climate-change targets and the objectives of the NECP, can be achieved **without further soil consumption**. This is possible by combining a renewed effort by the national industry to **expand the PV manufacturing capacity** along the whole value chain, with a coordinated R&I action to

develop innovative products and services for the integration of **PV** in the built environment and, more generally, **for diffuse generation and auto-consumption**. This can create new business opportunities and new jobs not only in the energy sector. This **virtuous circle**, illustrated in the following scheme, can be activated by the funds of the recovery plan but it will soon benefit from its internal driving forces (very low and declining LCOE, Energy Communities, innovative technologies for PV integration and several others) which can make it **self sustainable**.



Expected Impact

Expected impact	Impact generated by the projects by 2025	
Increase utility-friendly integration of PV generation at high penetration levels	Residential/small commercials	Increase in self-consumption from 30% to 60% by using storage and energy sharing in renewable energy communities.
	Large commercial/utility scale	Use of Power Plant Controllers for interoperability, standardization and auto-configuration of PV plant components. Interoperability in terms of control and bidirectional communication between plants and central systems. 30% decrease in imbalance costs to due advanced forecasting.
Increase performance of PV systems	Residential/small commercials	Increase of 15% in annual energy yield for new plant. Increase of 5% in PR for new plants. Increase of 3% in annual energy yield for existing plant
	Large commercial/utility scale	Increase of 10% in annual energy yield for new plant. Increase of 5% in PR for new plants. Increase of 8% in annual energy yield for existing plant.
Increase profitability of PV systems	Residential/small commercials	Reduction in LCOE by 15% in new PV plant
	Large commercial/utility scale	Reduction in LCOE by 25% in new PV plant

Other impacts	Target 2025	Target 2030
Investments in sustainable energy triggered by the project		850 million € per year in more income for PV plant owners in the EU (600 million € per year for residential sector, 250 million € per year for utility scale).
Jobs created by the project	[redacted]	21,000 added jobs per year at EU level thanks to the savings triggered by the projects in terms of improved performance. 31,000 added jobs per year in Italy to achieve the PNIEC targets of 3 GW/y (compared to the current value of 800 MW in 2019). 23,400 added jobs per year in Italy in upstream sector for the delivery of modules outside of the Italian market.
Reduce the technical and financial risks by developing methodologies to assess the economic impact of failures in the field by developing preventive and data-driven corrective mitigation measures, thus decreasing the risk profile or PV projects to give confidence to investors and lenders and thus enabling lower WACCs.		
Contribute to the enhancement of the competitiveness of the EU PV industry and comply with **EU policies** to increase the share of renewable energy sources.		
Increase the innovation capacity of SMEs and contributes to the **creation of added value services that can be delivered by SMEs** in the field of downstream services for the PV sector		
Overcome non-technical barriers that prevent investors and stakeholders from increasing the share of renewable energy generation		

Increase performance of PV system in the residential sector in Italy and in Europe

The rooftop segment has a global share of newly installed capacity of around 30%. As an example, in Italy there are more than 800,000 rooftop installations which sums up to more than 4 GW of cumulative rooftop installations (1<Pn<20 kW).

Most of these PV systems do not have a monitoring system, which is perceived as a cost rather than an asset, thus there is no continuous control on the performance. A 10% unavailability in performance would correspond to a loss of more than 0.4 TWh (calculated as 10% of the electricity generated by 4 GW, around 4 TWh), around 80 million € loss in energy bill savings per year (considering 0.2 €/kWh as an average retail cost of electricity) just considering the residential sector. The residential sector in Europe could reach a value of 60 GWp by 2030. 10% unavailability would correspond to around 6 TWh of missed production with a value of 1.2 billion Euros. A 50% reduction in unavailability would correspond to 600 million euros per year of loss reduction.

Increase performance of PV system in the utility sector in Europe

The utility market segment in EU accounts for the 34% of the cumulative PV capacity by 2018[1]. A direct linear extrapolation (using the Low Scenario from the SPE GMO) would lead to around 100 GW capacity by 2030. It is rather difficult to estimate what the electricity valorisation will be in 2030 using PPAs. If we look at the German PV tenders average awarded tariffs, there was a -46% between April 2015 (91.7 €/MWh) and October 2017 (49.1 €/MWh). This value has been fluctuating since then with the most recent value of 49 €/MWh in October 2019. This could be a sign that the initial large decrease was due to market assessment and a fast learning rate in bidding for utility scale tenders. The experience gained in Italy so far is limited to 2 tenders where the number of PV plants

[1] Solarpower Europe Global Market Outlook 2019-2023

bidding for the auctions was rather low. In the second auction the bids for PV plants were of the order of 55-65 €/MWh. If we assume a 50% decrease in the next 10 years we could see PPAs of around 25 €/MWh in Europe (using Germany as the average case). A 7% unavailability rate would lead in 2030 to production loss of around 10 TWh (7% of an annual generation of 100 GW with a yield of 1400 kWh/kWp), 250 million of €. By 2030 the solutions developed by the projects will become state of the art leading to at least *150 million of €* in avoided losses (decreasing average unavailability down to 3%). The increase in at least 3.5% in yield thanks to more accurate yield prediction and design would generate extra income equal to around *20 million of €* in new utility scale PV plants (15 GW per annum in 2030). To consider the reduction in OPEX, we would need to extrapolate a value for 2030. Using a 30% reduction from the baseline value (20 €/kWp) and keeping the 2025 target value (15 €/kWp), the estimated savings would amount to *75 million €* in new utility scale PV plants.

The overall benefit in conservative terms for 2030 for the utility scale sector in terms of more generation in EU could be then estimated at around 250 million of €.

Impact on employment rate at EU level:

Growth of the European PV industry is a direct impact of the implementation of the proposed projects. The innovations developed will almost entirely be conceived and manufactured in, and offered from Italy, to the European Union and extended worldwide. The businesses as anticipated from these innovations will contribute to increase the economic growth and competitiveness of the Italian and European PV sector in the different segments of the value chain where the commercial partners are present. The underlying added value will be created almost entirely in Italy and thus strongly support the competitiveness of the European PV sector. The project impacts on market and industry development will directly stimulate job creation along the value chain, from designers to field installers, ensuring that there are opportunities for individuals with different skills and education levels. The consulting company Ernst & Young have recently revised in a study new estimations for job creation in the PV sector stating that every installed MW of PV implies around 3 upstream jobs and 11 downstream jobs, both direct and indirect in Europe[2]. These created jobs are largely directly and indirectly related to research and development, balance of system components, system integration, installation and construction and O&M and to a lower extent to PV manufacturing. Based on this information we have estimated the additional jobs required for a significant deployment of PV as 14 jobs per MW of additional capacity installed in Europe. The projects will help in bridging the gap between the low and the medium scenarios from the SPE GMO where in 2023 the added capacity in Europe is 16 or 32 GW, respectively. From 2025, the solutions will be available in the market and will become fully adopted by 2030. By 2030, 850 million € of extra investments will be available per year (from the impact previously calculated), which with a CAPEX of 500 €/kWp (taken as a weighted average between residential and utility scale PV in 2030) would correspond to around 1.5 GW, generating at least 21,000 added jobs per year.

In Italy the solutions will help in bridging the gap between the current level of installation, around 800 MW in 2019 and what is required to reach the PNIEC targets, around 3 GW/year. 2.2 GW of added installation would create around 31,000 jobs/year in Italy if the added value is created in Italy in both the up- and downstream sector as proposed by this document.

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[2] Solar PV Jobs & Value Added in Europe, Ernst & Young and SolarPower Europe, November 2017

1. Introduction

1.1. Photovoltaics and its central role in the National Energy and Climate Plan of Italy

Recent studies on the effect of the **lockdown** introduced in most of the countries affected by the COVID-19 pandemic, show that the average **global reduction of CO_2 emissions** in 2020 could range **between 4% and 7%** depending upon the actual duration of the restrictions[3].

It is really striking to note that a **4%-5% annual decrease of CO_2** emissions from now to 2040, is just what is **needed to ensure** that the rise of global **temperature will not exceed the 2°C threshold** above which climate scientists expect dramatic and possibly irreversible effects on the Earth's climate. In order to contain the rise of global temperature, **below the 1.5°C** target agreed at the COP21 in Paris, CO_2 emissions should decrease by **7% a year** for the next 20 years. This corresponds to the effects expected in 2020, in the worst-case scenario for the COVID-19 pandemic[4].

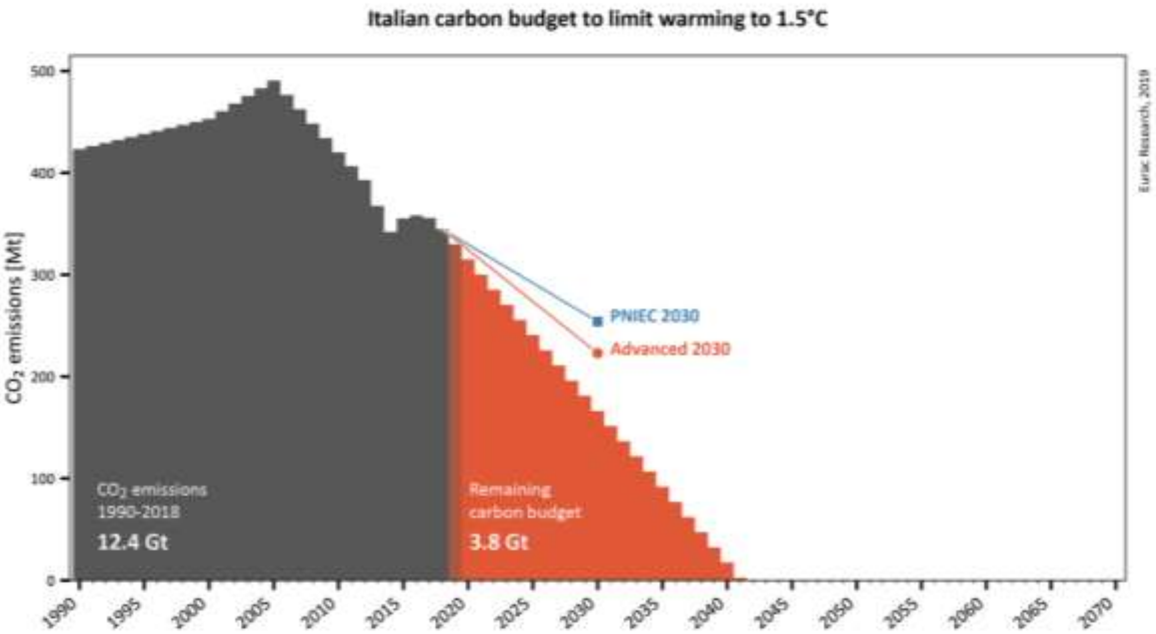

Figure 1: Italian Carbon Budget 1.5 C scenario. Source: Eurac Research

These numbers clearly help us grasping the amount of effort required at the global level to tackle climate change. The current estimation of the effects of the pandemics on the global economy points towards a recession with no precedent since last century's great depression (global GDP reduction of at least 6% in 2020). This means that **the only option to reconcile economic recovery with** the non-deferrable **actions to prevent the disastrous effects of climate change**, is to **speed up the growth of the green economy starting from the energy sector**.

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[3] .Le Quéré, C. et al. Temporary reduction in daily global CO_2 emissions during the COVID-19 forced confinement. Nature Climate Change 1–7 (2020) doi:10.1038/s41558-020-0797-x.

[4] UNEP: 1.5C climate target 'slipping out of reach'. Carbon Brief https://www.carbonbrief.org/unep-1-5c-climate-target-slipping-out-of-reach (2019)

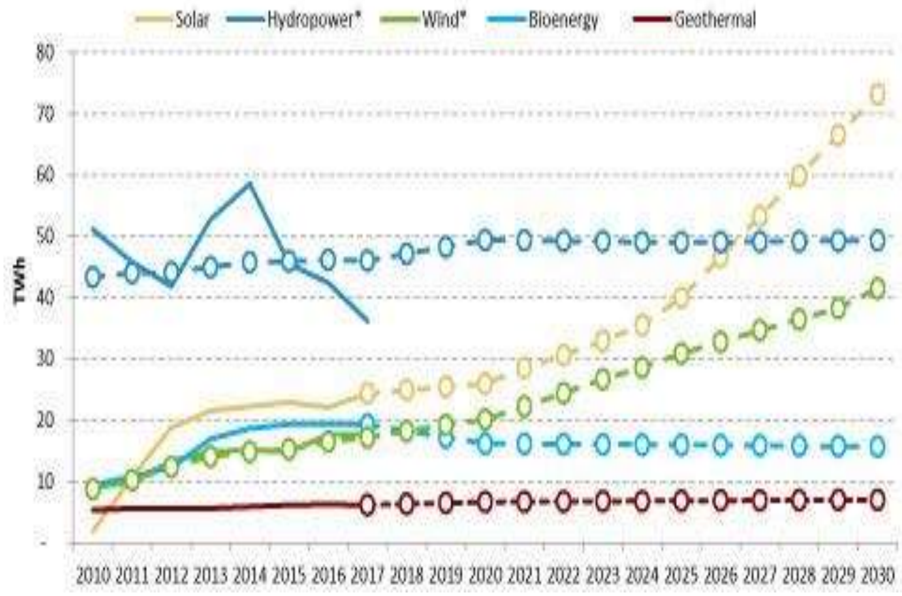

Figure 2: Growth trajectories for electricity from renewable sources for 2030 [Source: Italian Integrated Energy and Climate Plan – https://www.mise.gov.it/index.php/it/198-notizie-stampa/2040668-pniec2030 (2020)]

The Italian **Integrated Energy and Climate Plan**[5] sets the targets for the national renewable energy capacity to be reached by 2030. **Photovoltaics** and wind are set **to expand** respectively **by 300%** and 200% with respect to the current (2020) cumulative installed capacity as shown by the graph above.

One of the key issues related to the predicted expansion of both wind and photovoltaic generation capacity is **soil consumption**. Although the current PV installations contribute to only 0.5% of the total of 23000 km^2 of consumed soil (about 8% of the national surface area), pressure in mounting on local and national authorities to limit the development of large photovoltaic plants if the consumption of more soil is involved.

Research and Innovation are key to develop solutions that can address this issue, thus removing one of the major obstacles that currently prevent the expansion of photovoltaics in Italy. By looking at the details of soil consumption in Italy, **areas already classified as "consumed soil"**, like buildings (30% of the consumed soil), roads (40% of the consumed soil), currently used and abandoned industrial sites, parking places, permanent greenhouses and several others, can be convenient locations for the installation of a wide range of different photovoltaic plants and **can contribute to a significant fraction of the national electricity demand**.

The following table shows the estimated average yearly production of electric energy that could be obtained in Italy by installing the most efficient PV systems currently available on the market (module efficiency = 22%) on just the 2.5% of the area currently occupied by different types of buildings. This is just an example of the potential impact of photovoltaics integrated in the built environment as pointed out, among others, by Solar Power Europe in their "Solar Rooftop Initiative"[6]

[5] Pubblicato il testo definitivo del Piano Energia e Clima (PNIEC), Italian Ministry of Economic Development (MiSE), https://www.mise.gov.it/index.php/it/198-notizie-stampa/2040668-pniec2030 (2020)

[6] Solar for all new and renovated buildings in the European Union. https://www.solarpowereurope.org/campaigns/solar-for-eu-buildings/.

Type of Building	Area occupied by PV modules km²	Nominal Power GW	Energy Output TWh/year
Buildings in residential areas with continuous fabric	15.9	3.50	4.0
Buildings in residential areas with discontinuous and sparse fabric	73.2	16.09	18.5
Buildings in industrial, commercial, infrastructural and other artificial areas	22.3	4.90	5.6
Buildings in predominantly rural area	70.6	15.53	17.8
Buildings in predominantly natural area	8.9	1.96	2.2
Façades	26.2*	2.62*	2.2
TOTAL	**217.1**	**44.6**	**50.4**

Calculation based on data on soil consumption in Italy, published by ISPRA (2017)[7]
* façade area = 15% of the roof area, façade module efficiency = 10%

The last row of the table shows **that the total average electricity which can be generated by covering just 2.5% of the area occupied by buildings, is comparable to the extra PV capacity Italy has planned to install by 2030 (IECP)**. Several studies show that the maximum potential of building-integrated photovoltaics is significantly larger than 50TWh/a as the average fraction of the building area that can be potentially covered by photovoltaic panels could reach 15% to 20% (120 GW rooftop potential used in Prina et al[8]).

This is even more important if combined with the new European and national regulations giving way to the paradigm of "**Energy Community**" based on distributed generation of energy and, most of all, on the free exchange of energy among producers-consumers (prosumers) of energy inside the same energy district.

Another important **option** for the expansion of the photovoltaic installed capacity **is offshore generation**. Floating photovoltaic plants have been widely experimented in a variety of water basins and several large installations are under way throughout the world. In Italy the use of floating photovoltaics in combination with wind and wave energy has been proposed for innovative offshore installations called "**energy archipelagos**" where most of the generated electricity could be used for the production of hydrogen and other power-to-X applications.

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[7] Soil consumption, territorial dynamics and ecosystem services.Edition 2017. Istituto Superiore per la Protezione e la Ricerca Ambientale https://www.isprambiente.gov.it/en/publications/reports/soil-consumption-in-italy-1.

[8] Multi-objective investment optimization for energy system models in high temporal and spatial resolution, Prina et al, Applied Energy, 2020, https://doi.org/10.1016/j.apenergy.2020.114728

1.2. Global Photovoltaic market: demand, supply and trends of the total installed capacity

Solar PV gross capacity is expected to grow by 4.4 TWac (5.4 TWdc) between now and 2050.

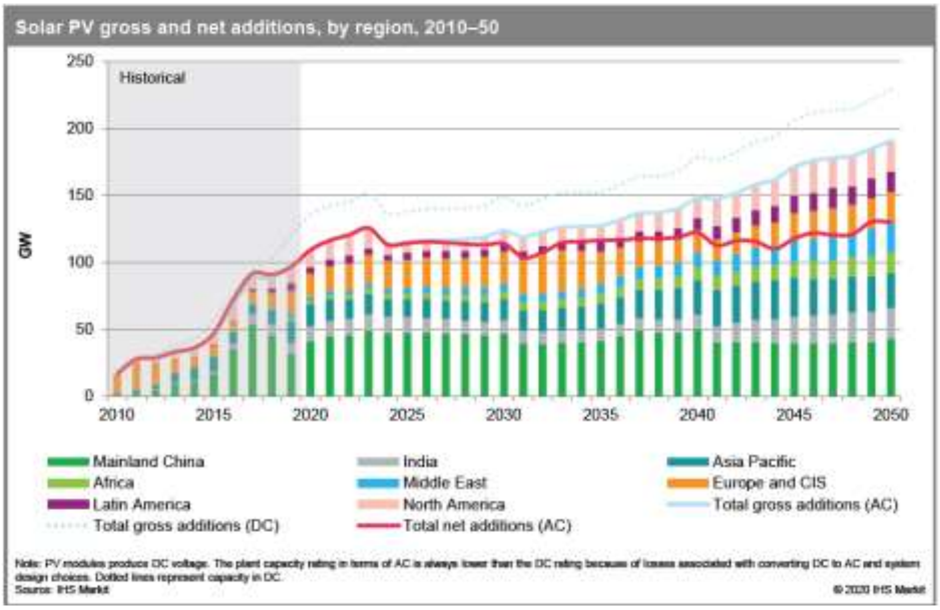

Figure 3: Solar PV gross and net additions, by region, 2010-50

Gross additions for are expected to grow by an average of about 140 GW (170 GWdc) per year for a constant annual growth rate of approximately 2%.

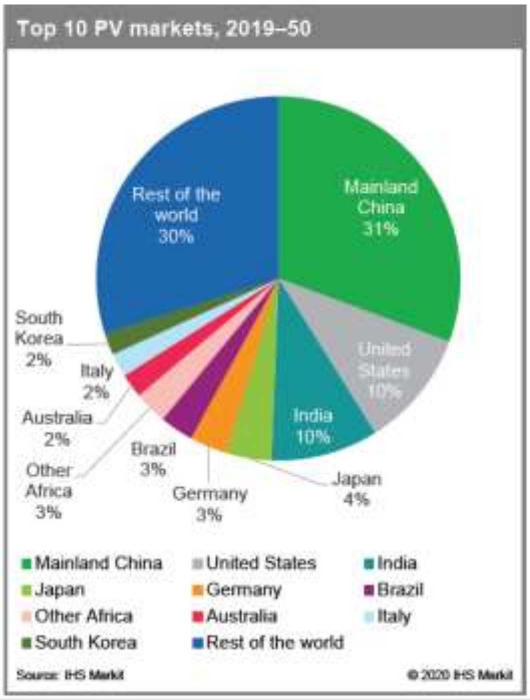

Figure 4: Top 10 PV markets, 2019-50

Demand in Europe, especially Southern Europe, is also growing fast. After a lull in the mid-2020s, thanks to the phaseout of subsidies in Europe and the United States and authorities reining in uncontrolled growth in mainland China, growth will pick up, driven by strong power demand growth in emerging markets. From the late 2020s, replacements will constitute a growing share of total PV modules sold.

Overall, mainland China will represent 31% of gross solar capacity additions and India 10%. Europe will account for 15% and North America 11%. The remaining 34% will be added in the emerging markets of Latin America, Africa, the Middle East, and Asia.

Distributed PV systems, or systems smaller than 5 MW, are expected to make up half of PV installations globally.

In Europe and North America, DG is driven by consumer preferences and the possibility to offset high retail electricity rates, especially when coupled with batteries. However, net metering reforms in the United States will temper DG growth as reduced compensation for solar exported to the grid challenges DG economics.

In emerging markets, particularly in Sub-Saharan Africa, DG and microgrids are a way to connect the almost 600 million people without electricity today.

Off-grid PV, small systems that are not connected to the central grid could represent up to 9 GW in the next five years alone.

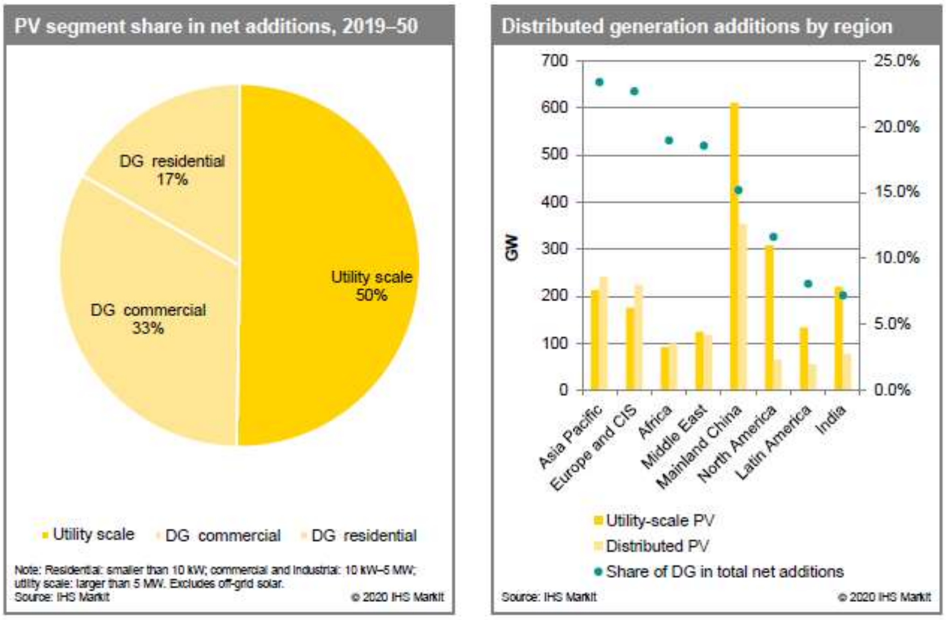

Figure 5: PV segment share in net additions, 2019-50 (left). Distributed generation additions by region (right)

About US$3.4 trillion is expected to be invested in PV assets globally between now and 2050, or US$106 billion annually.

1.3. Global Photovoltaic Industry: scenario, current opportunities and long-term vision to 2030/2050

The ETIP PV published in November 2018 the long-term Vision related to the Photovoltaic sector. The ETIP PV envisioned a world with 100% renewable electricity supply where electricity is accessible to all and where electricity makes major inroads into satisfying final energy demand for living including communications, zero-emission transport and mobility, efficient heating and cooling, and even sustainable fuels, chemicals and materials. By applying Solar PV, buildings will increasingly become places of energy production and not only of energy consumption. Thanks to the abundant availability of sunlight, the technology's modularity, and continuous efficiency improvements and cost reductions, Solar PV can become the largest source of energy worldwide (see Figure 6 for CAPEX development up to 2050).

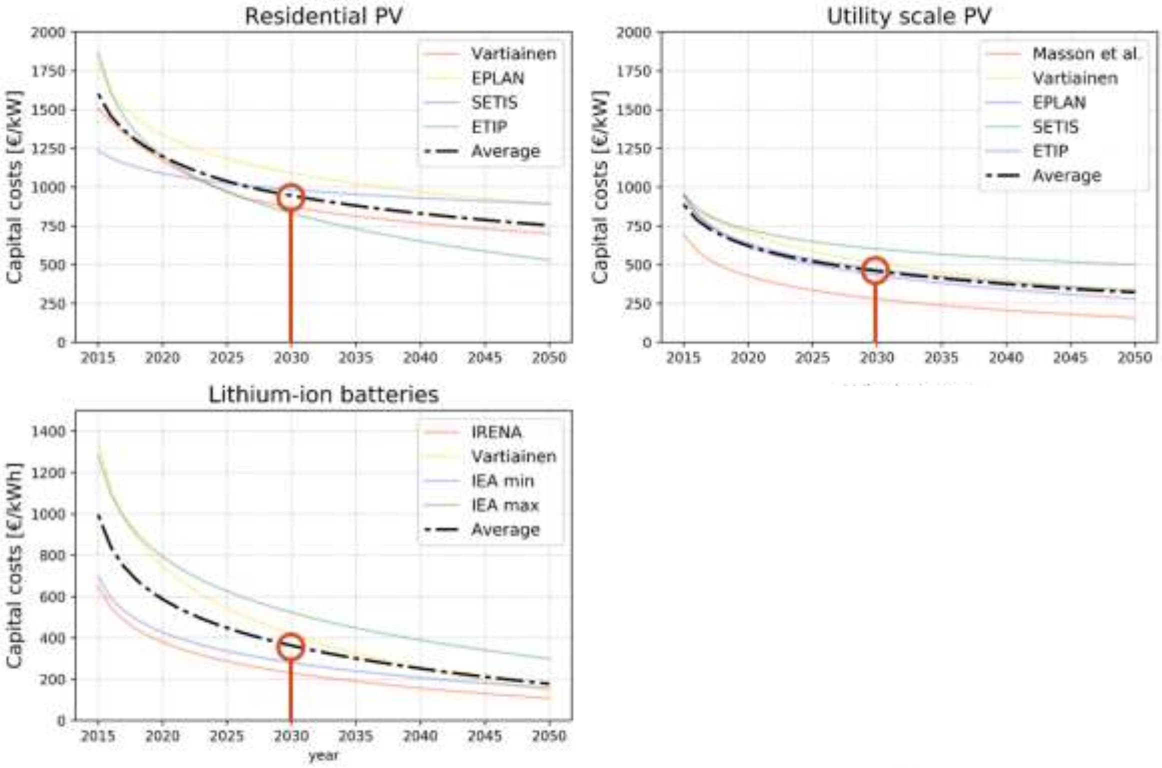

Figure 6: CAPEX development of residential and utility scale PV and Li-ion battery turnkey solution. Source: Eurac Research

In the future extremely competitive global solar PV sector, EU-based manufacturing can only regain space if the industrial initiatives can regroup into high-quality, technologically advanced products at scale. For this to happen Europe must ensure a large and growing internal market for solar PV installations that awards high-quality and sustainable products. In terms of energy security, solar PV is a strategically important asset for the energy transition. To enable internal market growth, barriers must be removed for both centralised and decentralised PV installations and new policies for the promotion of local manufacturing should be put in place.

Researchers at LUT have shown that on the assumption that i) no nuclear-, coal-, or oil-based power plants are installed after 2015, and ii) the renewable energy capacity share increase does not exceed 4% per year (3% between 2015 and 2020), then the cost of consumed electricity is minimized worldwide in 2050 with a generation mix where solar PV has a share of 69% (rooftop and utility scale) for a generation of 38000 TWh (22 TW). Annual installation rates would typically need to be a factor 10 greater than they are today to reach these totals. Taking into account the broad electrification in the heat, transport and industry sectors, then the PV electricity demand will be much higher. Latest estimates range up to about 104 000 TWh in 2050 which would require about 63 TW of installed PV capacity [Ram, 2019]. In this large growth scenario, Europe must play its part: The European Union needs to increase its capacity from 115 GW at the end of 2018 to more than 600 GW by 2025 and 4-9 TW by 2050 depending on PV's use in overall energy supply.

Price reduction has helped PV achieve grid parity in many European countries. The true competitiveness of Solar PV – a European case study [ETIP PV, 2017a] looked at three segments of the PV installation market in Europe (small-scale systems installed on homes, where the homeowner otherwise buys electricity on the retail market; mid-sized systems on commercial premises and large systems). Of the ten countries examined, under reasonable assumptions, about five are competitive today in every market segment. By 2050, buyers of PV systems in all 31 towns from across Europe considered in the study can expect to save money compared to buying electricity from the grid even for high costs of capital.

Regarding the projected LCOE in future scenarios, the main problem lies in the fact that there is not total openness on the whole range of price information of CAPEX and OPEX. Module prices are generally well known and fairly universal, but Balance of System (BoS) prices are not and they vary from project to project. There is even more ambiguity and variability over OPEX prices. The LCOE dynamics will see the share of BoS and OPEX increasing and the share of modules decreasing. This is obvious since the learning rate for modules is higher than for BoS and OPEX. The share of BoS and OPEX will increase from the current 23% to about 30% in 2050 and modules decrease from 17% to 7%. This emphasises the importance of realistic prices for BoS and OPEX.

Several studies have been made on the historical CAPEX prices. The challenge with these studies is that they are almost always out of date after the publication. During the last two years, the module prices alone have decreased by 38%.

IEA PVPS reported that the total utility-scale PV power plant market in 2017 had a size of 61.4 GWp with an average volume-weighted market price of 0.857 $/Wp. However, 74% of the total market in gigawatts was found to be below the average price, whereas Israel and Germany were already in 2017 on the CAPEX level of 0.55-0.60 $/Wp.

Another challenge is that the solar PV industry is developing so fast that it is difficult to forecast even the near future price development. 4- and 2-year old EUPVTP/ETIP PV CAPEX projections for 2019[9,10] were 0.60 to 0.65 €/Wp, ie, 30 to 40% higher than the CAPEX used in [Vartiainen2019]. However, it has to be said that a 20% difference in CAPEX is not very significant in future LCOE projections, and a ±50% difference in OPEX would have a similar effect.

The total PV capacity growth has a significant impact on the CAPEX due to the Learning Rate approach. Vartiainen et al showed that the cumulative installed PV capacity in 2050 has an impact of ±15% on the LCOE for the applied values of 9 TWp (slow growth case) and 62 TWp (fast growth case) in reference to the 20 TWp base case.

In the existing literature on energy transition studies the minimum value of 8.5 TWp in 2050 is given by IRENA[11]. The upper limit of 70 TWp in 2050 is given by Haegel et al[12].

For the LCOE calculation, the financial parameters, nominal WACC and inflation, have the biggest impact, apart from the location. Very progressive vs conservative solar PV growth assumptions have a smaller impact on PV CAPEX. Increasing the nominal WACC from 2 to 10% would double the LCOE. This proves that it is of high importance for the solar PV industry to convince the financial community that utility-scale PV is a safe and profitable investment. Policy makers need to be informed that PV is the cheapest form of electricity, especially if its inherent low economic, technical, and environmental risks are taken into account. In addition, it has to be highlighted that the high

9 Vartiainen E, Masson G, Breyer C. The true competitiveness of solar PV—a European case study, European Technology and Innovation Platform for Photovoltaics. 2017

10 Vartiainen E, Masson G, Breyer C. PV LCOE in Europe 2014-30, European PV Technology Platform. 2015.

11 International Renewable Energy Agency. Global Energy Transformation – A Roadmap to 2050, IRENA, Abu Dhabi, 2019

12 Haegel NM, Atwater H Jr, Barnes T, et al. Terawatt-scale photovoltaics: transform global energy. Science. 2019;364(6443):836-838

dynamics in the solar PV industry has led to PV CAPEX and PV LCOE levels not yet well reflected in literature and major reports used in decision making.

The business case for PV can be enhanced with electricity storage. Rooftop PV plus battery storage is already a big market in countries like Germany, and Li-ion batteries can also be used with utility-scale PV installations.

The battery storage demand for the entire energy system can decrease when more flexibility is provided by an integration with the heat and transport sector thus reducing the relative need for storage and thus stationary batteries. The role of batteries for future energy systems are increasingly investigated, since batteries offer a very valuable flexibility to substantially increase the penetration of solar PV not only in the power sector but for the entire energy system.

PV plus batteries are the cornerstones of the future energy system if we wish to tackle the climate crisis in a fast and cost-neutral way.

1.4. Italian and European Photovoltaic Industry: SWOT analysis

Strengths	**Weaknesses**
- Strong R&D capability along the whole value chain - Innovative technologies for next generation of high-efficiency solar cells and modules are being developed in Europe	- Production capacity of European PV cell and module manufacturers is still far below (at least one order of magnitude) the minimum level required to compete in the global market - Industrial initiatives in Europe are scattered and insufficiently supported by national and European institutions
Opportunities	**Threats**
- Increasing internal demand in EU and in Italy - Energy Communities are expected to boost diffuse power generation	- Persisting negative attitude of investors towards PV manufacturing - Aggressive competition by far-east manufacturers

1.5. The Italian Photovoltaic R&I Network

In Italy research and Innovation in the photovoltaic sector has been carried out mostly by public research organisations (**ENEA**, **CNR** and **RSE**) and several Italian **Universities** (Catania, Ferrara, Lucca-IMT, Milano Bicocca, Padova, Parma, Perugia, Roma Tor Vergata, Siena, Torino, Verona). Their combined contribution to national and international R&D and innovation projects amounts to about 75% of the total person effort invested by the national community of the PV stakeholders[13].

The Photovoltaic R&I network encompasses more than 40 laboratories distributed all over the country.

Among the national research organisations, both ENEA and RSE are involved with two of their sites where they concentrate almost all of their R&D activities on photovoltaics such as Silicon and tandem solar cells, concentrator photovoltaics and centralised/distributed generation. Because of its internal organisation, based on about 100 institutes divided in 7 disciplinary departments, the CNR contribution to photovoltaics covers essentially all the spectrum of R&D topics and is based on small research teams spread over 12 institutes and 16 different sites. The distribution of CNR labs, mirrors the network of university labs most of which are also based on small teams characterised by a high turnover. Among the universities one notable exception is **CHOSE**, a photovoltaic R&D centre at the University of Roma Tor Vergata, with a team of over than 30 among researchers, students and other technical staff working mainly on organic and hybrid thin film solar cells and modules.

The University of Milano Bicocca and the University of Torino, together with ENEA and the University of Roma Tor Vergata have been the most active research organisations in the PV Joint Programme of **EERA**.

An important strategic role in terms of critical mass, extensive industrial relations and ability to attract national and European investments is played by **EURAC** Research in Bolzano and by the Innovation Hub and Lab of **Enel Green Power** in Catania. These two centres have been playing an increasingly important role as virtual R&D hubs for industrial research and demonstration on utility-scale photovoltaics and building-integrated photovoltaics.

[13] SET Plan Survey (2017, 2019)

Figure 7: [The network of Italian laboratories working on R&I projects related to Photovoltaics]

Locations	Organisation
Bari, via Amendola 122/O, 70126	CNR
Bari, via Orabona 4; 70126	CNR
Bologna, Via Gobetti 101; 40129	CNR
Bolzano, Via A.Volta 13/A; 39100	EURAC Research
Cagliari, SS 554 Km 4,500 Monserrato (CA); 09042	CNR
Catania, Contrada Blocco Torrazze; 95121	ENEL Green Power
Catania, Via S. Sofia, 64 95123	CNR
Catania, Viale A.Doria , 6, 95123	University of Catania
Catania, Zona Industriale; Ottava Strada; 5; 95121	CNR
Chieti, Via dei Vestini, 66100	CNR
Faenza, Via Granarolo 64; 48018	CNR
Ferrara, Via Fossato di Mortara 17; 44121	University of Ferrara
Firenze, Via Madonna del Piano, 10; 50019	CNR
Fisciano, Via G. Paolo II, 132, 84084	CNR
Ispra, Via Enrico Fermi 2749; 21027	JRC European Commission
Lecce, c/o Campus Ecotekne via Monteroni; 73100	CNR
Lecco, Via Gaetano Previati, 1/E, 23900	CNR
Lucca, Piazza S.Francesco, 19; 55100	IMT School for Advanced Studies Lucca
Messina, Salita Santa Lucia Sopra Contesse, 5; 98126	CNR
Messina, Via F. Stagno d'Alcontres, 37; 98158	CNR
Milano, Piazza L. da Vinci, 32, 20133	CNR
Milano, Via C. Golgi 19; 20133	CNR
Milano, Via Cozzi 55; 20126	University of Milano Bicocca
Milano, Via Pascoli 70/3; 20133	Ribes Tech srl
Milano, Via Rubattino 54; 20134	RSE
Napoli, Piazzale Tecchio, 80125	CNR
Napoli, via Cinthia, 80126	CNR
Padova, via Giovanni Gradenigo 6/B; 35131	University of Padova
Palermo, V.le delle Scienze Ed. 17 e Ed. 18, 90128	University of Palermo
Parma, Parco Area delle Scienze 37/A; 43124	CNR
Pavia, Via Bassi 6; 27100	University of Catania
Perugia, Via Alessandro Pascoli; 06123	University of Perugia
Piacenza, Str. della Torre della Razza; 29122	RSE
Portici, P.le E. Fermi 1, 80055	ENEA
Portici, Porto Del Granatello 17; 80055	ENEA
Povo, Via alla Cascata, 56/C, 38123	CNR
Roma, Piazzale Enrico Mattei, 1, 00144	ENI
Roma, SP35d, 9, Montelibretti RM; 00010	CNR
Roma, Via Anguillarese 301, 00123	ENEA
Roma, Via Cineto Romano 42, 00156	CNR
Roma, Via del Politecnico 1; 00133	University of Rome "Tor Vergata"
Siena, Strada Laterina 8: 53100	University of Siena
Siena, Via A. Moro, 2, 53100	University of Siena
Torino, Via Pietro Giuria 7; 10125	University of Torino
Trieste, Strada Statale 14, km 163,5, 34149	CNR
Verona, Strada Le Grazie 15, 37134	University of Verona
Verona, Via dell'Artigliere 8; 37129	University of Verona

The **EGP Innovation Hub&Lab** is located close to the largest solar-cell and module manufacturing site in Italy, also owned by EGP, that is planning to expand its manufacturing capacity from the current 200MW/year to at least 2GW/year over the next few years. The Innovation Hub&Lab already hosts several technology transfer projects, involving private companies as well as public research organisations and is acting as an innovation pipeline for Enel Green Power not only in the field of photovoltaics. Is a campus with more than 100,000m^2 available of which 3000m^2 as indoor lab and office; inside there is an accredited lab for the main standard and evoluted test on PV module.

EURAC has a long standing experience on the downstream sector of PV systems (e.g. operation and maintenance of photovoltaic plants) but their decision to focus on photovoltaic integration in the built environment (or building-integrated photovoltaics) for distributed generation of electricity, has created the conditions for the development of a regional hub for industrial research and technology transfer in this field.

The current distribution of R&I activities of the national network, in terms of person effort, is highly skewed towards **low Technology Readiness Levels** (TRLs). A large majority of labs are involved in basic research on **new materials for photovoltaics** with a widespread interest on perovskites, which are one of the most promising options for the development of the short wavelength component of tandem solar cells based on high-efficiency crystalline-Silicon cells. Perovskites and Dye-sensitized solar cells are also studied for the development of (semi)transparent photovoltaic devices for windows and transparent curtain walls.

Inorganic thin-film solar cells are also studied in several labs to develop **low-cost deposition technologies** capable to make stable and efficient materials like $Cu(In_xGa_{1-x})(S_ySe_{1-y})$ (CIGSSe) or kesterites, more cost-effective and competitive for both high efficient (tandem) solar cells and building-integrated photovoltaics.

Further up the TRL scale are the R&D activities on **Silicon solar cells** and modules with a close link to the Hetero-Junction Technology (HJT) adopted by Enel Green Power for their new manufacturing facility in Catania. This is a typical example of how a very fruitful collaboration between a manufacturing company, who needs R&I partners all the way to TRL 8-9, and a national public research organisation (ENEA) cannot proceed beyond TRL~5-6 because of the **lack of a proper industrial-grade prototyping facility** equipped with pilot production lines.

Industrial **prototyping** is also missing in the value chain connecting new technologies and materials for thin film solar cells and the industrial manufacturing processes of **tandem solar cells**, innovative **thin-film modules for building** (or product) **integration** or for highly specialized applications like **agrivoltaics.**

While tandem solar cells are the natural evolution of high-efficiency Silicon technologies like HJT and can share the same route to market, the development of **new photovoltaic products for building integration require** a significantly different approach with the involvement of **a plurality of industrial actors from different sectors** such as building design and construction, services and utilities, electronics and domotics and several others. Currently all the (non-negligible number of) R&I projects carried out by the Italian PV network stop short of getting to the actual product development phase. Several **attempts have been made** by startup companies or joint ventures between companies of the building sector and research institutions, to fill the gap between a lab demonstrator and a product prototype **but none have been successful so far**.

Concentrator photovoltaics (CPV) is another complex sector involving several different industrial actors, from the manufacturing of ultra-high efficient solar cells, to the development of sophisticated tracking systems, optical components and mechanical solutions. Like in the case of building-integrated photovoltaics, a proper value-chain connecting R&D to market is still missing. One of the key players of the national R&I network is devoting a significant share of its resources to CPV and is promoting the formation of a national CPV value chain.

Energy storage is an increasingly important component of PV systems of all sizes. Storage is a separate SET Plan sector and R&D on this topic was not included in the survey. However there is a growing interest around the direct incorporation of a storage function in a photovoltaic product as well as the intelligent integration of storage in a photovoltaic system. Several labs of the network are involved in this activity.

Similarly, an increasing number of R&D projects in the field of **power and control electronics** carried out by different labs of the network, are looking to develop innovative solutions to manage the PV energy generated by a single or by a cluster of prosumers belonging to the same energy district in order to maximise auto-consumption.

Towards the bottom of the PV value-chain, innovative solutions for **operation and management** of existing PV plants is the subject of several projects involving both utility companies and R&D labs. This activity has a large degree of superposition with the **smart grid** sector where Italy is coordinating the SET Plan Implementation working group.

In order to get a detailed picture of the distribution of the R&I resources and facilities throughout the network and their current allocation to develop specific applications at a certain position in the PV value chain, a survey was carried as part of the activities designed to finalise the PV Implementation Plan of the SET Plan in 2017. Regular updates are being carried through as part of the activities of the European Project "PV IMPACT".

The information is based on the following fields:

- Description of Facility
- Knot name (top level)
- Location
- Value Chain/Process step
- Main PV Application
- TRL of Main Application
- Secondary Application
- Sample/Device/Module size
- Unique Selling Points (of facility)
- Machine-time Allocated to PV
- Throughput

and is organised in such a way to highlight the combined contributions of research organisations and other photovoltaic stakeholders to the key R&I activities as identified by the Implementation Plan of the SET Plan.

These are the PV applications proposed in the survey:

- New PV Materials
- Crystalline Silicon Solar Cells
- Inorganic Thin Film Solar Cells
- DSSC
- Organic Solar Cells
- Perovskite/Hybrid Solar Cells

- Tandem Solar Cells on Silicon
- Concentrator Solar Cells
- Light management solutions (incl. Luminescent Concentrators)
- PV flat panels
- BIPV/PIPV modules
- PV embedded in Fabric & Wearable PV
- Advanced manufacturing machines and production lines
- Combined Heat & Power Generation
- Power Electronics
- Control Electronics
- Characterisation/Test/Monitoring Tools
- Concentrated Photovoltaic Systems
- Smart PV Systems (IOT)
- Building-scale PV systems
- Utility-Scale PV Plants
- PV as Ancillary Service to the Grid
- Solutions for O&M/upgrade/decommissioning of PV plants
- Smart Grids
- Other Applications

Each facility is linked to its current PV applications, to the maximum TRL achieved so far and, most of all, to its unique characteristics (specific expertise of the operators and/or characteristics of the equipment), with respect to standard equipment available on the market.

Additional data about key technical characteristics of the equipment, such as the maximum size of the “processed units” (lab samples, wafers, solar cells, modules, inverters, systems, plants, etc) or the maximum throughput and/or overall capacity of the facility have also been collected.

This information is key to evaluate the potential, the strength and the weakness of the National Distributed R&I Lab in view of its involvement in the collaborative strategic projects. The industrial stakeholders can also benefit from this survey as it makes it easier to identify type and extent of the R&D partnership, the National Distributed lab can provide, particularly in the case of ambitious tasks of industrial-research included in the SET Plan Implementation Plan, such as the development of high-efficiency (>30%) tandem solar cells based on the integration of a “wide-gap” thin-film device in a state-of-the-art Silicon solar cell.

The survey clearly shows that some of the knots of the National R&I Network already act as de-facto hubs for specific topics such as “technologies for high-efficiency PV”, “Perovskite, DSSC and other thin-film PV technologies”, “PV integration in products and building components”, “PV systems for distributed generation”, “advanced O&M and upgrade of PV plants”. A strong coordination between these hubs could be the first effective step towards to establishment of a core R&D facility (F3) of the national distributed lab, directly connected to the rest of the R&I network (on one side) and to the national industrial prototyping facilities (on the other side).

2. Strategic objectives of the Italian R&I community of the photovoltaic sector

The Italian Photovoltaic ecosystem, including the PV industry, the R&I Community and the other stakeholders, have been actively involved in assessing the necessary measures to relaunch manufacturing and innovation and to create the conditions for a wider adoption of this energy technology as part of an overall strategy to foster Energy Transition and tackle Climate Change.

In **2017** the whole network participated in the identification of the R&I priorities of the PV sector in order to define the Italian contribution to the **SET Plan Implementation Plan**, finally approved by the SET Plan Steering Committee in November 2017.

The **R&I** priorities where organized in two "**Flagship Activities**" to reflect the growing differentiation of the PV sector into two increasingly different segments:

1) **Utility-scale generation**
2) **Distributed generation**, at the time defined as "building-integrated" or "product-integrated" photovoltaics

The following tables report the main objectives, tasks and rationale for each of the two flagship activities.

Flagship Activity: "Innovative Technologies for Modern Utility-Scale PV" as defined in 2017
Main Objectives to support the national and the European PV industry by contributing to the development of "advanced concepts for Silicon-based solar cells and modules" for large-scale power generation To demonstrate high-efficiency/low-cost utility-scale PV systems To develop innovative solutions for the upgrade, installation, operation , maintenance and decommissioning of existing PV installations, including measures to increase the energy generation of existing PV plants to investigate the integration of PV plants in small/medium grids, including remote islands **Tasks** 1. Si heterojunction solar cells and modules 2. Tandem solar cells obtained by combining crystalline Silicon with thin film solar cells 3. Innovative solar cell architectures for high conversion efficiency including back contact schemes and multi-junction cells for high concentration PV systems. 4. Energy Storage for utility-scale PV plants 5. Innovative Power and Control Electronics 6. Technologies for O&M/upgrade/decommissioning of existing utility-scale PV plants 7. Energy dispatch optimisation and related issues 8. PV integration in small and medium grids and management of different energy sources 9. PV as ancillary service to the grid

Rationale

Silicon heterojunction solar cells have recently exceeded the 26% efficiency limit as announced by Kaneka Corporation in Japan. On the industrial front the large Chinese, North American and Korean manufacturers dominates the PV sector in terms of production capacity, manufacturing costs and shipping volumes. Is there still room for the European PV industry to compete?
The EU as a whole and Italy in particular are still among the major global players in terms total installed capacity and Italy hosts one of the largest European PV manufacturers, (3SUN), who is investing in R&I activities in collaboration with a wide network of R&D institutions and labs also active in several European projects and networks.
Around these two pillars a national R&I flagship activity can be designed with the main objective of supporting the existing PV utilities, providing advanced O&M (also by predictive diagnostic maintenance) and upgrade solutions and possibly develop a new generation of multi-junction PV modules where the crystalline Silicon technology is combined with emerging thin film technologies like Perovskites.
Besides the core Si-heterojunction technology R&I activities should focus on key technological issues like processing cost, device passivation, degradation control and mechanical stability. Important contributions are also expected from the development of new materials or deposition technologies for critical cell components like transparent conductive oxides (TCOs), anti-reflection coatings and metal contacts.
The well-established expertise of the Italian R&I institutions/labs in both Silicon, Perovskite and new emerging technologies can be exploited to develop new multi-junction devices with the potential to exceed 30% efficiency under 1 Sun.
Finally the expected evolution of the electricity distribution system with a gradual shift towards the development of local smart grids should provide new opportunities for the upgrade of the existing PV plants both in terms of new PV modules and new powerline components including storage solutions, power control and ICT.

Flagship Activity: Italian BIPV/PIPV value chain
as defined in 2017

Main Objectives

To foster the development of an Italian BIPV/PIPV value-chain

Tasks

1. Materials for BIPV/PIPV (solar cell components and substrates)
2. Thin film solar cells & modules for BIPV/PIPV
3. PV integration in products and building elements
4. Aesthetics and constraints imposed by urban regulations
5. Electronics and storage for electricity autoconsumption in buildings
6. PIPV for electric mobility and other special applications
7. Light management technologies for BIPV, including Luminescent Solar Concentrators
8. Design and Modelling: from new materials and their fundamental properties to device modelling and system engineering
9. Innovative processes and equipment for printed solar cells

Rationale

Although it is still a niche market BIPV/PIPV is expected to develop into a significant sector of the PV market in the near future. To support the development a national BIPV/PIPV value chain, R&I activities in traditional photovoltaic sectors like thin-film PV, new materials for low-cost/high

performance solar cells or power electronics, should be increasingly entangled with R&I activities concerning the integration of photovoltaic devices in smart products and building components. This also includes the development of innovative and smart solutions for the incorporation of multiple solar generators in existing local powerlines (flats, buildings, clusters of buildings) in combination with energy storage to gradually reduce the exchange of power between buildings and the national grid.
In this context the development of high performance solar cells on flexible and low-cost substrates is still the first necessary condition for the take-off of BIPV/PIPV market sector.
Photovoltaic structures on lightweight and flexible substrates have many advantages over the standard Silicon flat panels. Solar cells deposited on lightweight substrates can be wrapped onto any suitably oriented or curved structures and are suitable for a wide range of BIPV and PIBV applications. Chalcogenides, hybrid organic-inorganic (perovskites, DSSC), organic materials are the best candidates for these applications. In this context the effort to replace elements like In, Ga, Cd, Pb and Te with earth-abundant and "environmentally friendly" alternatives is also very important.
Several Italian laboratories have a great deal of expertise and know-how to develop new PV module prototypes based on these materials and designed to comply with the requirements of architectural/product integration. This includes for instance solutions for light trapping to increase efficiency/cost ratio, new encapsulation materials and processes, new electric contacts, wiring and connections and also materials recycling at the end of life of the new products.
Structural, aesthetic and electrical specifications of the new products should emerge from an integrated design approach involving researchers in the PV sector, electrical and electronic engineers, architects, civil engineers and ICT researchers. In particular the interdisciplinary collaboration between the PV and the Building sector should be a cornerstone of this flagship R&I activity.

After the final approval of the **SET Plan** Implementation plan for the Photovoltaic sector, the SET Plan Steering Committee with the support of the European Commission, decided to actively support and stimulate the current **implementation phase** that is the **translation of the R&I priorities into** actual **R&I** programmes and **projects** funded at the national level by all subscribing **Member States**.

Mission Innovation, a joint international agreement to double public funding to clean energy research and development, was identified as the **primary source of funding** for programmes based on the SET Plan priorities. Italy is an active partner of both the SET Plan and Mission Innovation and is looking to deliver results in line with the subscribed objectives.

Since April 2019, the European project "**PV IMPACT**" has been devoted to support and monitor the actions of the SET Plan Implementation Plan. CNR, EGP and EURAC are members of the Consortium. One of the **work package**s of the project is **focussed on Italy** with a series of actions designed **to support the national R&I network** and its efforts to contribute to the objectives of the SET Plan.

Between September 2019 and May 2020, the Italian network of R&I stakeholders of the PV sector were involved in **three workshops** organised by PV IMPACT (the last one by video-conferencing), with the aim of **identifying the most appropriate actions to meet the priorities and the objectives of the Implementation Plan**.

What follows is a **brief summary** of the four **key types of actions** emerged from the discussions:

1. Strategic R&I projects to support the relaunch of the National PV manufacturing capacity through the whole value-chain in such a way that competitiveness is fuelled by innovation and by the know-how generated by R&I stakeholders of the national network

2. Strategic R&I projects designed to speed up the development of innovative products and solutions for PV distributed generation and Energy Communities, starting from building-integrated photovoltaics, and to foster the creation of new value-chains in this rapidly expanding market segment.
3. Actions to make the national network of R&I operate as an organised national distributed laboratory where public research institutions can cooperate synergically to meet the most ambitious targets of the strategic R&I projects.
4. Creation of at least two industrial prototyping facilities at national level, jointly run by public research institutions and industries, to enable quick and effective technology-transfer routes to market.

After the summary, **paragraph 3 and 4** will be devoted to a more **detailed description** of the proposed actions, in the frame of the two national flagship programmes.

2.1. Strategic R&I projects to support the expansion of the National PV Manufacturing Capacity

The first key action is related to manufacturing capacity. The SET Plan strategic documents clearly state that "Europe has the ambition to be the world number one in renewable energy". The photovoltaic sector is key to accomplish this ambition and a pre-condition, for Europe, to lead the way towards an accelerated and deeper penetration of the PV technology is to **expand the European manufacturing capacity**, all along the value chain, including solar cell manufacturing which was severely undermined by the aggressive competition of the Asian manufacturers over the last decade.

In order to reclaim a leading position in the solar cell marketplace, the European industry should develop **new Unique Selling Points** for their products in order **to counterbalance** the **current** severe **gap** in terms of **production capacity with respect to the major Asian manufacturers**.

In other words, the new expansion of solar cells manufacturing capacity in Europe should be fuelled by a decisive competitive advantage both in terms of product and process innovation.

Product innovation should be based on the capacity to adapt to an increasingly differentiated demand, as new market segments are expected to take off and expand alongside traditional ground PV installations. These emerging market segments such as Product Integrated Photovoltaics or PIPV (including Building-Integrated PV and Building-Applied PV), Floating PV or Offshore PV, or new solution for tracking system compatible with agricultural use, can drastically reduce soil consumption and are favoured by the increasingly competitive costs of PV electricity and by the new opportunities for distributed generation offered by the new legislation on Energy Communities. In order to address the future demand for these relatively new types of applications, a whole range of new products need to be brought to the market such as bifacial, light or flexible PV modules, high efficiency modules or innovative PV generators that are more resilient to erratic irradiation (due to changing weather conditions of partial shadowing).

Process innovation is also an important driver to climb the competitivity ladder. Innovative manufacturing processes with a reduced Carbon footprint can lead to a significant reduction in manufacturing costs because of a reduced number of process steps but also thanks to the incentives that are bound to be introduced to accelerate the transition to a more sustainable production system.

The Italian R&I community and the largest Italian PV cell manufacturer, believe that a **target** of **Solar Cell manufacturing capacity** of **10GWp/year** can be reached **in Italy by 2030** based on the expected expansion of the PV market in Europe and in Africa and on the expected competitive advantage the Italian manufacturers can achieve thanks to the progress in R&I.

2.2. Strategic R&I projects to develop new value-chains and foster distributed PV generation

This **key action** is at the root of the second national flagship programme, that is Product/Building Integrated Photovoltaics (PIPV/BIPV).

The top-level objective of this programme is to **create the conditions for the development of a new value chain connecting the manufacturers of PV products to the building sector, from industry 4.0 to industry 5.0 , IOT, utilities and other services for residential, commercial and industrial applications**.

The recent introduction of new national legislation for the kick off of the "**Energy Communities**", opens a completely new scenario for a rapid diffusion of distributed generation and energy trading down to the scale of a single residential unit.

In this scenario Photovoltaics is bound to play a key role but **several bottlenecks need to be removed** in order to foster the development and the penetration of new and innovative PV products beyond the conventional rooftop installations. The removal of these bottlenecks requires non marginal and combined effort to develop and promote new products and services, to favour the creation of new business opportunities and to adapt building regulations to the new scenario.

2.3. Establishment of a National Distributed Research Infrastructure

As revealed by the results of the survey on the Italian R&I skills and facilities, carried out in 2017 and updated in 2019 and 2020, the core R&I activities is devoted to research and development projects not exceeding a TRL of about 4. Moreover, the lack of coordination among different national schemes and between national and regional R&D programmes has, so far, made it difficult to establish synergic interactions between the stakeholders, to create fruitful links between industries and research institutions and to pursue ambitious strategic objectives in tune with the objectives of the National Energy and Climate Plan and with all the commitments Italy subscribed as part of the international actions to tackle climate change.

In order to overcome these limitations and maximise the potential of the national R&I expertise and facilities, the Italian PV stakeholders agreed on the urgent need for the establishment of **a national "distributed" R&I laboratory** by coordinating the expertise and the facilities spread over several tens of public and private research institutions in order to achieve the necessary critical mass required to achieve significant breakthroughs in research and development and to meet the needs of national and European PV industries looking to develop a competitive advantage over current market leaders.

The Distributed PV lab should increasingly develop into an intelligent network of specialised knots to be pursued by encouraging cooperation and coordinated actions between labs over pure competition. It is expected to become the key infrastructure for the execution of the high-impact strategic R&I projects but it has also been conceived to be a unified and organised R&D partner for the PV industry, whose product-development roadmaps require quick responses, coordination and critical mass. The Distributed PV Lab should also be able to accompany the industrial partners all the way to the final steps of the TRL ladder where they are expected to be joint users of the Industrial Prototyping Facilities (F1 and F2).

2.4. Creation of National Industrial Prototyping Facilities

The results of the surveys on the distribution of expertise, resources and R&I facilities devoted to PV throughout the national R&I Network, have revealed a severe lack of investments in the most critical segment of the TRL scale, connecting R&D to manufacturing and scale-up of production capacity.

Public R&D institutions as well as national and regional private-public organisations, play a very important role in R&D activities and projects in the field of photovoltaics, up to TRL~5 but don't have the resources and the facilities to support the industrial partners through the industrial prototyping activities from TRL6-7 to TRL 9.

These activities require investments that are orders of magnitude larger than what is needed for R&D. In most cases the crucial part of the activity is the development of pilot production lines where the overall quality of the new product can be assessed alongside with efficiency and scalability of the manufacturing process.

Successful pilot production lines are usually the result of a joint effort between PV product manufacturers, research organisations and suppliers of production equipment and key product components.

Even if industrial prototyping requires increasingly more specific and dedicated equipment as the new products and/or processes become ready for production, there is a wide range of technology-transfer projects which can share the same industrial equipment and facilities in the early but crucial tasks at TRL 6-7. At this stage, pilot production lines still need to be set-up with a high degree of flexibility with many process check-points and a low degree of automatization.

For instance, the development of high-efficiency tandem solar cells is based on the integration of a specifically-designed thin-film PV technology, such as Perovskite Solar Cells, in a mature manufacturing process based on Silicon technologies such as Silicon Heterojunction (HJT) Solar Cells. No matter which thin film technology is adopted for the top component of the tandem cell, the development and the optimisation of the new combined process requires a state-of-the-art (small-scale) pilot line for HJT Solar Cells as an essential backbone. Moreover, crucial process steps such as substrate cleaning and preparation, inline characterisation, wafer processing and others, require industrial-grade facilities that are not normally available in R&D labs where tests are usually carried out at smaller scales both in terms of solar cell size and production volumes. A wide range of similar examples can be identified throughout the whole value chain both in the case of Utility-scale PV and BIPV/PIPV

To fill the gap between R&D and market, national or (in some cases) regional industrial-prototyping facilities are the most effective solutions to reach the necessary critical mass for competitiveness, to foster synergic collaborations between industries and public research organisations and to create the conditions for self-sustained innovation.

Italy should invest in at least **two national innovation hubs** jointly managed by industries and research institutions and accessible to any company or group of partners willing to develop a proved concept into an industrial prototype.

The national hubs should be developed from existing experiences of fruitful interaction between research and PV industry and should be devoted to projects starting at TRL 6-7 and aiming to reach TRL 8-9.

The national R&I hubs should act independently of any existing organisation and operate like central hubs of a star network with a priority over any other knot of the network when it comes to public strategic investments in large industrial prototyping facilities.

At this stage the most suitable candidates to become national R&I hubs are Catania for all the activities linked to the national flagship programme “Utility-scale PV” and Bolzano for the flagship “BIPV/PIPV”.

2.5. Key targets and expected impact of this Plan

Task	Targets	Impact of this plan
PV manufacturing capacity in Italy	10 GWp/year by 2030 30,000 new jobs per year in the upstream sector	Coordinated support of the National R&I Network to the industrial roadmap of Italian (EGP and others) and European manufacturers
Total installed PV capacity in Italy	50 TWh/year of new PV installed capacity by 2030 (Italian IECP) Ref: 25TWh/year total installed capacity in 2020	Solar Cadastre to 1) assess the overall potential of PV installations in the built environment 2) identify the most appropriate sites with minimum impact on soil consumption
Soil consumption per unit (new) PV capacity	At least 50% of new PV capacity from repowering of existing PV plants, reuse of consumed soil and from integrated-PV by 2030	
PV for Energy Communities	Energy Communities to become the most important driving force towards Positive Energy Districts	100 Pilot Energy Communities in Italy (by 2025)
LCOE of utility-scale PV	15€/MWh by 2025[14]	These objectives are priorities of the strategic R&I projects involving the National Distributed R&I laboratory The National Facility for utility-scale PV will enable a swift industrial implementation and scale-up of the key R&I results
PV Quality: reliability, lifetime and recycling	PV module lifetime increased to 40 years by 2030 PV plant performance ratio, 85% in residential/commercial PV plants and 90% for utility scale plants installed in 2030.	
Standard efficiency of solar cells and modules (Peak Power)	25% module efficiency by 2022 28% by 2025 (tandem cells) >30% by 2030 (tandem cells)	
PV energy efficiency	> 25% increase with respect to current PV systems, by means of: -Bifacial cells and module design -Sun tracking -Improved thermal response -Power electronic efficiency -Smart PV plant control	
New value-chain of Integrated PV	New business opportunities to be created as joint initiatives of companies of PV sector and: Building development/restoration, services, utilities, domotics, automotive, agriculture and others Estimated new jobs: 14000/28000 jobs/GW[15]	At the National Facility for integrated PV and distributed generation, new multi-functional products are jointly developed by PV experts and end-users/product manufacturers of other sectors

[14] WACCreal: 1.96%, WACCnominal: 4%, CAPEX: 400 Euros/kWh, OPEX: 8 Euros/kWp/y, Yield: 1560 kWh/kWp (Rome), performance loss rate: 0.25%/y

[15] Solar PV Jobs & Value Added in Europe, Ernst & Young and SolarPower Europe, November 2017

3. Strategic Projects and Actions: Flagship "Utility-scale PV" of the SET Plan Implementation Plan

This flagship programme is essentially a **national mission**, as defined in the preparatory documents of Horizon Europe, to relaunch the national PV industry around four main pillars:

1) Innovative products with a quick route to conversion efficiencies >30%
2) Competitive Levelised Cost of Energy (LCoE) with a quick route to 15€/MWh by 2025
3) Increased PV module and system reliability
4) Very low environmental impact of both manufacturing plants and PV power plants (including soil consumption)

Within the scope of this mission is also the provision of the tools to create and share the knowledge and skills necessary to achieve the main goals, that is:

1. Network development;
2. Industrial prototyping infrastructure creation;
3. Technological development.

The first two actions are functional and synergic to the achievement of the technological objectives included in the two strategic project proposals, one looking at short term objectives and based on incremental innovation and one pointing towards radical innovation and new products.

Outcomes/Expected Impact:

development of a set of innovative solutions (in the next 3-5 years) at different level of maturity (from TRL 6/7 to 9/8), which will be consolidated in the PV value chain to foster the overall growth of the national and EU's PV industry.

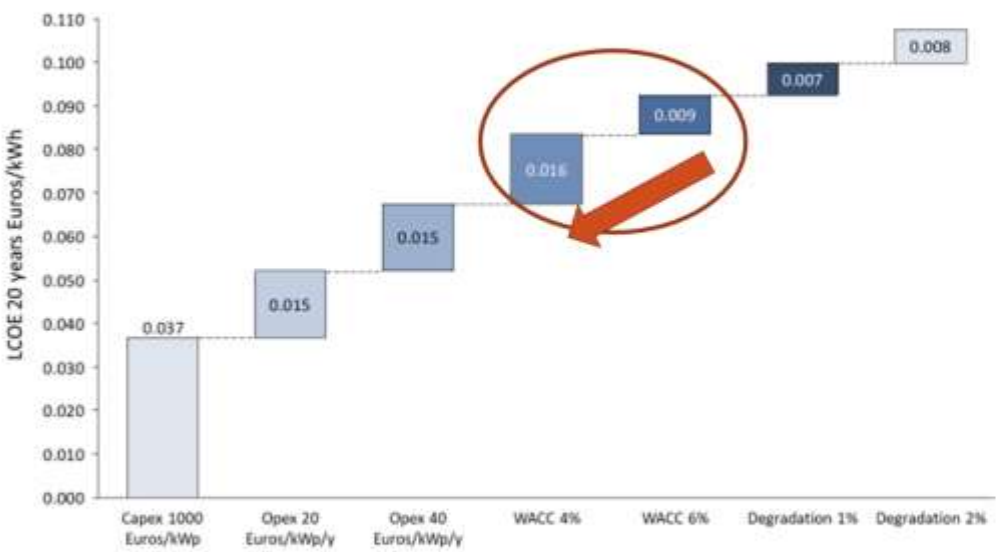

Figure 8: Impact of WACC on LCOE. High quality projects can have access to lower financing costs

3.1. Action 1: Strategic Project “Incremental Innovation from Solar Cells to O&M of PV plants, to relaunch of the Italian PV industry and meet the objectives of the NECP”

Incremental innovation (from TRL 6/7 to TRL 8/9) will be primarily aimed to:

1. increase efficiency, reliability and average life of PV products (cells, modules, inverters, etc.);
2. optimize PV production processes, related machinery and systems for operation and maintenance of PV plants;
3. reduce time to obtain certifications for PV components

Objectives

Demand for innovation in these areas stems directly from industrial end-users and industrial PV panel manufacturer and is not strictly limited to technological problems.

Electricity generated by photovoltaic systems is changing the energy landscape as we know it. GWs of capacity are added worldwide year after year where the cumulative 1 TW goal could be achieved already in 2022. By the end of the next decade the TW annual market could become reality. PV already represents a share of more than 8% of the electricity generation in some countries (Italy, Germany, Greece, to name a few) and with these values in mind the penetration levels will quickly reach the double-digit all-over Europe. It is within this scenario that the PV sector must ensure that:

- the installed power capacity in GW can also reliably generate TWh of electricity for an extended lifetime

- PV plants can provide ancillary services and ultimately become dispatchable to increase utility friendly integration

The ultimate target should be to demonstrate competitive utility scale solar plants based on European industrial solutions with a target LCOE of 15€/MWh for conventional PV and 30 €/MWh for PV+storage by 2025.

The reliability and lifetime of a PV plant depends mainly on the quality of the components. The economic impact is a function of the number of failures and the lead time to detect a failure, to respond after the detection and to ultimately resolve the issue. The economic impact can be reduced by means of mitigation measures which can be preventive or corrective. In new PV projects, the focus must be on the application of novel preventive mitigation measures. These can vastly reduce and minimise the probability of failure occurring in the field once the PV plant is in operation. For existing PV projects, advanced data driven mitigation measures need to be developed to go beyond the state-of-the-art concept of corrective maintenance as well as progressive repowering interventions to extend plant lifetime and increase the production capacity without requesting additional space. Planning of future PV plants must also consider the impact to the distribution or transmission grid and solutions must be introduced to enable seamless integration. All data coming from the various phases carry important information that can only be fully exploited by the community as a whole if the data can be stored and transferred along the value chain.

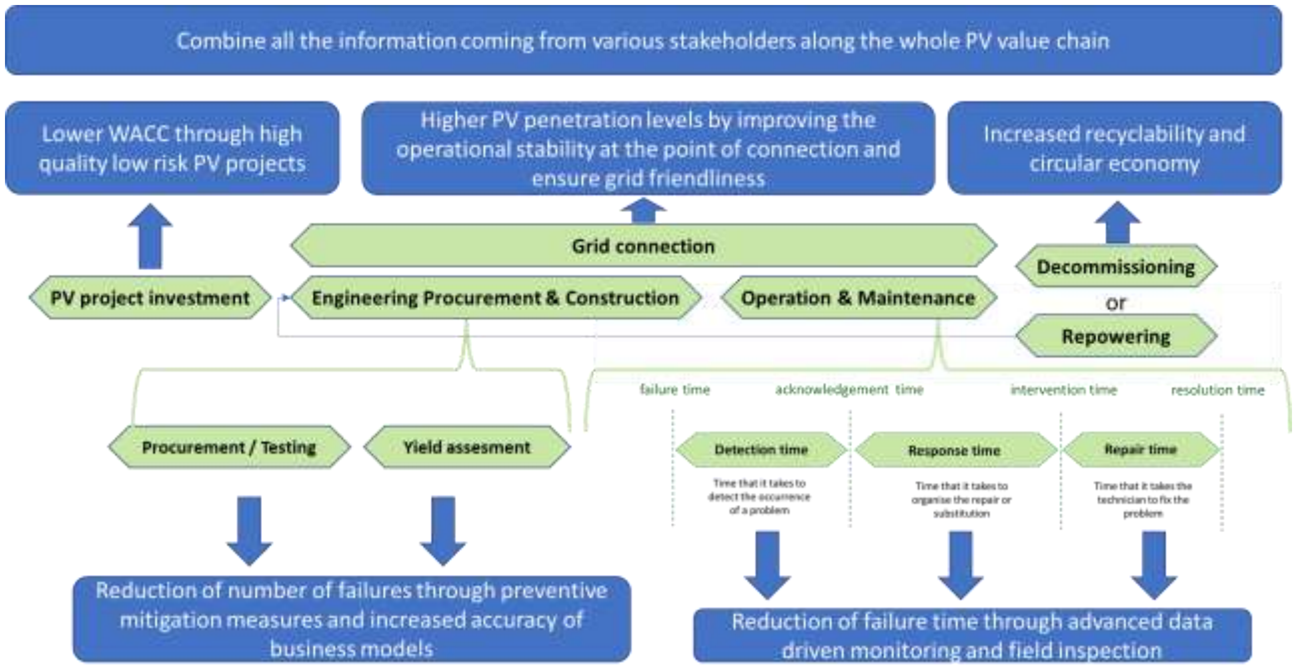

Figure 9: Innovation along the value chain in PV projects credit: EURAC

Specific objectives of technical development involve both type of innovation and the entire PV value chain. In addition to cells and modules, several innovative concepts will be developed with regard to process integration/EPCM, plant O&M, plant end-of-life and waste management (i.e. plant layout optimization, energy storage integration, glass hydrophobic coating, trackers cost reduction and performance optimization, UAV inspection, anomalies detection, air pollution related losses, etc.).

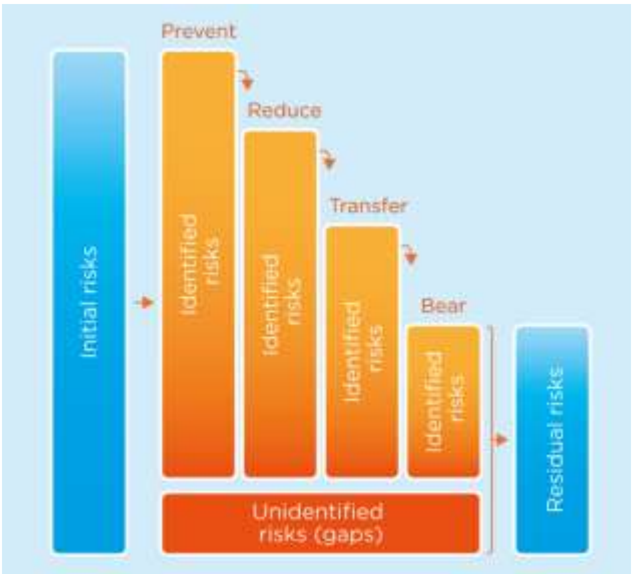

Figure 10: Technical risk framework as developed in H2020 project Solar Bankability (coordinator: EURAC)

PV projects in any market segment require a dedicated technical risk framework where the requirements may vary depending on the complexity of the project. In general terms, initial risks need to be identified and quantified and all the stakeholders operating in various phases along the value chain need to be involved to vastly reduce and minimise the residual risks.

This can be done by preventing the occurrence of failures and by reducing the impact of failures once they become evident. Technical risks which cannot be transferred to other stakeholders will ultimately stay in the hands of the PV project owner. A clear technical risk framework is important as it can “quantify” the quality of a PV project and thus demonstrate the advantages in terms of business model (more reliable generation for a longer lifetime) compared to other projects of lower quality. A project perceived of high quality by lenders (in terms of equity or debt) will have access to lower WACC (Weighted Average Cost of Capital) which is the most important parameter affecting the LCOE (Levelised Cost of Electricity), and ultimately the IRR (or other benchmarks). Quality in PV projects starts from the planning phase where a fundamental role is played by the accuracy and uncertainties related with the yield assessments. A yield assessment with reduced uncertainties (thanks to improved models and access to better site dependent data, e.g. irradiance) can lead to a much more favourable business model. Procurement is the next important step where extended testing beyond what is prescribe by the standards can increase the confidence of the right choice of PV components.

It is during these two steps that the remuneration of PV projects can be vastly improved by ensuring a reduction in failure rates and a more positive business case. After a successful implementation of these preventive mitigation measures, the PV project needs to focus on the transportation and installation phase where quality assurance needs to be included to make sure that all the components are in their best conditions for the operational phase. A reliable generation for a longer lifetime can then be ensured by innovative O&M practices which include data-driven measures coming from both field experience and monitoring. Finally, all the information collected along the whole value chain need to stream into a platform that can act as a decision support system for the best actions to follow in case of deviations. The decision support system platform must be based on self-learning algorithms that include the important feedback coming from the operators.

The project aims to achieve the following specific targets:

Value chain involvement

The innovation carried out at each step of the value chain must be the result of the push-pull approach between stakeholders operating in clearly well-defined and separated phases of a PV project which usually work with only their main objectives in mind and have little or no influence on the other stakeholders. PV modules and inverters must be built with in mind the needs of EPC contractors and O&M operators; knowledge, information and decision steps carried out during the design phase will be transferred to the operational phase; design of large PV plants and access to large portfolio of distributed PV will be used to increase the hosting capacity of the grid and avoid curtailment and increase availability during the operational phase. This approach will have an overall benefit in terms of performance and profitability of PV systems.

Manufacturing Process

- Demonstrate more efficient manufacturing processes by implementing and developing advanced automation and artificial intelligence applied to several aspects from big data analysis to preventive and intelligent maintenance.
- Improve the performance of key PV products in terms of safety and LCA. Also by designing the product to facilitate end-of-life recycling. This includes features for simple disassembly, recycling, and reducing or eliminating the use of toxic components.

Cells

- Achieve an efficiency target of 25% in production by 2022
- Fabricate reliable devices that are manufacturable in mass production with the possibility of reducing the amount of materials.
- Improve environmental sustainability and bankability.

Modules

Increasing the size of PV cells and by introducing novel module architectures based on solar cell segmentation or shingling to reduce the resistive losses and increase the active area of the module. Also, developing smarter layout that can help control the voltage output in order to optimize the installation effectiveness. Developing smart module and digital solutions: electronics on board to harvest all the available power at module level, anomalies detection using IoT (beyond Industry 4.0 development)

Integration and EPCM

- Improve applicability through better aesthetics, form freedom, function integration, and shade tolerance;
- Improve sustainability and bankability.
- Demonstrate medium to large scale PV plants with reduced balance of system based on the efficient management of the input power while ensuring the reliability and reducing the footprint
- Demonstrate new structural, mechanical solutions and tracking systems to increase the capacity factor (kWh/kWp) and reduce the energy cost
- Demonstrate the short term (at least 3h) dispatchability of programmable PV plants by using properly sized storage units

Operation and Maintenance

Achieve common annual performance ratio (PR) at PV plant level (including periods of unavailability and after correction for expected degradation in the field) of:

1. 82% PR for residential and small commercial plants in 2020;
2. 87% for other plants installed in 2020;
3. 85% for residential and small commercial plants in 2025;
4. 90% for other plants installed in 2025.

PV plants can be complex systems with thousands of components. Statistical analysis of reliability at component level can only be entirely enabled through the digitalisation of the information. Digital Twins are electronic model of PV plants together with the electrical hierarchy of the individual components from the transformer level, through to inverters, combiner boxes, parallel/series strings and down to PV module level. The creation of Digital Twins must be combined with precise 3D modelling to allow for more accurate yield assessments based on improved models which include novel technologies and PV plant layouts. UAV can play an important role in geolocalising products within an utility scale plant on top of carrying out multispectral imaging assessment.

Waste Recycling & Plant De-commissioning:

Solar photovoltaic (PV) deployment has grown at unprecedented rates since the early 2000s. Global Solar Photovoltaic capacity is estimated to increase significantly from more than 600 GW in 2019 to about 1,600GW in 2030 and is expected to rise further to 4,500 GW by 2050. In 2018, Italy connected 440 MW of PV systems, increasing cumulative installed capacity to 20.1 GW according to the annual report of the Italian Ministry of Economic Development [MSE 2019].

As the global PV market increases, so will the volume of decommissioned PV panels. At the end of 2016, cumulative global PV waste streams are estimated to reach about 0.5% of the cumulative mass of all installed panels (equivalent to 100’000 metric tonnes). According to a report by the International Renewable Energy Agency (IRENA), the total volume of accumulated global photovoltaic panel waste is estimated to reach to around 60 to 78 million tons by 2050. As a result, PV panel waste presents a new environmental challenge in the next future, creating an opportunity to create value from decommissioned solar PV plants.

- **Incremental innovation** (from TRL 6/7 to TRL 8/9) in PV end-of-life management offers opportunities to develop technologies to support:

I. PV Waste Reduction

Actions should be primarily aimed to:

a. increase efficiency, reliability and average life of PV products (cells, modules, inverters, etc.) reducing the impact of end-of-life (including also early failed) yearly generated waste.

b. design sustainable PV production processes and innovative module design in order to decrease raw material usage per unitary power (material weight per W peak), mainly for Critical Raw Materials and Precious Materials, such as silver, indium, silicon, copper, aluminium, etc.

Many activities could be developed in this area, such as: reducing front and or back glass thickness or replacing it with different materials; reducing wafer thickness; reducing silver and indium usage in the manufacturing process of cells and modules;

II. "Less Waste More Value" Policy - EoL PV Recycling

Sectors like PV recycling will be essential in the world's transition to a sustainable, economically viable and increasingly renewables based energy future. End-of-life PV management could become a significant component of the PV value chain, since a large stock of raw materials and other valuable components can be recovered and re-injected into the production of new PV panels or be sold into global commodity markets.

End-of-life management for PV panels will spawn new industries, can support considerable economic value creation, and is consistent with a global shift to sustainable long-term development. PV manufacturing waste could be included in the same value chain, extending the potential stakeholders interest to PV manufacturers (waste reduction will lead to environmental and financial positive impact)

III. Improving sustainability and bankability of PV recycling:

Preliminary estimates suggest that the raw materials technically recoverable from PV panels could cumulatively yield a value of up to USD 450 million (in 2016 terms) by 2030. This is equivalent to the amount of raw materials currently needed to produce approximately 60 million new panels, or 18 GW of power-generation capacity. By 2050, the recoverable value could cumulatively exceed USD 15 billion, equivalent to 2 billion panels, or 630 GW.

Since currently only moderate PV waste quantities exist on the global waste market, there are not sufficient quantities or economic incentives to create dedicated PV panel recycling plants. End-of-life PV panels are thus typically processed in existing general recycling plants. Here, the mechanical separation of the major components and materials of PV panels is the focus. This still achieves high material recovery by panel mass even although some higher value materials (that are small in mass) are not fully be recovered.

In the long term, however, constructing dedicated PV panel recycling plants could increase treatment capacities and maximise revenues owing to better Secondary Raw Materials quality, with an additional effect on the increase of recovery of valuable constituents.

Increase of the recycling profitability by establishing new metals' revenue stream compared to ongoing industrial recycling (Ag, Si, In, Ga mostly not recovered) and by combining all steps automated in one recycling scheme will strengthen the potential business models of such designed plants. Considering the difference between material revenues and process recycling costs, an added value coming from dedicated PV automated recycling plants is expected.

IV. Strenghten Sustainable Production Policy Framework

A side action, necessary to strengthen sustainable waste management, is to empower consumers and public and private buyers, through the development of eco-design directive and the energy labelling regulation for PV. International regulations will be the necessary tools to identify industrial best practices for Circular Procurement and circularity metrics in PV module supplier selection.

3.2. Action 2: Strategic Project "Radical Innovation in manufacturing processes, PV technologies, products and systems to maximise the penetration of Photovoltaic Power Generation"

A comprehensive action based on radical innovation (from TRL 3/4 to TRL 6/7) is designed to **speed up the development of the most promising technologies** and solutions for utility-scale photovoltaics in order to offer viable solutions for a complete transition to renewable electricity.

In the short-to-medium term a significant effort should be put on the development of a new generation of high-efficiency Silicon solar cell, in particular on HJT solar cells which are set to replace PERC and other well established technologies as the most viable solution, in terms of cost to efficiency ratio, for large scale manufacturing. Among the key R&I tasks is the consolidation of the cell architecture by further optimizing passivation and carrier selection at the contacts. The concurrent optimisation of light transmittance and conductivity of transparent conducting oxides is also a priority which is linked to the strategic objective of abating the dependence on rare elements such as Indium.

In the medium to long run the development of new high-efficiency PV cells and modules, capable of exceeding the efficiency limit of single-junction Silicon cells, are a top priority. **Tandem (multijunction) photovoltaic devices** based on the integration of semi-transparent thin film solar cells (perovskites, CIGS or other innovative materials) on state-of-the-art Silicon cells, are considered to be the most promising solution to increase power generation per unit area.

Despite very promising results have already been claimed by several research labs and companies in Europe and in the United States, **critical technological issues remain open** regarding the cost of certain solutions (as in the case of the III-V/Silicon solar cells) or the lifetime of any PV device containing organic components as in the case of tandem cells based on perovskites.

Coupling perovskite or other thin film top cells with silicon heterojunction cells can lead to high performing devices that can be well matched in a monolithic series configuration. Such cells can be assembled in a module by using low temperature interconnection with electrical conductive adhesive improved with graphene.

The key objective should be to demonstrate that efficiency targets of **28% by 2022 at prototype level and 2025 at industrial level** and possibly **35% by 2030** can be achieved with a **projected LCOE equal or lower than 15€/MWh**

On the module side, new technologies to **reduce weight** (such as carbon fibres), **improve light trapping**, incorporate **smart functions** and others, are considered a priority alongside with the solutions to extend module **lifetime** to a target value of **40 years by 2030**.

Reducing the use of materials or replacing high-cost materials with low-cost alternatives is also a priority. For instance:

- low temperature treatments in silicon solar cell processing, (Si HJT or others), can enable the use of thinner silicon wafers (100 µm or less).
- Copper metallisation can replace silver paste printing, thus reducing the metallization costs.
- TCO contacts can prevent the migration of copper in silicon active area, thus facilitating the transition from Ag to Cu.

The combination or integration of different technologies are also a key topic to improve resiliency and versatility of a PV power plant. In this category **CPV-PV hybridization** is a promising solution which can build upon the extensive R&D and demonstration work carried out by the CPV community, starting from advanced solar tracking systems. Deep **integration of thin film batteries or supercapacitors with solar cells** and modules is also in this tier as a key solution to reduce power fluctuations due to the erratic behaviour of weather conditions.

Finally the development and validation of manufacturing processes and equipment to enable pilot production of new innovative products, like tandem solar cells, is an essential objective of this action which should then feed into the activities of the national industrial prototyping facility described in the next paragraph.

3.3. Action 3: National Industrial-Prototyping Facility

3.3.1. Technology development centre

The national hub will be a technology-development excellence centre, which will foster innovation by converting pioneering basic research into advanced processes. The hub has to be strongly industry driven and application-oriented. The main scope is to nurture innovation and accelerate the pace of technology transfer in the field of photovoltaics. Its mission will be to bring novel high-tech solutions for solar components and systems to technological maturity, serving the national industry. The hub will develop new generations of photovoltaic cells, modules and system components, supporting the transition to an energy system in which solar will play an essential role. The center will be able to support industry, spanning from technology development to full size product prototyping and demonstration systems.

To this purpose, some technology development lines will be realized, with infrastructures that include specialty systems for coating, patterning, printing, and fabrication processes, as well as pilot manufacturing lines – from glass cleaning and wafer etching up to the assembly of functional modules. It can also process fully printable PV modules. Among the number of tools and equipment the most important will be focus to the fabrication and study of:

- High-performance crystalline silicon cells

- Perovskite or other wide band gap solar cells
- Multi-junction solar cells, by matching wide-gap top cell with silicon bottom cell
- Interconnection and PV module technology
- Building integrated photovoltaics
- Polymers and reliability of PV components

The hub will be very important, as it will contribute to support the national and European efforts to limit dependency on fossil fuels and reduce greenhouse gas emissions in three key areas such as renewable energy, energy efficiency/storage, and development of materials.

Within this flagship action, the most appropriate and effective location for a national facility devoted to industrial prototyping is Catania because of the presence of both the EGP manufacturing plant an R&D Pilot Line located close to the factory and the innovation Hub&Lab of Enel Green Power. **In particular, the area of the 3SUN factory can host the development facilities in already existing building.**

Although the proximity to the EGP labs and plants is essential for the facility to benefit from the direct interaction with the industrial ecosystem involved with the largest PV manufacturing plant in Europe, the new prototyping facility should be designed to operate independently of any specific commercial and industrial interest.

Enel Green Power Innovation Lab is already a testing facility for PV modules that can be furtherly improved by increasing the test typology portfolio and also extending to high level formation the aim of the structure. In principle we can extended the competences of the testing facility to cover all the technologies involved in the realization of a PV plant. This will done by creating a facility to engineer innovative solutions for PV modules (like multiple junction modules of new generation), Inverters, Storage, Smart Power application, AI approaches to design, tracker and fixed structure working on the materials, on the eco-design and on circular economy.

In parallel, it is also fundamental to develop new testing criteria and methods to be ready for new technologies and to improve the capability of lifetime prediction.

The Innovation facilities could also allow to design and to prototype innovative PV modules thanks to a flexible multipurpose R&D production line able to process several different solution to overcome limitations of actual PV module technologies paving the way towards the PV solar technology of the future.

This framework allows to invest also in the high formation and on the possibility to create a new large research group operating in Catania that can host people from all the country.

It is possible to define also a formation path in collaboration with University of Catania involving also the main institution at national level to create a string collaboration for example by giving the opportunity of on field experiences.

Actually, the already existing facilities give the unique opportunity to exploit a consolidated environment to reach an excellence centre along all the PV value chain.

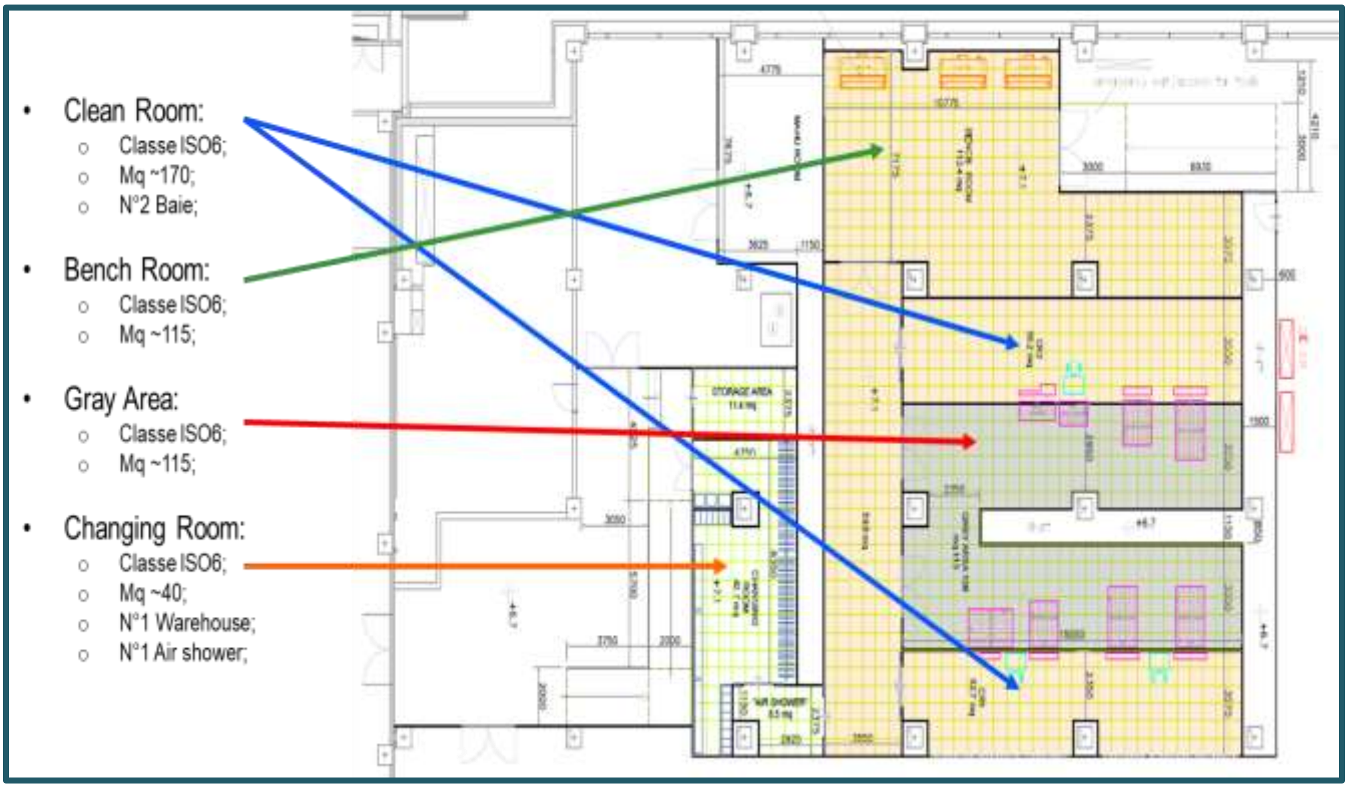

Figure 11: Example of Technology Development Line. Cell development line

Figure 12: 3SUN Area. About 20 000 m^2 are available mainly at the level 2 of the building for implementing the excellence center (in the blue areas). The 3SUN building is organized in three floors the manufacturing areas are at the 1st and 3rd levels, respectively.

3.3.2. Overall Investment in Terms of Equipment and Facilities

The hub will comprise lines for realization of innovative silicon based solar cells as well as of advanced multiple junction solar cells by realizing high wide gap solar cells that will be coupled with silicon-based solar cells. Moreover, the hub will have a cell assembly line that will be able to interconnect advanced solar cells and assemble them in modules of large area. In PV it is very important the scale-up that involves both scaling the area of the PV device and the number of solar cells and modules to be realize. The latter aspect is very important for evaluating in a correct way the possibility of technological transfer to manufacturing. In addition, the hub must have a fully equipped characterization laboratory for analysing physical, chemical and structural properties as well as electrical and optical characteristics and electronic and photonic characteristics. In addition the laboratory has to be equipped with advanced reliability characterization tools such as climatic chambers and other tools to accelerate the aging of the devices and determine the reliability.

The study has to be done both in indoor facilities and in outdoor installations, the latter case is very important for the correct evaluation the impact of environment.

The following tables indicate the estimated amount of investment and the expected head counts of researchers, technicians and administrative employees.

Overall Investments for the Hub

Item / Area	**Costs k€**	**Purpose**
Cell Fabrication Line Tools Total Costs	15000	**To** realize prototype single junction solar cell and develop the technology that can be transferred to manufacturing
Additional equipment for multiple junction solar cell total costs	8500	**To** realize prototype multiple junction solar cell (tandem) and develop advanced metallization
Advanced Assembly Total Cost	2500	To realize prototype modules (small and large area) and develop the technology that can be transferred to manufacturing
New Silicon Wafer Tools	4200	To fabricate epitaxial wafers as new substrates for HJT solar cells
Characterization Lab	**5900**	To perform detailed physical-chemical, structural and microscopic characterization of materials and devices as well as to study their electronic and photonic characteristics
Outdoor Total Costs	**2000**	Outdoor systems testing
Facilities Total Costs	8000	Facilities and Infrastructure
Facilities & Adaptation Works Total Costs	**46100**	

Detailed Investments

Prototype Solar Cell Fabrication Line

Scope: to realize prototype single junction solar cell and develop the technology that can be transferred to manufacturing

Equipment	Costs k€	Purpose
Wet Benches	2000	Used for wet etching (HF, HCl), O3 treatment and texturing (KOH, etc)
plasma enhanced CVD (PECVD)	5000	Used for deposition of a-Si, a-SiOx, SiN, SiC with various doping species
Physical Vapor Deposition (PVD)	2500	Used for deposition of metals, transparent conducting oxides, other
Atomic Layer Deposition (ALD)	1500	Used for the deposition of ultrathin layers with very controlled thickness
Screen Printers	800	Used for printing metallization grids
Curing Oven	400	Used for curing after the metallization
Laser annealing	400	Used for laser treating solar cells
Oven for annealing	100	Used for thermal annealing
Cell Laser Cutter	400	Used for cell segmentation
Plasma Treament / Hydrogen implantation	500	Passivating cells after cut
I-V Flasher for solar cells	200	Used for testing the solar cells
Electroluminescence tool	200	Used for testing IR emissions from solar cells
Photoluminescence tool	300	Used for PL analysis with high resolution
4-Probes and Hall Effect Measurements	100	Used for resistivity and mobility
Spectroscopic Ellipsometer	200	Used for advanced thickness and other analysis
Reflectometer	100	Used for reflectance measurement
Spectrophotometer	150	Used for optical parameters evaluation
Confocal Microscope	150	Used for evaluating surface roughness (pyramids, etc.)
Cell Fabrication Line Tools Total Costs	**15000**	

Additional Equipment for multiple Junctions Cell Line and advanced metallization

Scope: to realize prototype multiple junction solar cell (tandem) and develop advanced metallization

Equipment	Costs k€	Purpose
Chemical Mechanical Polishing	200	Tool for polishing
Chemical Vapor Deposition	1500	Tool for the deposition of organic-inorganic materials (perovskite)
Vapor Liquid-Solid Deposition	2000	Tool for the deposition of III-V compounds
Evaporatioin tools	1000	Used for the deposition of ultrathin layers with low energy in order not to damage the interface
Roll to roll deposition tool	800	Used for deposition of perovskite materials
Inkjet printer	800	Used for deposition of deposition through inks (perovskite, graphene, etc.)
Mask Aligner	200	Used for aligning masks for lithography
Resist spinning	200	Used for resist deposition
UV-Stepper (Lithography)	400	Used for photolithography
Dry Etcher (plasma)	400	Used for etching resist
Wet benches	300	Used for resist wet etching
Electroplating tool or other copper definition tool (inkjet)	500	Used for copper metallization
Electrical characterization tools	200	Testers, Multimeters, Voltage sources, oscilloscopes, LCR meters, etc.
Additional equipment for multiple junction solar cell total costs	**8500**	

Advanced Module Assembly

Scope: To realize prototype modules (small and large area) and develop the technology that can be transferred to manufacturing

Equipment	Costs k€	Purpose
Stringer	600	Used for cell interconnection in strings
Bussing tool	300	Used for strings interconnection
Mechanical bench for adjustment	100	Used to reworks cells or strings
Small area laminator	100	Used for mini-module lamination (glass/glass, glass back sheet, other materials)
Large area laminator	600	Used for larger module lamination (glass/glass, glass back sheet, other materials)
Large area flasher	250	Used for I-V testing
Conveyors and trails	150	Used for moving glasses and modules
Large area electroluminescence	400	User for IR microscopy on large area modules
Advanced Assembly Total Cost	**2500**	

Epitaxial Silicon Wafer Realization

Scope: to fabricate epitaxial wafers as new substrates for HJT solar cells

Equipment	Costs k€	Purpose
Atmospheric Pressure Chemical Vapor Deposition for Epitaxy	3000	Used for depositing epitaxial silicon
Wet etching tool	200	Used for chemical etching
Plasma etcher	500	Used for dry etching with plasma. Used for forming porous silicon
Plasma implantation tool	500	Used for surface doping and for passivation
New Silicon Wafer Tools	**4200**	

Characterization Laboratory

Scope: To perform detailed physical-chemical, structural and microscopic characterization of materials and devices as well as to study their electronic and photonic characteristics

Equipment	Costs k€	Purpose
Transmission Electron Microscopy + Microanalysis	1000	Used for micro analytic characterization
Scanning Electron Microscopy + microanalysis	400	Used for micro analytic characterization
Secondary Ion Mass Spectrometry (SIMS)	800	Used for surface analysis and depth profiling
X-Ray Photoemission Spectroscopy (XPS)	500	Used for surface chemical analysis
Micro-Raman Spectroscopy	100	Used for crystallographic measurement
Electrical Bench	100	Used for electrical characterization
Electrical Characterization Tools	200	Mustimeters, Testers, Parameter Analyzers, LCR Meter, Wave function generators, Oscilloscopes, etc.
Optical bench	200	Bench equipped with optical systems, spectrophotometry, etc.
Climatic chambers	1000	Humidity freeze, Thermal cycle
Load tests	200	Mechanical test
UV Test	200	UV stress test
Electroluminescence tool	400	Large area electroluminescence
Photoluminescence tool	400	Advanced PL test on wafers
Optical microscopes	100	optical microscopy
Other minor tools	300	
Characterization Lab	**5900**	

Outdoor Testing

Scope: Outdoor systems testing

Equipment	Costs k€	Purpose
External installations	2000	PV Installations for outdoor testing, Storage, Trackers, Ancillaries
Outdoor Total Costs	**2000**	

Facilities and Infrastructures

Facilities & Adaptation Works	Costs k€	Purpose
Chillers, Drains, PCW, UPS, exhaust, HVAC, laminar flow, specialty gas management, chemicals management, etc	5000	Supporting the lines including prototyping lines, laboratories and testing areas
ICT Hardware and Software	1000	ICT support and Networking
Building adaptations (internal works)	2000	Activities for restructuring building internal areas
Facilities Total Costs	**8000**	

3.3.3. Personnel

Technology Area	Activities	Personnel	Head Count
Prototype Solar Cell Fabrication Line	Realize prototype 1 junction solar cell and develop the technology that can be transferred to manufacturing	6 Researchers, 6 Support Technicians, 5 Maintenance Technicians	17
Additional for multiple Junctions Cell Line and advanced metallization	Additional steps to produce 2-junctions or tandem solar cells and develop the technology that can be transferred to manufacturing	5 Researchers, 5 Support Technicians, 3 Maintenance Technicians	13
Advanced Assembly	Realize prototype modules (small and large area) and develop the technology that can be transferred to manufacturing	5 Researchers, 5 Support Technicians, 3 Maintenance Technicians	13
New Silicon Wafer Fabrication Systems	Realize absorber materials like wafers alternative to conventional commercial crystalline wafers	3 Researchers, 4 Support Technicians, 3 Maintenance Technicians	10
Advanced Characterization Tools	Perform detailed physical-chemical and microscopic characterization of materials and devices	4 Researchers, 5 Support Technicians, 2 Maintenance Technicians	11
Outdoor Experimental Solar Installations	For external testing of modules and strings	4 Researchers, 4 Support Technicians, 3 Maintenance Technicians	11
Direction / Management	Directive functions; Coordination	5 Managers	5
Administration and Financial Support	Administrative functions; Funded Programs Reporting, etc.)	10 Employees	10
Total personnel			90

3.3.4. Examples of tools to be used in the hub

Figure 13: Left: typical view of technology development line with a capacity of realizing some thousands of solar cells per day. Right: A typical screen printer metallization tool for the solar cell pilot line

Figure 14: Left: A PECVD for deposition of amorphous silicon or of SiOx or SiN or SiC or other layers for passivation. Right: Tray used for a Physical Vapor Deposition machine in a solar cell pilot line.

Figure 15: Left PV Modules Mechanical load test tool. Right climatic chamber for aging tests on PV modules. Both tools are very important for reliability tests in a characterization Lab

Figure 16: Tool for fast deposition of epitaxial layers of silicon based on atmospheric pressure chemical vapor deposition to produce thin epitaxial wafers for next generation solar cells

Figure 17: Examples of installation for outdoor testing

Figure 18: Left: A Secondary Ion Mass Spectrometer (SIMS) used for surface and thin layer chemical analysis. (b) A scanning electron microscope for microscopy and microanalyses. Both tools to be used in the materials characterization laboratory in the hub

3.4. Action 4: Specific services offered by the national distributed lab to downstream industrial stakeholders

Downstream industrial stakeholders (e.g. contractors of the manufacturing companies, O&M operators, service providers for ancillary services, investors, etc) have complementary, but not less critical, R&D needs with respect to the upstream stakeholders.

The distributed national lab proposed in this document can support them with a variety of different services, coordinated at national level, such as:

- Measure the performance of PV modules and systems in different climatic conditions
- Test novel diagnostic techniques in the field
- Provide a facility to train EPC and O&M operators
- Test novel installation layout
- Develop novel data driven algorithms for performance analysis, early fault detection and fault prediction
- Develop novel methodologies for maintenance, replacement and reuse of PV components
- Develop a new kind of lab for augmented reality, virtual reality and integration of automation and robotics for Solar plant

4. Strategic Projects and Actions: National Flagship "BIPV/PIPV" of the SET Plan Implementation Plan

The participants to the flagship Distributed PV have met 3 times to discuss about the common challenges in the field, organise work in dedicated working groups, define specific objectives at WG level and main objectives.

The following main objectives have been defined during the last meeting which was held Virtually (with around 70 participants) on the 26th of May 2020. These 3 main actions are the basis for ambitious projects of broad impact which could support and provide the necessary framework for the achievement of the targets set in the National Energy and Climate Plan (NECP or PNIEC in Italian).

4.1. Action 1: Strategic Project "A 3D solar cadastre for Italy to assess the full potential of distributed PV"

State of the art:

The concept of Solar Cadastre is not novel. The first examples of Solar Cadastres date back to 2010-2011 with the one of the city of Brixen[16], in South Tyrol, as the first implementation of a Solar Cadastre in Italy (project PV Initiative, funded with the ERDF instrument of the Province of South Tyrol). That early experience led to the extension to the territory of the Province of South Tyrol within the project Solar Tirol (funded with the INTERREG Programme 2007-2013)[17]. Typically solar cadastres are limited to the estimation of the PV potential at roof level due to the lack of 3D building models. Several challenges are linked with the availability of up-to-date georeferenced data of the building typology, building footprint, etc and to a high-resolution digital terrain model.

Project Concept:

The aim of a solar cadastres for Italy is:

1. To create a freely accessible, geo-referenced solar potential data base, which will allow private users and public bodies to estimate the solar potential on a roof and façade level (and other areas depending on the interest and regulatory framework at local level).
2. To provide a tool to urban planners, developers and energy managers to design renewable energy communities
3. To give concrete recommendations to public authorities and politicians about the relevance of solar energy and the potential to further develop solar energy in Italy.

[16] http://www.eurac.edu/en/research/technologies/renewableenergy/projects/Pages/PVinitiative.aspx

[17] http://webgis.eurac.edu/solartirol/

The approach incorporates the workflow for convenient and successful analysis of large amounts of spatial data, includes an integration of different formats as vector and raster and allows query operations and spatial analysis. The initial data, the Digital Terrain Model (DTM) and Digital Surface Model (DSM), are derived from the LIDAR data and provided as input information for solar radiation simulations.

The main data sources are ambient temperature grid, cadastre data and vector data of protected areas. The estimations of photovoltaic generation can be based on different algorithm and allow to work with different PV technologies.

Figure 19: Example of rooftop Solar Cadastre (http://webgis.eurac.edu/solartirol/)

The availability of a Solar Cadastre at national level could go beyond the use for distributed PV. It could also be used to plan novel multifunctional solar PV landscape and aesthetically pleasing greenfield/brownfield integration.

Project Key Outputs:

The information provided to the user will include considering about energy performance depending on the chosen technology, economic and sustainability KPIs, etc.

For the consideration of complex business models based on net-billing schemes, self-consumption, use of storage, etc, a consumption profile needs to be assigned to each building and hence the building typology and final use is an important information. These data can only be available if the relevant regional department is included in the workflow. This could also enable the direct access to information layers based on existing regulatory framework, barriers, etc.

Finally, the solar cadastre must be linked to a product or energy package database (provided by Italian manufacturers) where the use can directly see the aesthetic, functional, energy integration on the building envelope.

Project expected budget

The budget will depend on the need to update the DTM of Italy with a higher resolution. We consider that a contribution between 15/20 million Euros would allow this challenge to be addressed appropriately.

4.2. Action 2: Strategic Project “100 virtually connected renewable energy communities”

State of the art:

System integration is the base for a low-carbon transition. While traditional energy systems are governed by unidirectional flows and distinct roles, the new energy systems are multi-directional, highly integrated and digitized. "Smart demand" response programs - in buildings, industry and transport - introduce flexibility, avoiding electricity infrastructure investments. The integration of electric vehicles introduces floating flexibility avoiding investments in storage. Storage technologies can provide a range of services and can create positive business cases.

The EU directive 2018:2001 introduced the normative framework for the concept of collective self-consumption (Art 21) and renewable energy communities (REC) (Art 22). In Italy, first implementations of Renewable Energy Communities are enabled by the Decree “Milleproroghe” 28 February 2020 (art 42 bis) with a limit set to a maximum of 200 kW[18]; the level of remuneration is still under discussion.

Several projects are already looking at models to smart manage the energy flows among photovoltaic systems, batteries, electrical distribution grid and end-users (e.g. Lampedusa project and demostrators at ENEA Casaccia from ENEA, demonstrators at the University of Catania, ERDF INTEGRIDS and H2020 STARDUST projects from EURAC, UVAM projects with Evolvere, ENELX, RSE, Project BLORIN in Lampedusa and Favignana with REGALGRID). The modelling environment is used to test the energy management system in a building or in a district and the relevant control rules to maximise the exploitation of renewable energy sources and the economic benefit of the end users depending on the objective function.

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[18] https://www.gazzettaufficiale.it/atto/serie_generale/caricaDettaglioAtto/originario?atto.dataPubblicazioneGazzetta=2020-02-29&atto.codiceRedazionale=20G00021&elenco30giorni=true

The energy transition to be effective needs business model innovation supported by system regulation and policy. This step is necessary in order to promote a change of the actual business model based on corporate utility of selling units of energy to consumers that drives the whole energy value chain to increase throughput, locking system users into unsustainable practices. Supply business models on smaller scales (as in renewable energy communities) have the potential to:

1. maximising material and energy efficiency,
2. substituting fossil fuels with renewables;
3. encouraging sufficiency;
4. encouraging sustainability;
5. promoting demand management,
6. giving to new entrants the possibility to compete with incumbent firms.

The REC manager requires the installation of suitable devices at residential user level and installations or interventions aimed at improving the energy efficiency of the dwelling, as energy upgrading of the building envelope and/or of technological systems or the replacement of equipment.

Project Concept:

The EU Directive 2018:2001 introduces the concept of collective self-consumption (Article 21) and the creation of renewable energy communities (Article 22). New services and business models are needed to enable their effective implementation.

A Demand Response (DR) Aggregator / Energy sharing manager allows the active participation to the electricity market of smaller energy consumers/prosumers, which have negligible impact on the market as single subject, by creating customized, automated controls for consumer loads and appliances that enable remote access using ICT along with advanced metering infrastructure. At the same time, ES Managers / DR aggregators can provide the Distribution System Operators (DSO) with a cost-effective mechanism for reducing the need for grid infrastructure and a tool for better integration of renewable energy technology. Integrating new technology resources into existing infrastructure and energy markets poses large challenges for power systems because the DSOs usually do not have the appropriate mechanisms for monitoring or controlling low voltage networks where these resources are connected.

The relations within the renewable energy community (REC) needs the presence of a Network manager responsible for generation and consumption price regulation and the contractual conditions of Smart Contracts. The Economic Operator will provide the services needed within the REC managing the output of the energy transactions (in terms of tokens) and rewarding behaviours from the REC partners which can provide flexibility.

The advantages of the integration of PV at building and district level are among others: voltage regulation, reactive compensation, peak shaving, power quality, balancing out generation variability, addressing mismatch between generation and demand, and load transfer.

The key elements of future RECs will have thus to include: i) smart contracts based on the use of distributed metering of the energy flow and on the use of blockchain, ii) reward positive behaviour, iii) improve the grid observability through distributed metering, iv) maximise sector coupling, v) provide and exploit ancillary services, vi) develop energy profiles to be used for the predesign of RECs (optimal position of PV at district level and storage needs). New business models need to be developed to enable positive cash flow models for the service providers. The REC configuration needs to go through stress tests in terms of future scenarios of RES and EV penetration and emerging legislative framework. Blockchain-based management algorithms and protocols will be key to develop and improve reliability and increase the degree of security and information management.

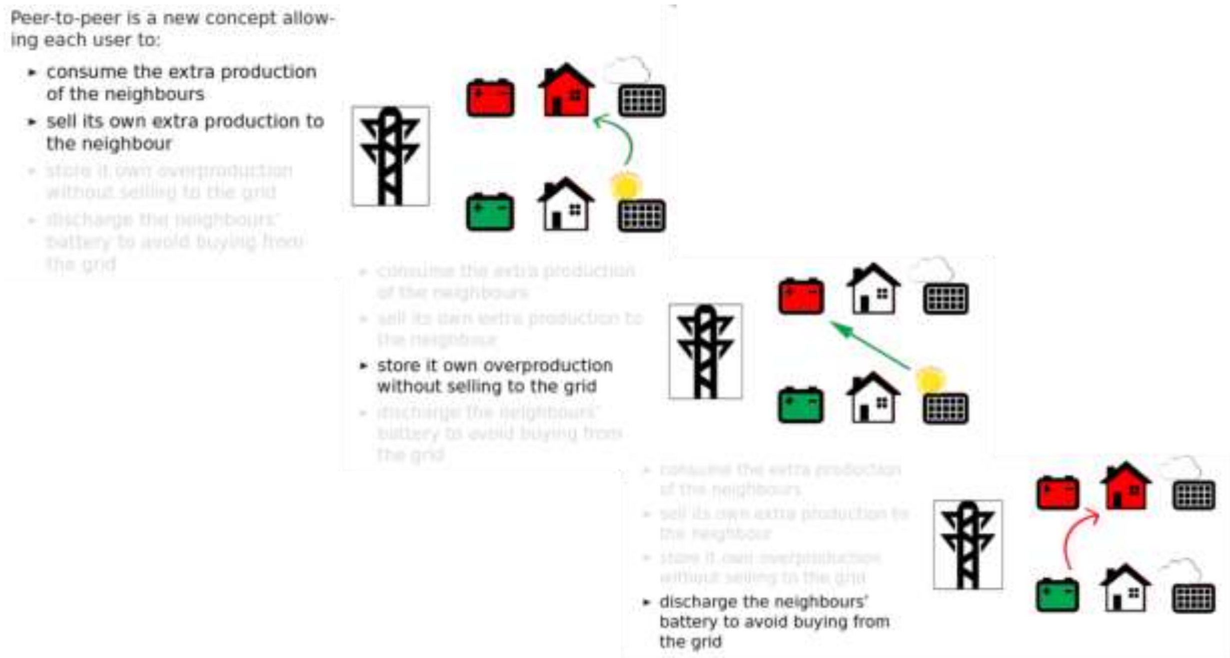

Figure 20: Peer to peer exchange of energy

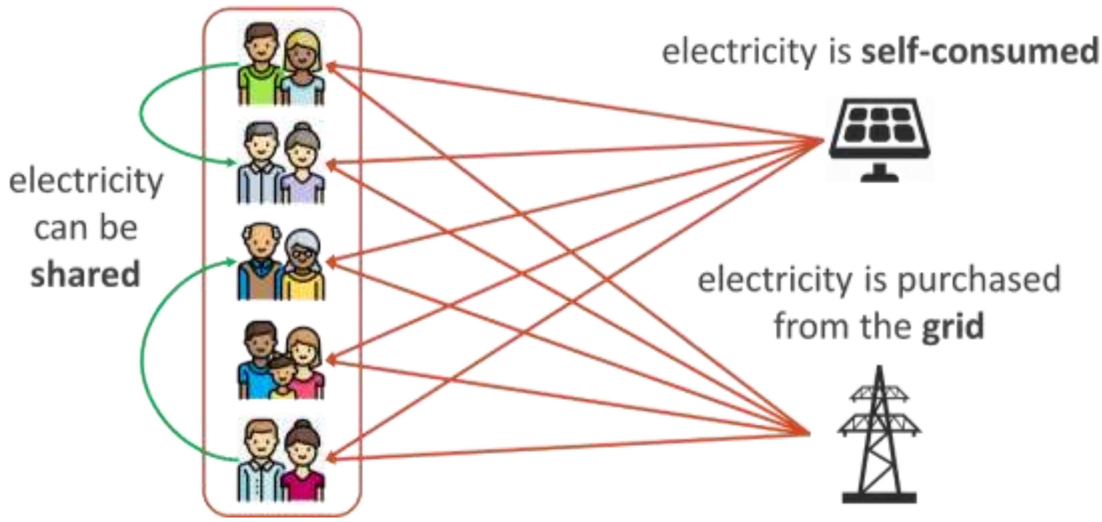

Figure 21: Simplified view of collective self-consumption

Project Key Output and requirements:

RECs will then manage to promote consumers to energy partners (renewable self-consumers). As the optimal implementation of an Energy Community is still unclear, it is important to study how in different geographical / resource / buildings mix context a REC can eventually work and perform and how the various stakeholders can all benefit from its implementation.

The project would thus involve the creation and demonstration in Italy of 100 Renewable Energy Communities with the following scope:

- once anonymised monitored data will be shared in an open platform, accessible to various market players
- the energy community could also be represented by a large multi apartment block
- various energy sharing models can be investigated
- the REC will work as a regulatory sandbox to enable testing of experimentation which is at the moment not allowed by the current regulatory framework (or to test alternatives to the consultation document prepared by ARERA in April 2020[19]).
- sector coupling through the synergy between different energy networks
- create the needed flexibility that can be aggregated in Virtual Power Plants/Load and participate to the balancing market

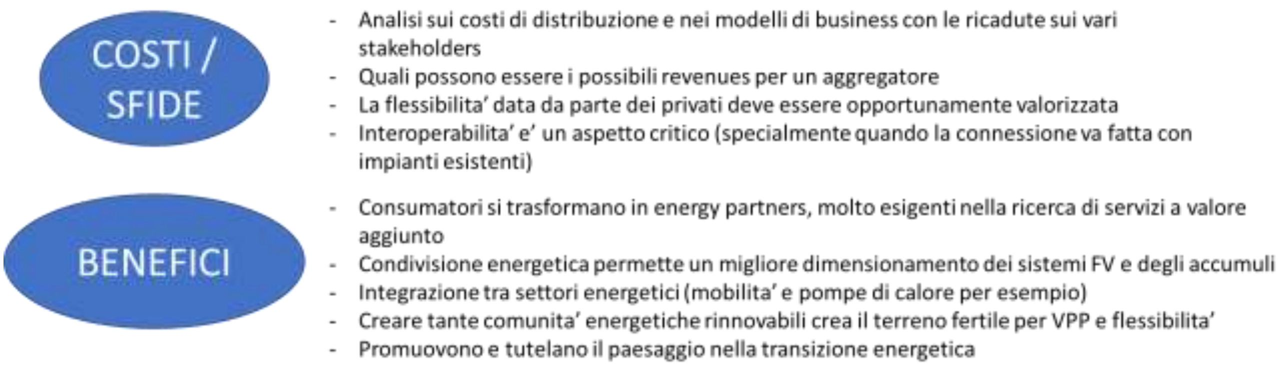

Figure 22: Outcome of the third workshop from WG3 1/2

[19] https://www.arera.it/it/docs/20/112-20.htm#

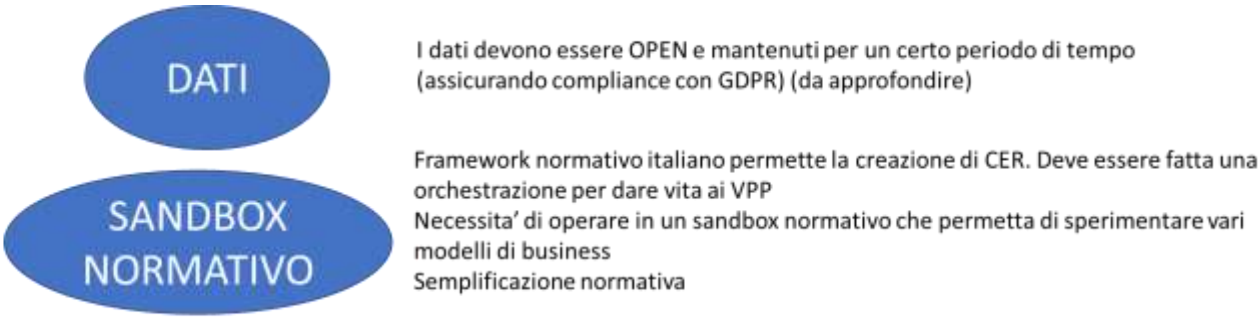

Figure 23: Outcome of the third workshop from WG3 2/2

We expect that the project will lead to a direct overall PV added capacity of at least 20 MW. Successful implementation of the project will lead to early adopters. Assuming a replication potential of 20 new RECs for each successful implementation, the overall PV capacity could be of the order of 400 MW over a period of 3 years mobilising private investment of the order of at least 1 billion euros (leverage effect of 5 for each public invested euro).

Project expected budget

We consider that a contribution of around 1.5/2 million Euros per REC would allow this challenge to be addressed appropriately with a total investment of 150/200 million Euros. The following items should be also considered as eligible costs:

- IT and metering infrastructure
- Sensors to improve the observability in the distribution grid
- PV system components
- Electrical storage
- Heat pumps
- E-charging stations

4.3. Action 3: The creation of a national facility for distributed PV

Distributed PV modules and systems need to be integrated considering three different aspects[20]:

- technological integration
- aesthetical integration
- energy integration

All three aspects need to be tested in dedicated facilities to satisfy the needs of different stakeholders.

4.3.1. Technological integration: Indoor testing

A multifunctional approach is needed for the evaluation of BIPV modules and systems, addressing both electrotechnical and building requirements.

This aspect leads to a complexity of BIPV testing, that requires facilities and expertise in two different fields: PV sector and Building sector.

The report IEA-PVPS T15-11:2020 “Multifunctional Characterisation of BIPV” issued by the international expert group of the IEA (International energy Agency) Task 15 project provides an overview of the existing testing procedures of BIPV systems. The report reflects the complexity of the BIPV characterization and includes several testing that are related with BIPV topic.

The standard EN 50583 “Photovoltaics in buildings” (Part 1: BIPV modules, Part 2: BIPV systems) is the first reference standard for BIPV and focuses on the properties of photovoltaic systems relevant to essential building requirements as specified in the European Construction Product Regulation CPR 89/106/EEC, and the applicable electro-technical requirements as stated in the Low Voltage Directive 2006/95/EC / or CENELEC standards. This standard is basically referencing all international standards, technical reports and guidelines relevant to BIPV topic.

A huge effort would be needed to address all listed testing according to report IEA-PVPS T15-11:2020 and to standard EN 50583.

Table 1 synthesizes the most relevant testing identified for BIPV topic. It is not an exhaustive list of all possible testing related to BIPV, but it provides an overview on the most relevant ones. The last column provides general information on the current state of the art in Italy, considering current infrastructure capabilities of the main actors within the Italian network.

[20] https://bipv.eurac.edu/en

Test category	Description	Product type	Standard	Italy SOA
Fire reaction	Fire reaction of façades (SBI)	Façade	EN13823	Partially covered)
	Fire reaction of roof	Roof	CEN TS 1187	
	Ignitability of products	General material testing	EN 11925-2	
Mechanical resistance of system	Wind load	Façade / Roof	EAD 090062-00-0404 (previously ETAG 034)	Partially covered
	Impact (hard and soft body)	Façade		
	Hail impact	Roof	Adapted from IEC 61215	
	Adhesion: Tensile Lap-shear strength	Façade / Roof / Other	ISO 4587	
	Adhesion: Tensile Strength	Façade / Roof / Other	ASTM D C297	
Glass in building (safety) (EN 14449)	Impact resistance	Façade / Roof	EN 12600	Partially covered
	Humidity ageing test		ISO 12543- Part 4	
	High temperature			
	Resistance manual attack		EN 356	
Ageing tests and PV performance	UV preconditioning	Façade / Roof	IEC 61215	Partially covered
	Thermal Cycling			
	Humidity Freeze			
	Damp Heat			

Table 1: most relevant testing identified for BIPV topic

4.3.2. Technological and aesthetical integration: outdoor testing

The report IEA-PVPS T15-05: 2018 “BIPV research teams & BIPV R&D facilities, an international mapping” issued by the international expert group of the IEA (International energy Agency) Task 15 project provides an overview of the existing international BIPV R&D testing facilities. EURAC and ENEA outdoor testing laboratories are included in the mapping. The report clearly highlights which are the current lack of measurement capabilities of the two Italian research entities compared to international laboratories (considering 17 country members), taking into consideration the classifications given in standard EN 50583.

In particular, further development of the current Italian outdoor testing capabilities include:

- Environmental influence measurements (driving rain, moisture ingress, windload, windproofness, windsuction, hail impact, snowload)
- Specific thermal impact measurements
- Specific electrical measurements

Figure 24 shows the level of effort in BIPV R&D investments per Country, based on a survey involving all BIPV R&D teams involved in IEA Task 15 project. The level of effort on testing against norm and outdoor testing in Italy is rated as medium/small. It is clear that additional effort and resources are needed to achieve higher impact at international level.

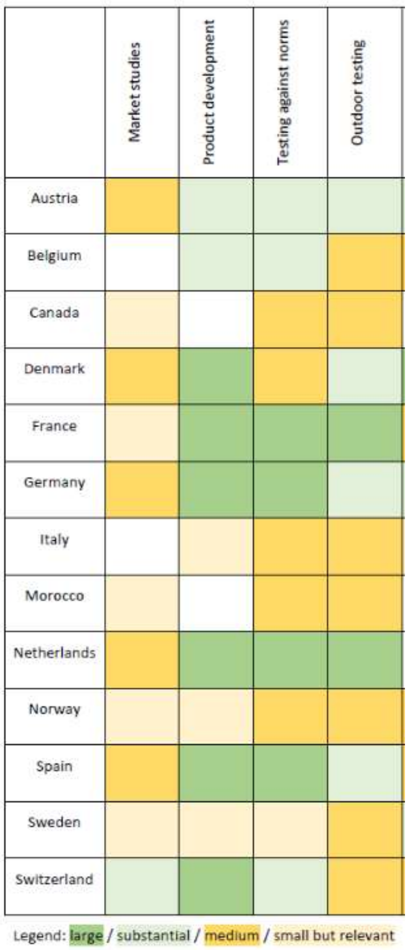

Figure 24: Level of effort in BIPV R&D investments per Country (Source: report IEA-PVPS T15-05: 2018)

The benefit of outdoor testing is that it gives the opportunity to designer and architects to see how various technologies look like in a relevant environment.

4.3.3. BIPV characterization and industrial prototyping

The three workshops "rete nazionale fotovoltaico distribuito/BIPV" carried out within H2020 PV IMPACT project, clearly highlighted the current State of the art of the Italian current positioning on BIPV prototyping capabilities. There is a clear gap between several universities and research centers working at low TRL (technological readiness level) and few Research Institutes working at high TRL level. As shown in Figure 25, there is a clear need to bridge this gap by creating new "prototyping hub" ("centro per la prototipizzazione") including facilities for module/system level prototyping.

Figure 25: slide presented during the third event of "rete nazionale fotovoltaico distribuito/BIPV" on 26.05.2020 by David Moser (EURAC)

The creation of such a "prototyping hub" entails the need of the development of a R&D PV Module manufacturing lab, that might be divided in:

- Solar Cell and Material characterization lab

- PV Module Manufacturing lab

- PV Module Characterization and Test lab

The main target of Solar Cell and Material Characterization Lab (SC&MC) is to understand the main features of the materials involved in a PV module before the interconnection and lamination, as well as analysing the quality of different processes and detect possible defects during the manufacturing.

The PV Module Manufacturing Lab (MM) focuses on solar cell adaptation, interconnection and lamination into the desired module.

Finally, the PV Module Characterization and Test Lab (MC&T) analyse the quality of the manufactured module.

4.3.4. Required Investment

Table 1Table 2 shows the investment required in terms of equipment to enhance the Italian network competitiveness at international level for BIPV Indoor testing, BIPV Outdoor testing, BIPV characterization and industrial prototyping.

On the top of this equipment costs, additional Investment is required for Site location, Personnel, and general consumables to run the facilities, as estimated in Table 3.

Category	Type of action	Equipment Description	Equipment cost
BIPV Indoor testing			
Fire reaction	Indoor Testing	Fire testing equipment	1000k€
Mechanical resistance of system	Indoor Testing	Peel Test	20k€
	Indoor Testing	Hail Impact (MQT 17)	100k€
	Indoor Testing	Mechanical load (MQT 16)	150k€
	Indoor Testing	Additional equipment	200k€
Glass in building	Indoor Testing	General equipment	500k€
Ageing tests and PV performance	Indoor Testing	Electric insulation (MQT 03,15)	10k€
	Indoor Testing	Light- stabilization (MQT 19)	175k€
	Indoor Testing	Climatic Chamber	250k€
	Indoor Testing	Additional equipment	200k€
TOT			2600k€
BIPV Outdoor testing			
Data acquisition	Outdoor Testing	Spectroradiometer	50k€
	Outdoor Testing	Monitoring system	25k€
Lab mockups	Outdoor Testing	Various upgrades of existing infrastructure	100k€
	Outdoor Testing	Balance of system components	50k€
TOT			225k€
BIPV characterization and industrial prototyping			
Characterization	Indoor Characterization	External Quantum Efficiency System per dimensione pannello.	150k€
	Indoor Characterization	Spectrophotometer	40k€
	Indoor Characterization	Electroluminescence automatic machine for BIPV modules	100k€

	Indoor Characterization	I-V Solar Cell tester	100k€
	Indoor Characterization	Differential Scanning Calorimeter	75K€
	Indoor Characterization	Thermographic camera	40k€
	Indoor Characterization	Lock-in Thermography	60k€
Prototyping	Indoor Prototyping	Solar Cell cutting laser machine	60k€
	Indoor Prototyping	Tabber and stringer machines	700k€
	Indoor Prototyping	Module laminators	300k€
	Indoor Prototyping	Autoclave for glass glass modules 1.5x3m	350k€
TOT			1975k€
	Additional equipment		300 k€
TOT			4875k€

Table 2: Equipment Investment required to enhance IT network competitiveness at international level for BIPV Indoor testing, BIPV Outdoor testing, BIPV characterization and industrial prototyping

Personnel cost	Consumables, energy cost	Site location cost
500k€/year	200k€/year	100k€/year

Table 3: additional estimated costs

Considering both tables, the total initial investment cost is estimated to be of the order of **5 M€**. Operational costs are estimated to be **800k€/year**.

The infrastructure would be developed over a 5 years period with an overall financial commitment needed of the order of **9/10 M€.** During the initial 5 years, industrial engagement in terms of private financial contribution for the use of the facility will be sought together with the access to third party funding (e.g. Horizon Europe). The aim is to reduce the commitment from base funding in operational costs down to 50% in the long term. It is important to keep a share of base funding to allow free access to the facility by research centres and universities.

4.3.5. Energy integration: Laboratory for Renewable Energy Community

Once successfully tested in terms of reliable power output and generation, the integration of PV modules and system must be tested for their integration in the distribution grid. Various labs already exist in Italy as nano/micro grids that can test electrical parameters by combining PV generation with electrical storage, e-charging, etc. Typically the focus is entirely on the electricity grid. Only recently, Research Institutes and Universities have worked on micro grid concept that explore synergies between various energy grids (see for example Figure 26**Error! Reference source not found.**).

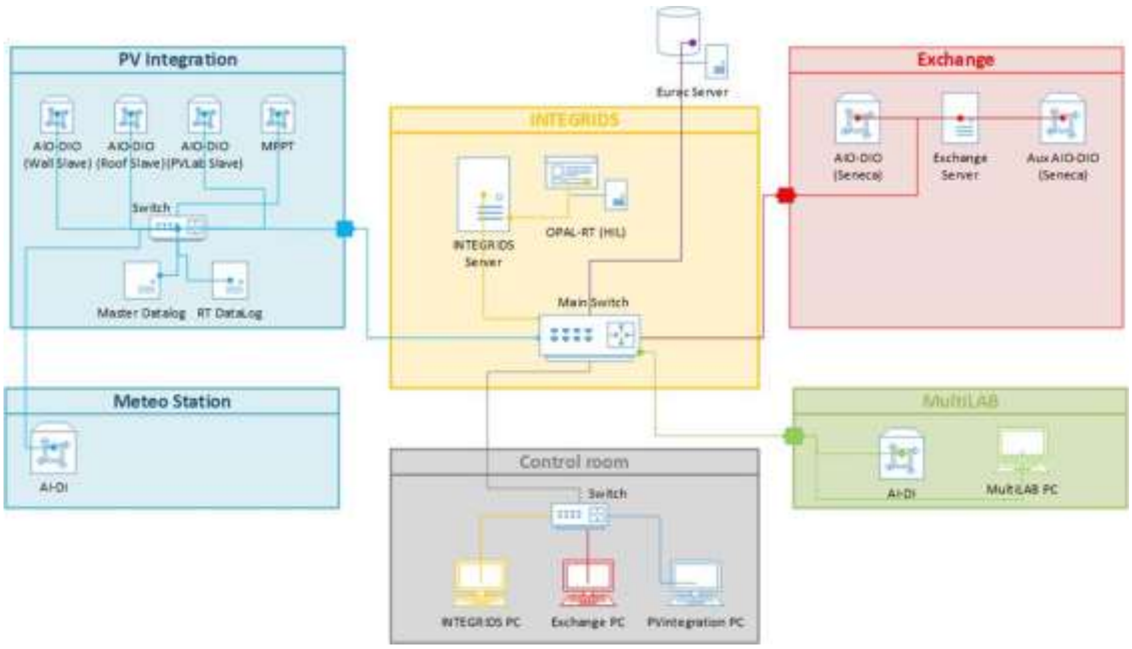

Figure 26: EURAC INTEGRIDS Virtual Micro grid facility

All these facilities could be mapped and virtually connected to demonstrate concepts related to energy flow and communication inside Renewable Energy Communities and between various RECs. This distributed lab facility would extensively test the synergy between energy grids, sector coupling, flexibility management and ICT infrastructure.

4.3.6. Required Investment

The required investment in a project that design and install the IT infrastructure needed to connect the various testing facilities (micro grids) available in Italy would be of the order of 2 M**€.**

4.4. Specific actions proposed by the working groups of the National R&I Network

WG1 STANDARD and NORMS

Specific Objectives:

On top of the existing norms, various institutes in Italy are focussing on fire prevention in PV systems using remote system rapid shutdown. These devices can help firefighters and PV plant owners in case of emergency.

Various tests have been carried out (coordinate by RSE) to verify the fire resistance of different PV module typologies (e.g. glass/glass, glass/polymer) installed on roofs or facades.

In addition to the need of having norms and guidelines referred to the single component, the attention should also be extended at system level including topics such as: cable positioning, failure detection, PV module maintenance and replacement.

WG2 Technology development

A very critical issue for most of the technologies currently explored for BIPV solutions other than rooftop installations, is the overall added value of the incorporation of a PV function in a building component. The efficiency of the embedded PV converter is a critical parameter but not the only one and not necessarily the most important, when it comes to deciding between a conventional building component and a version with an added PV function.

In many cases the task of "integrating" a PV module in an existing product (a window, a façade element, a roof tile, a sun-shading unit, etc.), developing electrical interconnections and thermal management solutions, ensuring safe and easy installation and O&M and so on, is much more complex and expensive than the development of the bare PV module. This requires investments that are orders of magnitude larger than the budget that even a multinational company of the building sector Is prepared to invest for these types of projects.

This is why important industrial projects like Dyepower[21], with their smart PV windows and semi-transparent facades, could not take off despite the very encouraging results obtained at the R&D scale.

This means that, no matter what PV technology is used for BIPV or PIPV applications, the most critical technological task is "integration" where a plurality of different technologies and industrial know-how other than PV are involved. This task cannot succeed without the support of a proper industrial prototyping facility with a completely different (multi-technological) approach with respect to a conventional PV prototyping facility.

[21] Dyepower was a private public partnership focused on stabilized large area DSC modules for BIPV with a pilot production line based in Rome

The choice of the most appropriate PV material, cell architecture and interconnections, module size and shape, its mechanical and thermal properties and so on, depends crucially on the specifications of the final product which cannot be pushed through the conventional PV value-chain.

At the same time it is essential that basic and proof-of-concept research on photovoltaic technologies like DSSC, perovskites, inorganic thin film PV, organic PV, ultra-thin Silicon, luminescent concentrators and other light-trapping technologies, high efficiency PV cells/concentrators and others, are properly supported to establish an effective and bidirectional technological pipeline with the industrial prototyping tasks.

WG3 Integration in the energy system

The specific objective is entirely in line with the Action 2.

WG4 Sustainability

Specific Objective: Definition of a systemic approach that serves to generate the eco-profile of a product also in relation to the environment / context in which it is inserted.

- Choice and / or definition of Key Performance Indicators for the most effective option choices in a life cycle perspective, also in accordance with the PEF (from which we must start but still needs improvement, for example in the case of PV it does not consider the inverter). The KPIs will have to give indications on the combined economic and environmental performance that can be useful both for the designers and for the whole technical community
- Creation of a national database to support producers for the development of eco-design studies
- Dynamic analysis of scenarios (loss of efficiency, durability, evolution of energy mixes, etc.)
- Circular economy and value chain: particular attention to the category resource depletion critical raw materials, PV end of life and decommissioning (recovery and recycling especially with reference to CRM), circular supply chains (secondary raw materials and raw materials with low environmental impact), PV seen as a product-service (Energy Service Companies or other entity may be asked to deal with the entire life cycle of PV), attention to the value chain which is fundamental to increase circularity
- Use of storage systems (second life of batteries for stationary applications). The literature highlights the need to recover the materials of the batteries that have reached the end of their life, but also to evaluate the useful life of the batteries also by looking at how the batteries are managed in combination with PV systems (in some cases it may be more useful to exchange with the network rather than accumulating to extend the useful life). In order to deal with the complexity of the problem, the importance of collaborating with manufacturers for primary and specific information is highlighted.

WG5 Best practices and architectural integration

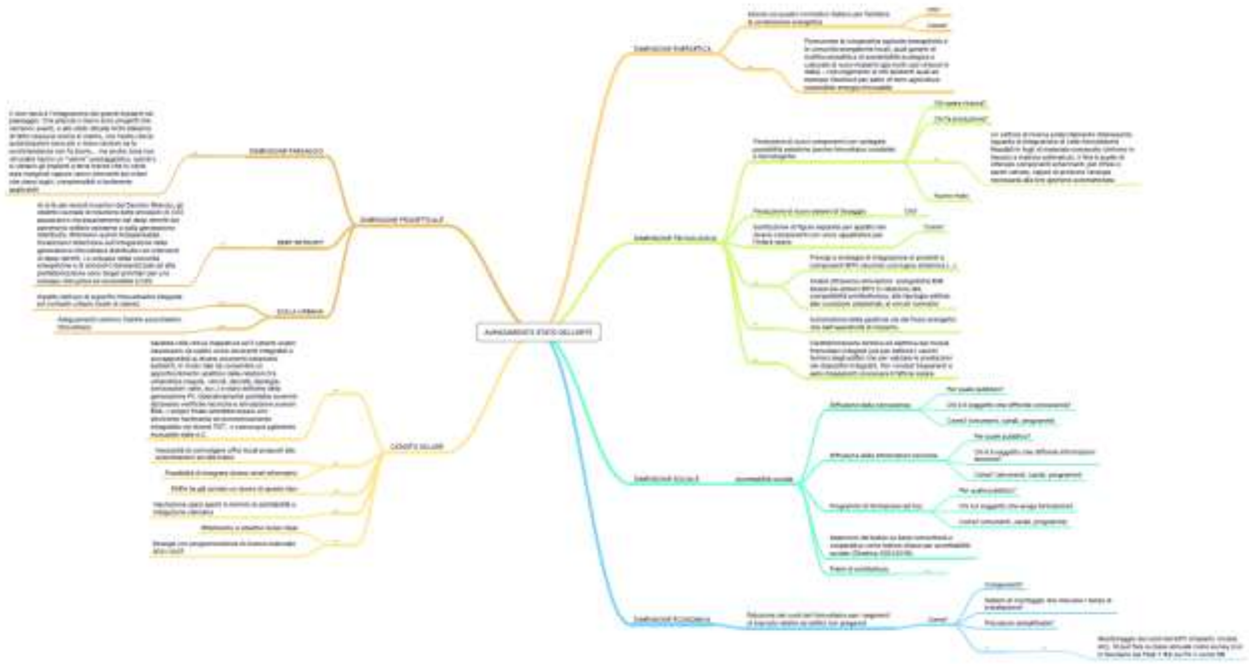

Figure 27: Progress beyond the state of the art in architectural and landscape integration of PV modules

5. Strategic actions to strengthen the National R&I Infrastructure

The first phase of the creation of a national distributed lab, connecting all the R&I stakeholders of the PV sector, will be the establishment of an active coordination scheme among the labs and the organisations they belong to.

In order to be effective, the coordination will be based on these actions:

- Monitoring of expertise and lab facilities in each of the main R&I organisations and, in particular, in public R&D institutions such as ENEA, RSE, CNR, Universities and in Public & Private Partnership (PPP) organisations such as Clusters, Technopoles and other R&I Consortia
- Periodic self-assessment of the overall impact of the Network both in terms of the ability to address the R&D priorities as defined by national (National Research Plan and others) and European strategic plans (SET Plan Implementation Plan and others) and in terms of the overall response capacity to the R&D demand from the national and European PV Industry.
- Identification of the gaps in the Network in terms of lack of human resources, investments, know-how and facilities to tackle strategic R&I tasks. This should be the pivotal step of a comprehensive optimisation action aiming to reduce superpositions and to increase synergies among different labs of the network in terms of research objectives, use of the lab facilities, recruitment of new R&D personnel devoted to PV activities, participation in large integrated projects, technology transfer to national and European industries of the PV sector
- Creation of a **Permanent Consultation Board** among the main R&I organisations to coordinate both the participation in large strategic programmes related to photovoltaics and the response to the R&D demand from the PV industry

The **Permanent Consultation Board** will also operate to

- Involve and engage different actors in the PV community (universities, research centers and training actors; students (universities) and new employees; energy companies; policy makers, authorities, public administrations and authorities of market regulation; social actors and energy citizens);
- Define a conceptual framework to facilitate and accelerate the creation of new teaching modules and updating the currently available learning programs;
- Promote interdisciplinarity in research, innovation and training services;
- Strengthen collaboration between universities and industry (organizing specific workshop);
- Develop a web platform for hosting the database of lab facilities and expertise and sharing networking events, workshops and technical documents
- Organise technical webinars

In the medium to long run, the network should develop an internal organisation to optimise its response to any call for strategic actions requiring a coordinated effort at the national or international scale. The participation in the strategic projects related to the SET Plan implementation plan and illustrated in this document is the first and most important challenge.

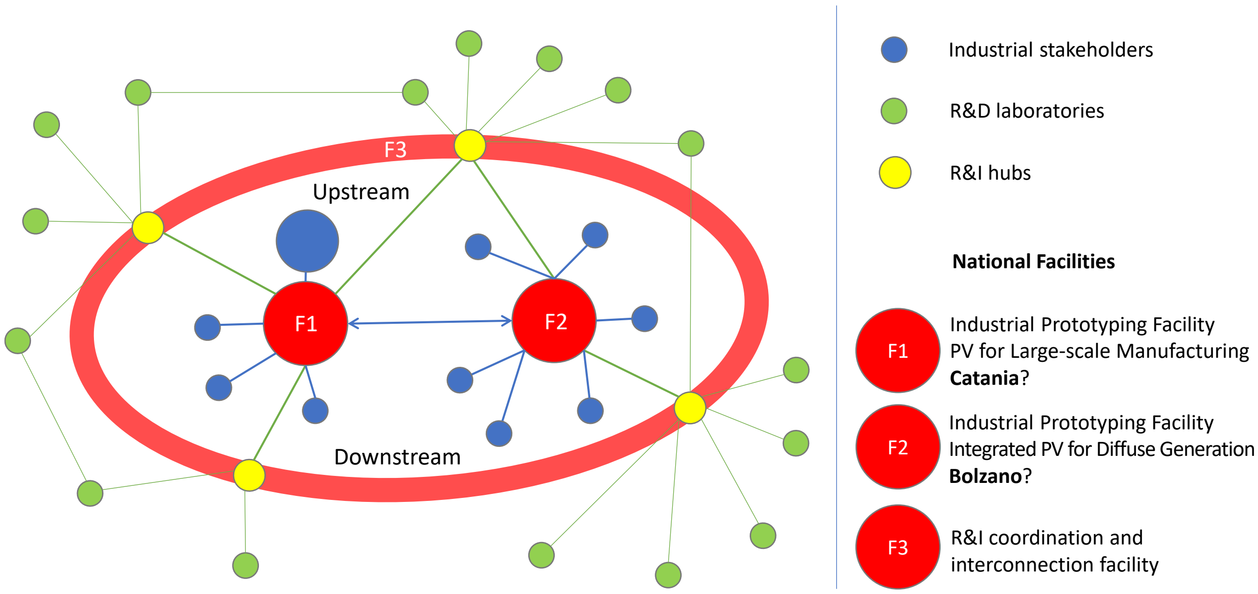

Figure 28: Topology of the National R&I Network of the PV stakeholders

The graph above represents the conceptual structure of the national network, with the single specialised labs (green dots) converging towards more interdisciplinary and connected R&I hubs (yellow dots). The various clusters are then connected to each other (F3) and to the national prototyping facilities (red dots) where the highest level of the technology transfer processes is carried out jointly by the technology developers and the end users.

6. Roadmap

- The chain of initiatives leading to the present report starts in late 2016 with the formation of the new Temporary Working Groups (TWG) of the SET Plan. Italy participates in all the TWGs including the Photovoltaic Working Group
- January 2017: A national working group to support the SET Plan activities on Photovoltaics is formed on request of the Italian member of the PV TWG. It includes all active representatives of Italian research organisations in EERA.
- February 2017: Online survey on "Current R&I Projects in the field of Photovoltaics in Italy" and "R&I Units/Labs devoted to Photovoltaics", organised by the national working group.
- March 2017: The national working group prepare a first draft of "Proposed National Flagship Activities for the SET Plan" based on the results of the survey and submits it to the national R&I community. Comments and amendments from the community again collected online
- April 2017: The second survey is closed and a final abstract of the "Italian Flagship R&I Activities on Photovoltaics" is finalised by the working group. That document becomes the Italian contribution to the SET Plan Implementation Plan where the contributions from all active Member States of the EU are merged.
- June 2017: The National Flagship Activities are officially presented and discussed at a national event in Rome in the presence of the National Coordinators of the SET Plan, Marcello Capra and Riccardo Basosi
- November 2017: The PV Implementation Plan is finally approved by the SET Plan Steering Committee in Bruxelles
- 2018: The SET Plan TWGs become Implementation Working Groups (IWGs) with a clear mandate to monitor and actively promote the activities each Member State have included in the Implementation Plan
- January 2019: the European Commission publishes a call for projects to support the implementation of the actions contained in the PV Implementation Plan of the SET Plan. The project proposal "PV-IMPACT" is submitted by EUREC with the participation of three Italian partners (EGP, EURAC and CNR) and a full WP devoted to the SET Plan activities in Italy
- April 2019: PV-IMPACT is funded and starts its activities
- May 2019: The original 2017 survey on "R&I Units/Labs devoted to Photovoltaics", is updated and extended to include more information about the national R&I network.
- September 2019: First workshop of the Italian R&I stakeholders of the PV sector, hosted by Enel Green Power in Catania. The basic structure of the present strategic plan is discussed and elaborated.
- December 2019: Second PV IMPACT workshop devoted to the national flagship "BIPV". The discussion is organised in 5 working groups covering a wide range of R&I, business and regulatory issues associated to the new emerging BIPV value chain.
- May 2020: Third and final workshop, is rescheduled as an online event after the cancellation of the original conference, set to be organised by ENEA in Naples in March. During the online event several of the proposed strategic projects, included in this document, are presented and discussed
- July 2020: The "Strategic Plan for Research and Innovation to Relaunch the Italian Photovoltaic Sector" is finally released.
- Late summer 2020: Official presentation of the plan

7. Acknowledgements

The coordinators of this initiative wish to thank **all the participants** in the meetings, workshops, surveys, webinars and all the other events organised by the Italian PV Working group of the SET Plan and by the Italian partners of the European project PV IMPACT.

Their contributions have always been enthusiastic, constructive and stimulating and have contributed to an increasingly positive and collaborative environment which is undoubtedly, one of the most important assets of this plan.

A special thank goes to the Italian members of the SET Plan Steering Committee, **Riccardo Basosi and Marcello Capra** who have stimulated and enabled this initiative since the very beginning. Their reiterated appeal for the R&I community to join forces and work as a team has been a key driving force towards this first important objective.

Finally we wish to thank the **European Commission** for the support to the project PV IMPACT and to all the initiatives included in WP2 of the project workplan.

Annex 1: Organisations with active participation in the meetings

Organisation	Organisation Type
Alperia Spa	Utility
Amsterdam Academy of Architecture	Academy
Applied Materials	Upstream company
BayWa Re Italia	O&M Company
Campomarzio	Architects
CNR	National Research Organisation
Convert	Trackers
ENEA	National Research Organisation
Enel Green Power	Large company (Manufacturing / Upstream and downstream)
ENEL-X	Energy Service
ENI	Large company (R&D in BIPV/PIPV)
ETA Florence	Consultancy and Engineering
EURAC Research	Research Centre
Eurofinestra	Windows manufacturer
Evolvere	Energy Service
Finstral	Windows manufacturer
FRIEM	Inverter manufacturer
Futurasun	PV Module manufacturer
Glass2Power	PV Module manufacturer
GruppoSTG	PV Module manufacturer
GSE	Public company
IIT	Research Centre
IMO Automazione	Industry automation
IMT School for Advanced Studies Lucca	Research Centre
INArch	Association
Istituto Giordano	Certification body / Laboratory
MISE	Ministry of Economic Development
MIUR	Ministry of University and Research
Politecnico di Milano	University
Politecnico di Torino	University
Progetto Verde	Consultancy and planners
PROTO AMBIENTE	Environmental engineers
R2M	Consultancy company / BIPV
Regalgrid	Energy Service
RISE	Upstream company
RSE	Research Centre
Solbian	PV Module manufacturer
Studio Bombasaro	Architects
Sunage SA	PV Module manufacturer
SUNSIM	Consultancy and Engineeering

Università di Catania	University
Università di Catania	University
Università di Ferrara	University
Università di Firenze	University
Università di Milano Bicocca	University
Università di Napoli	University
Università di Palermo	University
Università di Roma Tor Vergata	University
Università di Siena	University
Università di Torino	University
Università di Siena	University
Università di Verona	University
Vigili del Fuoco di Trento	Firefighters
Vigili del Fuoco Nazionale	Firefighters
Zanetti	Façade manufacturer