# D.T2.4.3

**Friuli Venezia Giulia Energy Action Plan** Version n°0.5 11/2021

# D.T2.4.3: FVG Energy Action Plan

## A.T2.4 Regional Energy Action Plan definition

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## Partners involved

PP 5 – APE FVG

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# Interreg CENTRAL EUROPE

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|---|---|
| Priority: | 2. Cooperating on low-carbon strategies in CENTRAL EUROPE |
| Specific objective: | 2.2 To improve territorial based low-carbon energy planning strategies and policies supporting climate change mitigation |
| Acronym: | **PROSPECT2030** |
| Title: | **PROmoting regional Sustainable Policies on Energy and Climate change mitigation Towards 2030** |
| Index number: | CE1373 |
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# 1. EXECUTIVE SUMMARY

Friuli Venezia Giulia is one of the 20 Italian regions, the 17th by area (7.924 km2) and the 15th considering population (about 1.2 million inhabitants). It is located in the northeast of Italy and borders with Austria on the north side, with Slovenia on the east side and with Veneto on the west side while it is bounded by the Adriatic Sea on the south.

The economy of Friuli Venezia Giulia is one of the most developed in the country. Its core is based on small- and middle-sized enterprises aggregated in industrial districts (the so-called 'North-East model'), belonging mainly to the furniture and mechanic/mechatronic sectors, with a significant inclination towards exports. Specialized farming, agro-industry and high-quality tourism are other important sectors of economic activity. Friuli Venezia Giulia is an autonomous region with special statute. This means, for instance, that competencies over the energy sector are shared with the State: passing of new laws is subject to an agreement between the Regional Authority and the Central Government.

In the last decades, final energy use switched from oil to natural gas thanks to large investments in the transport grid and generation infrastructures. Nowadays, final energy is mainly supplied by natural gas, followed by liquid fossil fuels and by renewables. There are 2.3 GW of total thermoelectrical capacity installed, 0.5 GW of hydropower as well as of solar power and 125 MW of power from biomasses that allows to cover the regional demand of electricity (10 TWh) and to export the excess (2 TWh). Its geographical position favours interconnections with Austria and Slovenia, making the region also a corridor for imported electricity.

The exploitation of biomass in the thermal sector (mainly residential) and other production of energy from renewable sources, increased the coverage rate of regional final energy consumption (FEC) by renewable energy sources (RES) and derived heat to 23%. Nevertheless, the regional FEC (nearly 38 TWh) is due uniformly to the industry and residential sectors (33% and 31% respectively) followed by transport and services (18%). All sectors are still strongly based on the use of fossil fuels, especially natural gas and liquid fossil fuels.

As for the effects on the environment, the energy demand is responsible for $CO_2$ generation of about 8.4 Mt per year, largely related to the industrial sector and followed in equal parts by the transport and residential sectors.

Albeit no clear regional energy strategy nor development plan have been designed in recent years, spurred by the EU's plan for the energy transition and the alignment by Member States, a change of pace is inevitable also at regional level. The targets towards climate neutrality are set and the ambition for Friuli Venezia Giulia is to forerun them by 2045. To reach this goal, regional policies on energy transition and climate change mitigation should stem from holistic, integrated, cross-sectoral and inclusive energy planning processes.

This report sets five sustainable development trajectories and defines the possible measures to be set in each trajectory, namely Sustainable Building, Bio-energies, Sustainable Mobility, Industrial Efficiency and Smart Grids. A SWOT analysis is performed, and effects on the short and long term estimated. In this way future scenarios for the energy system are simulated and the results compared with the political goals. Again, the urgency of a proper regional strategy with measures, a long-term financing strategy and milestone years emerges. In these regards, this document offers a good starting point for the regional authorities to develop such a plan.

# 2. INTRODUCTORY OVERVIEW

## 2.1 Status quo summary

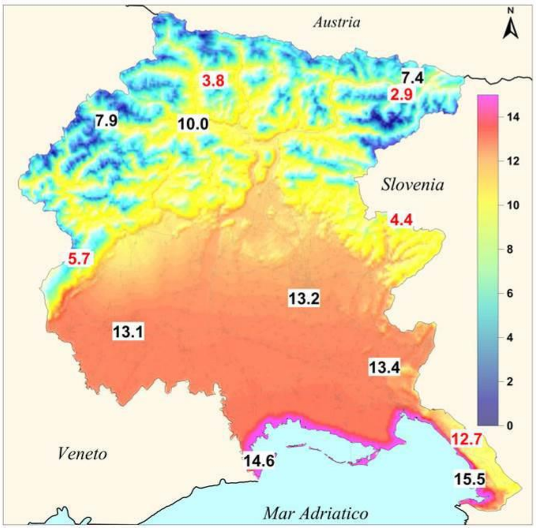
Due to its great geographical and socio-economic variety, the Friuli Venezia Giulia region stands as a very interesting case study for energy planning. With its landscape ranging from alpine valleys to Adriatic coasts, sparsely populated rural territories and urban areas, and with a diversified economy based on tourism, agriculture and industry at the same time, the number of factors that shape the energy system happens to be a quite complex one. Moreover, the strategical location at the border with Slovenia and Austria makes FVG an important crossroads for transport, gas and oil pipelines and electricity.


| | FVG | ITALY |
|---|---|---|
| Area | 7 924 km$^2$ | 302 073 km$^2$ (2,6%) |
| Population | 1 200 374 pp | 60 244 639 pp (2%) |
| Population Density | 153 pp/km | 199 pp/km |
| Municipalities | 215 | 7 903 (2,7%) |
| Households | 561 100 | 26 081 199 (2,1%) |

**Figure 1: Map and main data of the region**

The administrative region has a population of approximately 1.2 million people, mainly distributed in few urbanized areas (Trieste, Udine, Pordenone, Gorizia, Monfalcone) and in the neighbouring towns. Overall, the entire region is seeing a slow decline of population. This is more noticeable in marginal areas such as mountain valleys, where besides a low natality there is a relevant emigration towards the urbanized areas, where services and industries are mainly located.

As previously said, the climate conditions around the region are very diverse, ranging from Alpine to Mediterranean, with abundant precipitations that results in an oceanic climate. These features can be seen in Figure 2, where average yearly temperature and rainfall are depicted on the regional map. Municipalities' degree days range from a minimum of 2102 in the coastal areas to a maximum of 4437 in the higher valleys, resulting in large differences in the heating season and therefore in the heating demand and energy vectors.



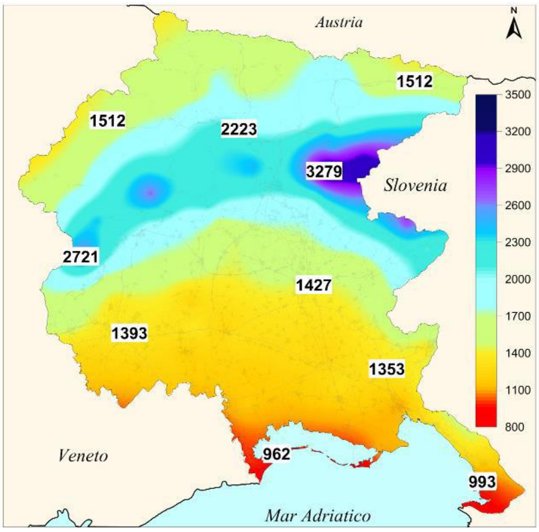
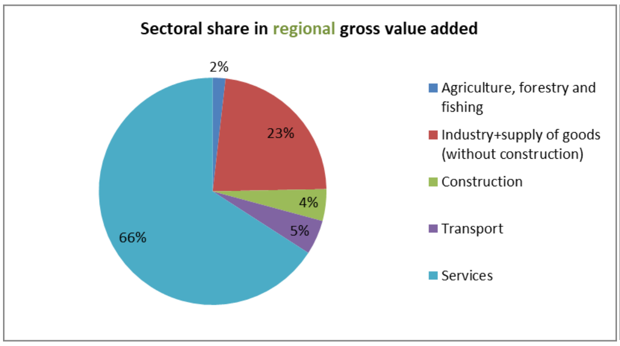




**Figure 2: average yearly temperatures [°C] 1993-2013 and rainfall [mm] 1961-2013 [ARPA FVG]**

The economy of the region is structured similarly to the rest of northern Italy. The majority of the flatlands area is dedicated to intensive agriculture. Industry represents another fundamental sector, with several energy intensive industries such as steel, pulp & paper and wood processing. Last, seasonal tourism is well established both on the coastal and mountain areas, with the city of Trieste being a tourist destination year-round. As it can be seen in fig. 3 with the Gross Value Added (GVA), the services sector produces the most wealth, counting for about two thirds of the overall value. Following that, industry plays a relevant role with about 23% of GVA, above the national average, while agriculture, transports and construction sectors represent a minor but not negligible share of the picture.



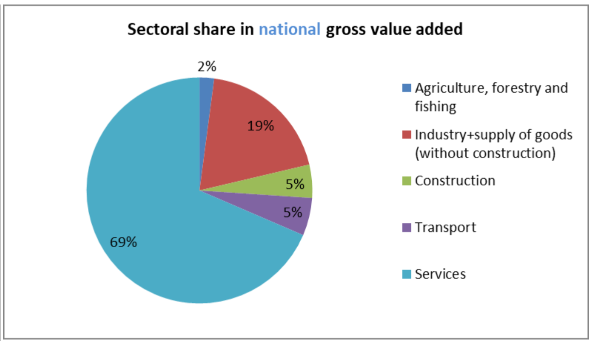




**Figure 3: Regional and national sectoral Gross Value Added (GVA)**

Due to its strategic position, the FVG region hosts some infrastructure that are crucial even from a national point of view. It represents in fact the main entrance of gas pipelines from eastern Europe, allowing millions of cubic meters to flow towards the rest of Italy. Besides that, the oil pipeline SIOT brings raw oil brought in by maritime oil tankers from Trieste to Germany, supplying a relevant share of German and Austrian oil demand. Last, medium and high voltage lines allow the national market to exchange large amounts of energy with Austria and Slovenia.

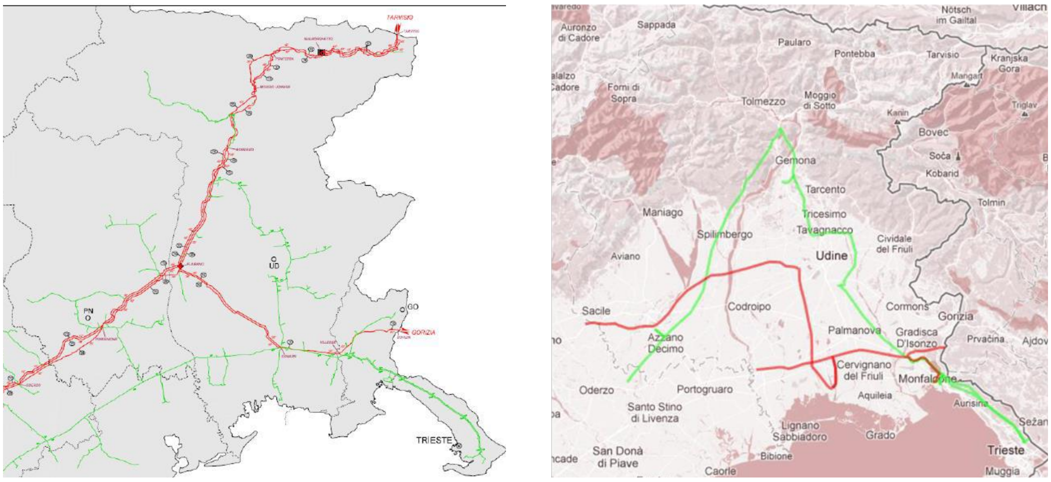



**Figure 4: Gas pipelines and High- and Medium-voltage electrical lines**

Figure 5 reports in a table how the final energy demand is spread among the different sectors for each energy vector. The same data are then depicted into two pie charts in figure 6 to better show the relative shares. The industrial sector represents the highest energy consumer with 33%, immediately followed by the residential one at 31%. Both sectors heavily rely on natural gas and electricity, which for the residential sector largely comes from renewable energy. After those, transport and services basically complete the regional energy demand.

| 2016 Regional Energy Demand [GWh] | Solid fossil fuels | Oil & oil products | Natural gas | Renewable energies | Non-renewable waste | Electricity | Derived heat | TOT |
|---|---|---|---|---|---|---|---|---|
| **Agri/forestry/ fisheries** | | 238 | | | | 121 | | **359** |
| **Industry** | 913 | 969 | 4.738 | 236 | 32 | 5.607 | 10 | **12.505** |
| **Construction** | | | 65 | | | 36 | | **101** |
| **Transport** | | 6.133 | 151 | 255 | | 502 | | **7.041** |
| **Services** | | 295 | 1.706 | 227 | | 2.184 | 1.561 | **5.973** |
| **Residential** | | 1.191 | 5.116 | 3.625 | | 1.340 | 524 | **11.796** |
| TOT | 913 | 8.826 | 11.776 | 4.343 | 32 | 9.790 | 2.095 | 37.775 |

**Table 1: Sectorial regional consumption in GWh, divided by energy vector category**

Of all energy demand, the vast majority is still fossil fuel based: only about 23% is renewable, 12% mainly consistent in wood biomass for residential heating and about 39% of electricity generation, so around 11% of the final demand. Focusing on the specific energy vectors, natural gas is the most important carrier across almost any sector, followed by electricity and oil products, which are mainly utilized in the transport sector.

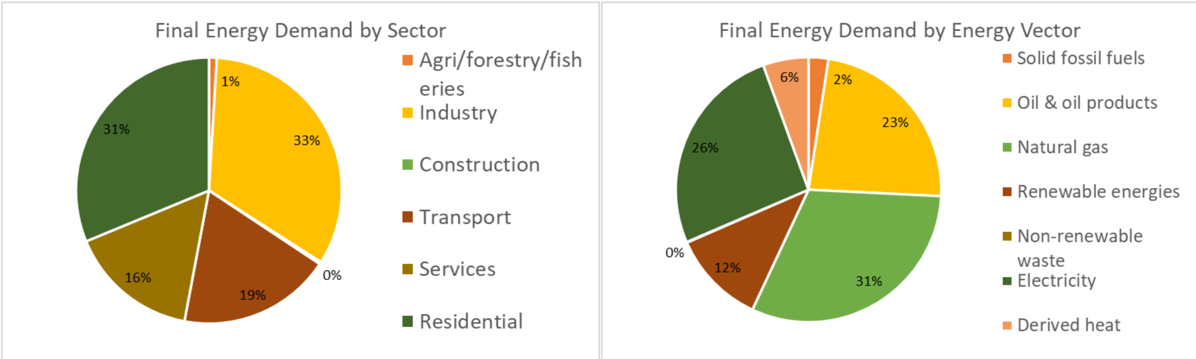



**Figure 5: Final Energy Demand by Sector and Energy Vector**

Focusing on electricity only, the yearly TERNA (TSO) report shows how Friuli Venezia Giulia region demand has been steadily increasing since the seventies until the 2008 crisis, then having a more stable trend after 2011. Its production also increased with some years where the region became a net exporter of electricity. Anyway, for most of the years depicted in figure 7 it can be seen how FVG has been a net importer of electricity, with a 2019 deficit equal to 1.406 GWh or 15,7% of the regional production. The total final demand is 10.330 GWh, averaging 8.340 kWh per inhabitant with a national average of 5.057 kWh.

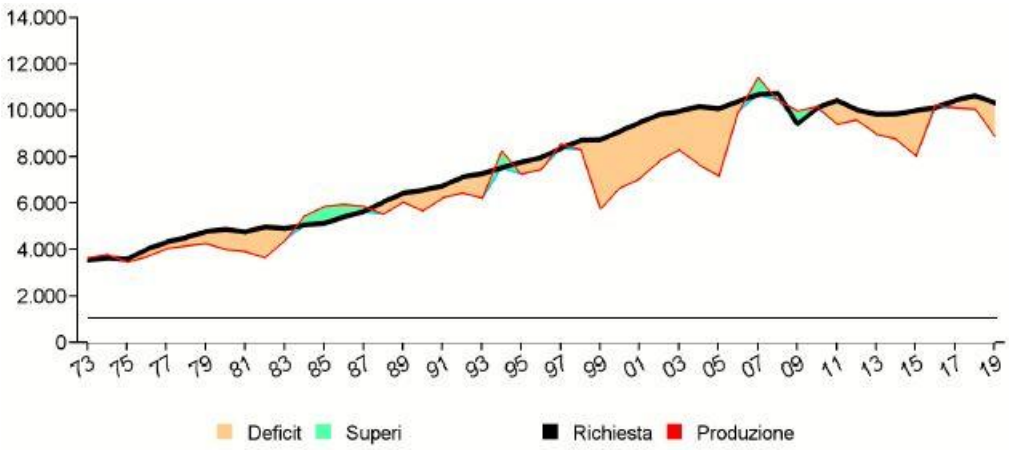



**Figure 6: Import-Export regional electricity balance [TERNA 2019]**

Analysing more in detail the 2019 generation statistics, it can be seen the big role that hydropower plays in the regional configuration (tab 2). With more than 500 MW of installed power, hydro accounts for about 20% of the regional production depending on the year. Besides that, the huge number of small residential PV plants is also able to provide 550 GWh of renewable electricity, being relevant also compared to the conventional coal and gas power plants production, which accounts for 74% of the regional production. Wind, due to unfavourable geographical conditions, was not developed and most likely will not play any role in the regional energy system.

| 2019 Active Power Plants | N° of plants | Net Installed Power [MW] | 2019 net yearly production [GWh] |
|---|---|---|---|
| Hydro | 244 | 504 | 1.731 |
| Thermal Plants | 223 | 1.629 | 6.660 |
| Wind Turbines | 5 | Negligible | - |
| PV | 35.490 | 545 | 551 |

**Table 2: 2019 FVG plants, capacity and production by source**

Regarding $CO_2$ emissions, in the two graphs of figure 7, the current situation is depicted by both sector and energy vector. In particular, regarding the sector it can be seen how the industrial sector, which consists of many energy-intensive industries such as steel and pulp & paper, contributes to almost half of all emissions. After that residential, transport and services contribute similarly to the rest of emissions. Regarding the energy vector, about 56% are related to the electricity use, mainly produced with natural gas. The direct use of natural gas for cooking and heating purposes adds another 20%, while oil products basically complete the emissions with another share of 20%. Coal contribution is almost marginal.

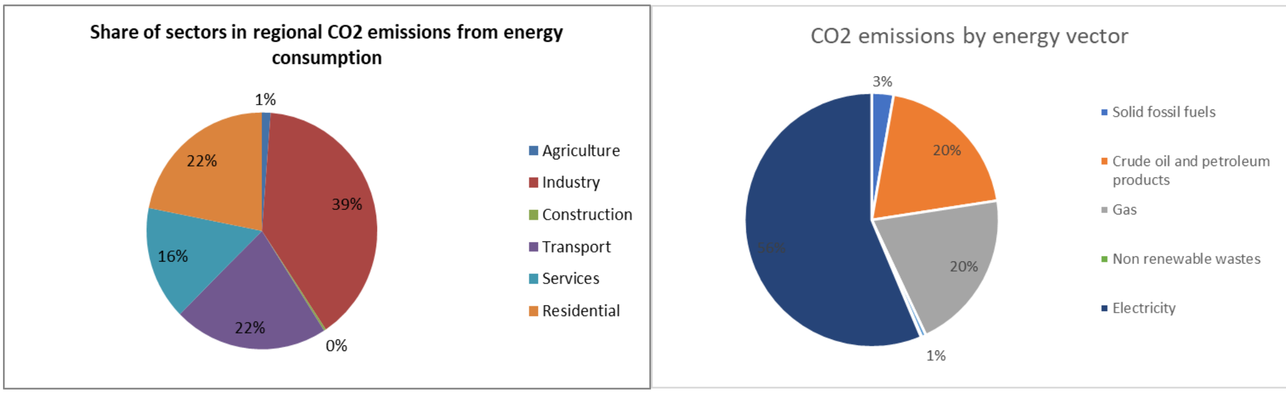



**Figure 7: $CO_2$ emissions, related to sector and energy vector**

## 2.2 Current development trends

Within the last few years there was no clear regional strategy or development plan, and the region moved alongside the rest of Italy following national incentives. The most relevant trends are energy efficiency in industrial processes and buildings, LED public lighting and PV deployment, both on a residential and industrial scale. As for the national and European levels, first steps are also being made regarding residential storage systems and electric vehicles, but not yet with a significant impact on the system.

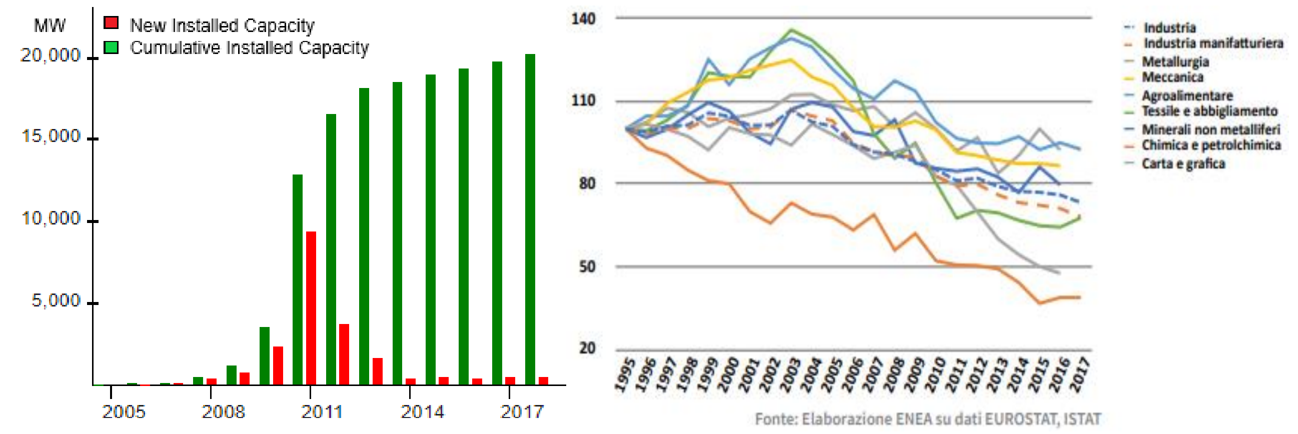



**Figure 8: PV yearly and cumulative installation & energy intensity in Industry**

With the last incentive scheme named "Superbonus 110%", great attention is being put to residential energy efficiency, renovating existing buildings by improving window frames and glasses, coatings and roofs to improve thermal insulation. Coupled with these interventions, the substitution of old methane boilers with more efficient ones and with heats pumps, powered with small residential PV plants is also shaping the present residential energy demand.

Some RES-based district heating networks were developed within the last few years, facing the existing gap with some neighbouring regions like South Tirol and Carinthia. Some of these plants showed technical and operational flaws of different kind, often resulting in economic difficulties. Nevertheless, regularly new funds are made available to further expand the existing plants and develop new ones.

## 2.3 Development potentials

As of today, untapped potential for renewables is mainly lying within solar and bio-energies. Regarding the latter, woody biomass has a huge untapped potential. The FVG region, as the other alpine areas, has a long tradition of forestry activities and wood industry, from music instruments and furniture to construction and domestic heating. Coupling this tradition with the technology of district heating can help the heating sector rely less on the import of natural gas and oil, with consequent benefits for the environment and for the local economy.

Currently the 23 wood biomass plants in the region, mostly heat-only and small-sized, require about 16.000 tonnes of wood chips per year, counting for both A and B quality wood chips. According to a detailed study of the yearly availability, this number only represents about 31% of the yearly wood chips potential, leaving a large margin for new projects and improvements. In figure 10 it can be seen how the A-class woodchip potential is present among the different mountain areas of the region. Besides evaluating the resource, on the map the non-methanized areas are also showed. The possible synergy between local availability of biomass and the need of a heating system that substitutes LPG and oil in these municipalities is clear. Moreover, the existing plants and the logistic platforms for wood chipping and storage are represented by the green and purple dots, showing how the logistic platforms are already in place.

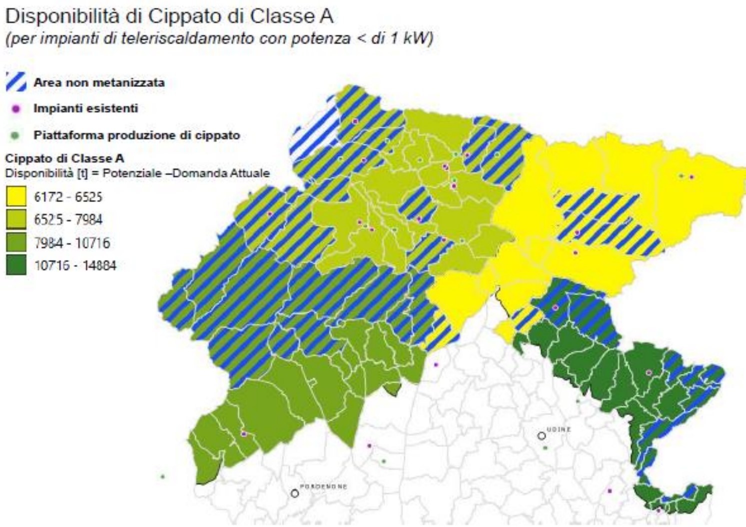



**Figure 9: A-class wood chip potential and methanized areas and logistic platforms**

Regarding other bio-energies, biogas already had a big push in 2011-12 due to a favourable incentive scheme applied in those years. As on one side it obtained the expected result to deploy several 1 MW plants on regional level, often the biomass introduced into the digesters was not simple agriculture leftovers, but entire cultivations grown on purpose. Regarding this biofuel, more attention is needed to better manage these plants and utilize a more sustainable source of organic waste, including urban collected waste.

As PV is an already established technology for both residential, industrial and commercial systems, the challenge is to push the deployment of such technology on a larger scale and in smarter ways. One example could be to avoid the use of ground-mounted panels and try to exploit the large availability of industrial building's roof surface. A possible tool to foster the spread of the technology is certainly the Energy Community concept: sharing the energy produced instead of selling it directly to the grid for a lower value can in fact incentivize the interest towards PVs.

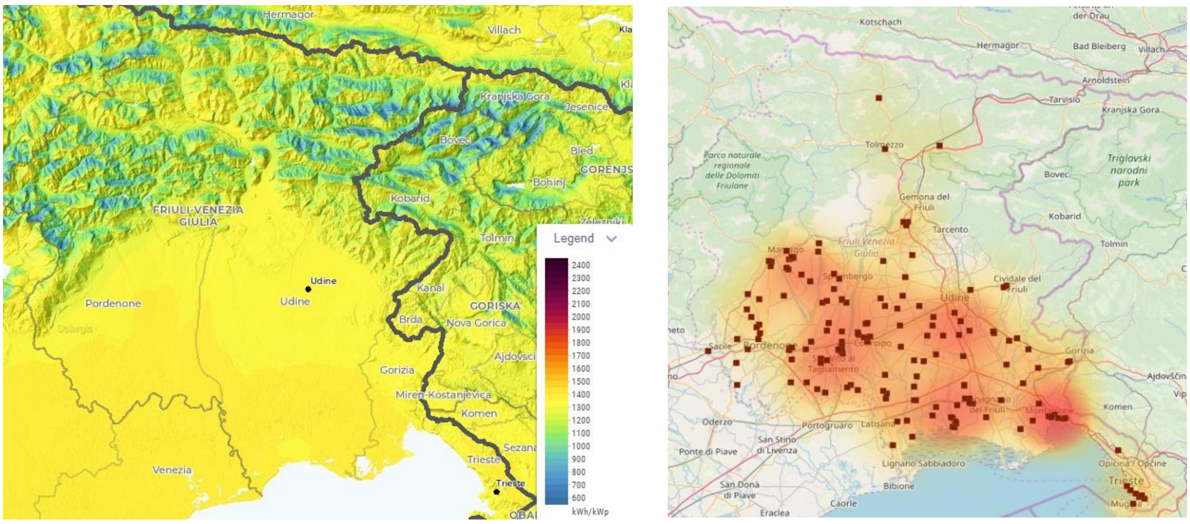



**Figure 10: PV output potential and waste heat sources**

Not to be forgotten, waste heat from industrial processes and thermoelectrical plants represents another untapped potential (fig. 11-b). Many big industries with thermal processes could convey the heat from their processes into other processes or room heating, in an energy efficiency perspective. As an alternative, when the heat demand is low or difficult to couple with the source, small ORC generation might be considered. Same approach should be applied to thermoelectric plants, often built without a way to recover waste heat or in locations where it is hard to find nearby heat demand. The development of multiple and efficient district heating networks could represent a decisive step to recover these heat sources, lowering local emissions and bringing additional value to local economy.

# 3. MISSION STATEMENT

The Smart Specialization Strategy (S3) aims to identify research, development and innovation (R&D&I) investment priorities and evaluate the ideal measures to be implemented within the next EU programming period. The S3 approach is place-based and it applies to several sectors, including energy and sustainable development. Italy designs a national S3 and 21 regional strategies. The national and regional S3s are coherent and complementary. In 2020 Friuli Venezia Giulia was called to renew its strategy and pinpoint its priorities for the 2021-2027 programming period. Representatives from university/research centres, industry, public authorities and civil society operating in the energy and environmental sectors were involved in the entrepreneurial discovery process (EDP) to frame those priorities having a competitive advantage and the potential to bring about economic transformation at regional level. The selected priorities in the energy sector are, at the time of writing, under assessment for the approval of the revised S3 by the Regional Authorities. The same priorities were taken as the basis for the development of regional energy planning activities within PROSPECT2030.

## 3.1 Key energy priorities, priority matrix and timeframes

As a result of the EDP within the revision process of the regional S3, five priorities have been selected in energy-related fields to boost regional innovation building on local strengths.

- The first selected priority is Sustainable Building. This topic has already received great attention in the last years with several actions already implemented, from retrofitting incentives to new construction standards and certifications, but presents also new opportunities. It has been estimated that a substantial renovation of the existing building stock would lead to 20% to 35% of final energy savings in the residential sector, which currently accounts for 31% of the regional energy demand. The promotion of energy efficient interventions is already happening in Italy, with financial schemes that cover partially or completely the expenses. Focus is being put on reducing the heat demand of existing buildings: façade and roof coatings, insulated window frames and double to triple glasses. Besides that, the installation of residential PV systems and the electrification of the heating system by installation of heat pumps is also subject to a clear positive trend. Certifications like “CasaClima” and “PassivHaus” create new building standards and some municipalities have implemented them as compulsory, moving the market towards an energy efficient direction. Regarding new trends and opportunities, eco-constructions and low-carbon material are starting to gain interest, such as clay and straw, as well as some innovative design and techniques, such as 3D printed houses.
- Second key priority is Sustainable Mobility. Currently the transport sector accounts for about 19% of the final energy demand and appear to be one of the most difficult sectors in which to take action. In the road transport sector, the penetration of EVs is still negligible and there are serious doubts that a full electrification might be a feasible and reasonable solution, starting from the production and final disposal of exhaust batteries. For trucks and commercial transport, electricity has not moved its first steps, and hydrogen is not yet economically and technically viable. Different solution is the introduction of biofuels, with

minimal impact on the vehicle technology but multiple doubts on the hypothetical supply chain.

Besides converting the existing number of vehicles to alternative sources, focus should actually be put on removing private cars where possible and switch to bikes and public transport. Especially in urban areas, there is an increasing interest toward sustainable mobility, with the construction of new cycling paths, creation of pedestrian areas and intensification of bus routes. Moving from and to cities, trains and railways are a very efficient and sometimes underestimated solution, especially where railway infrastructures are old and do not support high speed trains, and the number of trains is insufficient to generate a widespread habit. Regarding the aviation sector, which is anyway very marginal in the region, it appears very difficult to have an impact on the fossil fuel usage. Different topic is maritime transport, which represents a fundamental sector in the regional economy, especially considering the port of Trieste, first in Italy for volume of goods.

- Third priority is Bio Energies. About 40% of the region is forest-covered, mainly in mountain areas, but only 60% of the forest have management plans and overall, only 15% of the annual growth potential is retrieved. While the wood industry is historically well established, ranging from instrument craftmanship to furniture and carpentry materials, there are very few examples of biomass-based DH networks. This technology, besides being beneficial for the environment with respect to fossil fuel heating, could also represent a great opportunity for the local economy. Where the land is not forest-covered, agriculture and livestock are the major land-usage activity. Large amounts of vegetable waste and animal manure get often simply piled up to compost and used as traditional fertilizers or burned. This traditional habit does not only waste a huge energy potential but generates itself methane emissions into the atmosphere. Through a controlled anaerobic digestion process, all these agricultural by-products can produce large quantities of biogas and still give back large quantities of solid substrate to be used as fertilizer. Regarding the production of liquid biofuels, the process should be evaluated on an LCA scale also considering the dedicated farming.
- As it addresses the most energy-demanding sector in the region, one priority is dedicated to Industrial Efficiency. Iron & Steel, Pulp & Paper and wood processing are highly energy intensive industries, both under the electrical and the heat point of view. Within these industrial plants there are many possibilities for synergies between different processes, like for example using the waste heat of one process as an energy source for another. Energy storage and conversion could also be interesting solutions in order to decrease the overall energy demand without affecting the production. On a longer term, innovative technologies and new low-carbon fuels could increase efficiency and decarbonize the industrial sector.
- The last priority includes multiple innovative practices and approaches often addressed to as Smart Grids. Flexible, monitored and automated grids can provide multiple tools for planners, operators and users in order to decarbonize the energy system. Real-time monitoring of consumption and distributed generation can unlock potential for demand-response technologies, helping to increase the utilization of renewables. Besides that, it also provides the data necessary to design tailored regulations and incentive schemes, in order to boost public engagement. Energy Communities and Self-Consumption Communities

clearly fit into these new structures, opening new possibilities and challenges, the latter ones especially regarding the electrical grid operations and stability.

## SPECIFIC MEASURES FOR EACH ENERGY PRIORITY

For each of the aforementioned priorities, 3 to 4 specific measures have been identified, defining possible actions to take to address effectively the S3 priorities.

For the priority **Sustainable Buildings**, four main measures have been identified as promising paths to obtain results within the next programming period:

- Energy efficient retrofitting. Promoting energy efficient interventions on both private and public buildings with incentives and by engaging private citizens. Fostering of energy efficiency labelling standards and promotion of good practices and construction certifications, cooperating with regions and public administrations to make them compulsory for new constructions. For example, a high-efficiency building should be found in every municipality, as a best practice example for the citizens;
- Eco-constructions. Sustainable and ecological materials, besides a certain amount of wood, are still not so common in the construction industry, which still largely relies on concrete and synthetic insulation. The interest towards new solution is growing, and the opportunities for the sector are notable. The production of catalogues and criteria to define these materials, including whether it is local or not and its process footprint could make the construction sector shift towards a more sustainable approach. Coupling this with construction standards and energy efficient certifications, it should be possible to trigger a positive trend;
- Small-scale RES Integration in buildings. Integration of solar PV and heat pumps (mainly using air as heat source, but ground ones have showed to be effective too) is already an ongoing process. Adopting a smarter regional strategy, studying how to adapt this process to the distribution grids and considering this within an energy community perspective could have a non-negligible impact on the energy system;
- Demand side smart energy devices. Besides improving the energy efficiency of residential appliances, the interactions and timing of the appliances among each other and with the grid itself could bring great benefits. Appliances that operate according to the grid load can help to smooth peak demands and make the most of local renewable energy use, minimizing grid management and generation issues and bringing economic benefits to the citizens.

The **Bio Energies** trajectory focuses on exploiting the large regional potential from both forestry and agricultural waste, with three main measures:

- Forestry management models. FVG region is forest-covered for around 40%, mostly in alpine valleys and hilly areas. Of this large surface, only 60% has a management plan written by a forestry doctor, which evaluates the status of the forest, the annual growth and the available retrievable resource. Many of these plans are out of date. Technologies like LIDAR (Laser Imaging Detection and Ranging) can help monitor, manage and develop the forest with huge benefits for local communities. Besides that, fragmentation of forest into small properties make it difficult to operate with multiple owners and to actually reach some areas;

- Biomass DH plants and grids. Medium- and small-sized biomass fuelled DH plants are proven to be a cost-efficient and environmentally-friendly solution in alpine areas, with thousands of plants operated with success in Austria and Switzerland. In FVG region there is a large untapped potential of resources and small municipalities which would benefit from this technology. Adopting a quality management system, such as QM-Holzheizwerke, can help to improve the planning and operations of DH networks, decreasing local emissions and bringing economic benefits to both customers and operators;
- Biogas plants. In 2012 a considerable amount of biogas power plants was constructed in rural areas where agriculture is one of the main activities. Due to high and not optimized incentives, many of these plants are not operated efficiently, digesting entire crops instead of just agriculture residues and not exploiting the large amount of heat that is produced by the combustion. Establishing a standardized and more controlled procedure for small-scale biogas digester could lead to a relevant deployment without the necessity of oversized incentives. It could also lead to the establishment of local rural cooperatives which supply and manage the plant with agricultural residues and profit of the bio-methane, with a social and economic benefit for marginal areas. Biogas can then be burned to produce electricity or be refined and injected in the already existing methane grid. Moreover, small CHP plants could help to develop small-scale DH networks.

For the **Sustainable Mobility** trajectory, measures do not consider a single technology/process but rather focus on a transport-related area, namely terrestrial transport, maritime transport and alternative fuels/electrification supply chain:

- Decarbonization of terrestrial transport. This is the sector that captures the most interest and investment, both from privates and administrations. First approach should be to continue reducing the need of cars in urban areas and shifting to bike and public transport. Having a long-term project of lower speed limit areas, new bike lanes and a better integration of buses and trains is fundamental in order to effectively spend public money and reach goals faster. Regarding cars, EVs and hybrid cars are receiving great attention as well as large incentives. Recharging infrastructures are being deployed everywhere and the grid is being adapted to such new load. Besides the advantages of no local emissions and the increase of renewables self-consumption on a residential level, many doubts remain on the production and supply chain sustainability, especially regarding the batteries. An alternative that could couple well with the progressive electrification is biodiesel, for which the supply chain could be regionally developed and does not require the substitution of the existing vehicles and infrastructure;
- Decarbonization of maritime transport. Maritime transport represents a pivotal sector for the regional economy, with three commercial harbours, of which Trieste covers an international strategic role. By design, most large ships have an electric drivetrain and a maritime diesel generator that produces electricity. With a proper regional strategy on the production and usage of bio-diesel, results could be achieved also on the short- and medium-term. On the longer run, hydrogen could be the key technology for this sector, while electrification could be viable for ferries and short distance ships;

- Bio-diesel, bio-methane, hydrogen and electrification. As previously mentioned, bio-diesel and bio-methane could play a central role in the transport sector on the short- and medium-term. As the production of syngas is already common with several digestion plants, it is more a matter of evaluating the real potential, develop a regional strategy and building a regulation that avoids bad practices and helps generating a resilient sector that does not depend on incentives. A similar strategy could be applied to bio-diesel from agricultural waste. Regarding electrification, it should be analysed whether the electrical demand increase is suitable to the grid (with its geographical and infrastructural constraints) and for the generation (is it a flat demand or requires fossil peak power plants). As the process is already ongoing, data will be available over the next years and a better strategy could be put in place. Last, hydrogen seems to be the most promising solution on the long-term, as for now it is not economically viable and there is not enough surplus renewable electricity to sustain a relevant hydrogen production.

Next trajectory faces what is probably the hardest sector to decarbonize: **Industrial Efficiency**. The three measures identified should always be secondary to a general increase in energy efficiency of the industrial processes. The measures focus on:

- Waste heat recovery systems. Many industrial processes require and produce heat at various temperatures. Find synergies and cascade usage of the heat produced can help increase efficiency and reduce costs and emissions, with immediate economic and environmental benefits. When the heat source cannot be used within the plant itself for other processes, it is still possible to inject it into a DH network when close to urbanized areas or to produce electricity with a small ORC plant;
- Hydrogen in steel industry. Steel industry represents a major sector within the region, with high demand of fossil fuels for both processes and input materials. Hydrogen is a carrier with high energy density that can contribute to decarbonize these processes, reducing at the same time local emissions of NOx and dust. Not to be forgotten is that this hydrogen should be produced starting from renewable energy surplus and not from the breakdown of oil and gas;
- Hybrid solutions and multi-energy systems. With the higher penetration of renewable energy generation and faster fluctuations of commodity prices, energy flexibility could bring security and a more sustainable development in the industrial sector. Operate with multiple energy vector according to the availability and being able to switch between electricity and common fuels, or the capacity to convert and store energy with technologies like power to gas or hydrogen can have a notable impact on the sector.

The last trajectory is the **Smart Grids** one. Three focus measures have been identified also for this topic to foster energy transition at regional level:

- Energy Communities. The energy community topic is gaining more and more attention every day and both technicians and administrations agree that it is an innovative concept with a likely huge environmental and social impact. Engage private citizens as producers and market players can incentivize the deployment of small-scale RES such as PV, small hydro, biogas digesters. Besides that, distributed generation requires a smarter operation of the infrastructure but at the same time less interconnectors capacity. Small industries and service companies can also be part of the communities and benefit from the exchange.

The energy community concept should not be limited only to the electricity vector, as also renewable DH networks offer the opportunity of co-ownership and participation;

- Monitoring Systems and Demand Response. Having a deep knowledge of where, when and how energy is consumed and produced will allow grid operators, energy planners and market players to integrate renewable sources in a more efficient way. When this information is available in real time with a detailed geographical resolution, automated appliances, storage technologies and even electric vehicles can interact with the grid and among themselves in order to flatten the consumption curve, decrease the stress on the infrastructure and increase RES utilization;
- Renewable energy generation integration. Optimal distribution of both small- and large-scale RES can reduce transmission losses, infrastructural needs and help operate and balance the system. A proper planning in agreement between administrators and grid owners is necessary to adapt the energy system to future challenges. Focused incentives should be granted for specific target areas, and industrial installations should also be fostered in order to reduce the high needs of these demand areas.

## 3.2 Compliance with European and national targets and strategies

The reference regulatory framework addressing energy and climate at EU level is the Clean Energy for all Europeans Package (CEP). The targets of the CEP are currently under revision to align with the objectives set by the European Green Deal aimed at making Europe the first climate-neutral continent by 2050. In July 2021, the EC released the *Fit for 55%* by 2030 legislation package proposing the reduction target to be set at 55 %, alongside a revision of the EU's climate and energy legal framework. This large adjustment package includes thirteen cross-cutting legislative proposals comprising eight revisions of existing regulations or directives and five new proposals. The European Climate Law, passed a few weeks earlier, made these goals binding. The climate and energy objectives thus set are strictly connected to Next Generation EU and the Recovery and Resilience Facility since national plans will be assessed against a 37% target of expenditure for investments in the green transition.

At national level, Italy’s recovery and resilience plan foresees an adjustment of the strategic regulatory framework in particular with reference to the Integrated National Energy and Climate Plan and the Strategy for long-term GHG emissions reduction. The Directives on Energy Efficiency and on the Energy Performance of Buildings have been enacted into national law. The Renewable Energy Directive (RED II) was revised by the EC in July 2021 and is about to be transposed into the Italian legal framework. The implementation of the RED II will accelerate the development of RECs and Collective Self-Consumption Groups all over the country. As a matter of fact, several initiatives are already in the pipeline at local level as further proof of the fact that there is a great buzz around the issue.

The green transition is at the core of the National Recovery and Resilience Plan (PNRR) with some € 70 billion-worth investment package to increase the share of RES production and enable the digital transformation of the electricity grid. In line with the objectives set forth by the PNRR, the strategic areas of interventions at regional level have been identified alongside the commitment to establish a road map to make Friuli Venezia Giulia climate neutral by 2045, ahead of the 2050 targets set by the Green Deal. The FVG REAP incorporates, and create synergies among, EU and national climate and energy frameworks in a multilevel governance perspective to foster an inclusive and strategic regional development.

# 4. MISSION MAPPING

## 4.1 Levels of policy/governance

The Energy Union is based on three objectives of the EU energy policy, namely security of supply, sustainability and competitiveness. In order to reach these goals, the Energy Union has identified five key dimensions: Energy Security, Internal Energy Market, Energy Efficiency, Decarbonization and Research-Innovation-Competitiveness. In this section, each measure of each development trajectory is categorized according to the affected dimensions.

Moreover, the same measures will also be classified based on the sector they have impact on. The selected sectors are: Residential, Public, Services, Mobility, Production, Energy and Agriculture.

1) Assignment of **Sustainable Buildings** trajectory's measures according to the affected dimension. These measures focus on the reduction and decarbonization of the consumption related to buildings, with a great impact also on social awareness of administrations and private citizens.

| | DECARB | ENEFF | ENSEC | ENMARK | RE IN COM | META |
|---|---|---|---|---|---|---|
| ENERGY EFFICIENT RETROFITTING | 4.1.1 | 4.1.2 | 4.1.3 | 4.1.4 | 4.1. | 4.1.6 |
| ECO-CONSTRUCTION | 4.1.7 | 4.1.8 | 4.1.9 | 4.1.10 | 4.1 | 4.1.1 |
| SMALL-SCALE RES INTEGRATION IN BUILDINGS | 4.1.13 | 4.1.1 | 4.1.1 | 4.1.16 | 4.1. | 4.1.1 |
| DEMAND SIDE SMART ENERGY DEVICES | 4.1.19 | 4.1.2 | 4.1.2 | 4.1.22 | 4.1. | 4.1.2 |

According to the target sectors, as it could be expected, these measures focus mainly on the residential and public sectors, triggering as a consequence production and some related services. Responsibilities for policy implementation falls on the regional administration, which should regulate the technical details and define incentives. On the implementation aspect, municipalities could lead the way by implementing as many measures as possible in their public buildings, i.e. schools, town halls, hospitals etc.

| | RESID | PUBLIC | MOBILITY | PROD | SERVICE | ENERGY |
|---|---|---|---|---|---|---|
| ENERGY EFFICIENT RETROFITTING | 4.1.25 | 4.1.2 | 4.1.27 | 4.1. | 4.1.29 | 4.1.30 |
| ECO-CONSTRUCTION | 4.1.31 | 4.1.3 | 4.1.33 | 4.1 | 4.1.35 | 4.1.36 |
| SMALL-SCALE RES INTEGRATION IN BUILDINGS | 4.1.37 | 4.1.3 | 4.1.39 | 4.1 | 4.1.41 | 4.1.42 |
| DEMAND SIDE SMART ENERGY DEVICES | 4.1.43 | 4.1.4 | 4.1.45 | 4.1. | 4.1.47 | 4.1.48 |

2) Assignment of **Sustainable Mobility** trajectory's measures according to the affected dimension. The three measures affect basically the same four dimensions, namely decarbonization, energy security through the local production of fuel and diminished dependency on fossils, energy markets and research and innovation.

| | DECARB | ENEFF | ENSEC | ENMARK | RE IN COM | META |
|---|---|---|---|---|---|---|
| TERRESTRIAL TRANSPORT | 4.1.49 | 4.1.5 | 4.1.5 | 4.1.52 | 4.1 | 4.1.5 |
| MARITIME TRANSPORT | 4.1.55 | 4.1.5 | 4.1.5 | 4.1.58 | 4.1 | 4.1.6 |
| ALTERNATIVE FUELS | 4.1.61 | 4.1.6 | 4.1.6 | 4.1.64 | 4.1 | 4.1.6 |

With regard to the target sectors production, energy and mobility are the key sectors for technology production and alternative fuel supply. Local administrations and private citizens are only affected by the terrestrial transport measure.

Again, the development of a detailed plan is under the responsibility of the Regional Authority, which should also cooperate with the major cities and delegate urban mobility planning. Cooperation among neighbouring municipalities to develop proper infrastructures like bike paths and charging stations should be encouraged. For what concerns maritime transport, the dialogue must be between the port management administration and the Region, to speed up the process with a comprehensive and effective intervention. The regulation regarding production and distribution of alternative fuels should be developed on a national scale, with the contribution of research centres and stakeholders.

| | RESID | PUBLIC | MOBILITY | PROD | SERVICE | ENERGY |
|---|---|---|---|---|---|---|
| **TERRESTRIAL TRANSPORT** | | | | | | |
| **MARITIME TRANSPORT** | 4.1.73 | 4.1.7 | | | 4.1.77 | |
| **ALTERNATIVE FUELS** | 4.1.79 | 4.1.8 | 4.1.81 | | | |

3) Assignment of **Bioenergies** trajectory's measures according to the affected dimension. Exploiting local renewable sources has a great impact on energy security and energy markets, as it diminishes the dependency on imports. Besides decarbonizing the system, using local biomass from an effective and sustainable management of the forests can also have a beneficial effect on the public opinion.

| | DECARB | ENEFF | ENSEC | ENMARK | RE IN COM | META |
|---|---|---|---|---|---|---|
| **BIOMASS DH PLANTS AND GRIDS** | 4.1.85 | 4.1.8 | 4.1.8 | 4.1.88 | 4.1. | 4.1.9 |
| **BIOGAS PLANTS** | 4.1.91 | 4.1.9 | 4.1.9 | 4.1.94 | 4.1 | 4.1.9 |
| **FOREST MANAGEMENT MODELS** | 4.1.97 | 4.1.9 | 4.1.9 | 4.1.10 | 4.1. | 4.1.1 |

The affected target sectors are in first place agriculture (and silviculture) and production, with relevant effects on the energy and service sectors. Residential is only slightly involved, while there are relevant opportunities for public administrations, by reducing the heat bills and by earning from the management of unused forests.

A regulation regarding biogas plants providing limitations on what they digest, where they can be built and what size they can reach should be developed by the Regional Authority to avoid speculations and to obtain long-term benefits for the entire system. Regarding biomass plants and forest management models, besides a regional incentive, it must be up to the municipality to take the initiative and to start building local cooperatives for such projects.

| | RESID | PUBLIC | MOB | PROD | SERV | ENERG | AGRIC |
|---|---|---|---|---|---|---|---|
| **BIOMASS DH PLANTS AND GRIDS** | 4.1.1 | 4.1.1 | 4.1.1 | 4.1.1 | 4.1.1 | 4.1.1 | 4.1.1 |
| **BIOGAS PLANTS** | 4.1.1 | 4.1.1 | 4.1.1 | | 4.1.1 | | |
| **FOREST MANAGEMENT MODELS** | 4.1.1 | 4.1.1 | 4.1.1 | 4.1.1 | 4.1.1 | 4.1.1 | 4.1.1 |

4) Assignment of **Industrial Efficiency** trajectory's measures according to the affected dimension. This sector impacts basically every dimension but for the social awareness of population, ranging from decarbonizing industrial processes, to having a more secure and diverse supply, to promoting research and innovation to increase efficiency.

| | DECARB | ENEFF | ENSEC | ENMARK | RE IN COM | META |
|---|---|---|---|---|---|---|
| **HYDROGEN IN INDUSTRIAL PROCESSES** | 4.1.12 | 4.1.1 | 4.1.1 | 4.1.12 | 4.1 | 4.1.1 |
| **WASTE HEAT RECOVERY SYSTEMS** | 4.1.13 | 4.1.1 | 4.1.1 | 4.1.13 | 4.1 | 4.1.1 |
| **HYBRID ENERGY SYSTEMS** | 4.1.13 | 4.1.1 | 4.1.1 | 4.1.13 | 4.1 | 4.1.1 |

Target sectors are only production and energy, with the possibility of supplying heat to residential areas when the industry is located at a reasonable distance. The implementation in this sector might be the trickiest one because there are major economic interest and any intervention implies investments of millions of euros. About waste heat recovery and hybrid energy systems, the cooperation between industries and universities can help to drive public investment and bring effective improvements. As regards hydrogen, a more comprehensive strategy should be developed at regional and national level.

| | RESID | PUBLIC | MOB | PROD | SERV | ENERG |
|---|---|---|---|---|---|---|
| HYDROGEN IN PROCESSES | 4.1.1 | 4.1.14 | 4.1. | 4.1.1 | 4.1.1 | 4.1.14 |
| WASTE HEAT RECOVERY | 4.1.1 | 4.1.14 | 4.1. | 4.1.1 | 4.1.1 | 4.1.15 |
| HYBRID ENERGY SYSTEMS | 4.1.1 | 4.1.15 | 4.1. | 4.1.1 | 4.1.1 | 4.1.15 |

5) Assignment of **Smart Grids** trajectory's measures according to the affected dimension. In this trajectory measures affect basically every single dimension, as they touch the distribution system, the decentralized RES generation and the final consumption efficiency. In particular the Energy Communities measure appears to be the most polyhedral one, with great social impacts on top of the decarbonization, efficiency, market and innovation aspects.

| | DECARB | ENEFF | ENSEC | ENMARK | RE IN COM | META |
|---|---|---|---|---|---|---|
| ENERGY COMMUNITIES | 4.1.16 | 4.1.1 | 4.1.1 | 4.1.16 | 4.1. | 4.1.1 |
| MONITORING AND DEMAND RESPONSE | 4.1.16 | 4.1.1 | 4.1.1 | 4.1.16 | 4.1. | 4.1.1 |
| RES INTEGRATION | 4.1.17 | 4.1.1 | 4.1.1 | 4.1.17 | 4.1. | 4.1.1 |

According to the target sectors, all sectors besides mobility are included within this trajectory, with a great focus on the interaction between residential, public, energy and services. This measure is maybe the only one where the initiative of private citizens and small businesses is the main driver of the change. Incentives can be set by the Regional Authority, but communication activities and the engagement of privates play a crucial role. For the energy community establishment, municipalities could lead the way by playing the starting and management role, activating citizens which otherwise would not activate.

| 4.1.178 | RESID | PUBLIC | MOB | PROD | SERV | ENERG |
|---|---|---|---|---|---|---|
| ENERGY COMMUNITIES | 4.1.1 | 4.1.18 | 4.1. | 4.1.1 | 4.1.1 | 4.1.18 |
| MONITORING AND DEMAND RESPONSE | 4.1.1 | 4.1.18 | 4.1. | 4.1.1 | 4.1.1 | 4.1.19 |
| RES INTEGRATION | 4.1.1 | 4.1.19 | 4.1. | 4.1.1 | 4.1.1 | 4.1.19 |

## 4.2 Spatial focuses

All measures are also classified according to the Rural & Urban spatial focus. In most cases, measures impact both areas, with only the Bio energies trajectory that focuses on a single area.

| | URBAN | RURAL |
|---|---|---|
| 1A Energy efficient retrofitting | X | X |
| 1B Eco-Constructions | | X |
| 1C Small scale RES integration | X | X |
| 1D Demand side smart devices | X | X |
| 2A Terrestrial transport | X | X |
| 2B Maritime transport | X | |
| 2C Alternative fuels | X | X |
| 3A Biomass DH networks | | X |
| 3B Biogas plants | | X |
| 3C Forest management | | X |
| 4A Hydrogen in industrial processes | | X |
| 4B Waste heat recovery systems | X | |
| 4C Hybrid solutions/multi-energy systems | | X |
| 5A Energy communities | X | X |
| 5B Monitoring systems | X | X |

| 5C Renewable energy integration | X | X |
|---|---|---|

## 4.3 Specific measures for the transition

Of all the aforementioned measures, many follow the development of technologies and trends that will look very similar for most of European countries. Anyway, some others focus on some peculiar aspects of the FVG region that are worth mentioning, to develop the selected measures with more attention and focus on the local environment.

The strategic geographical location of Trieste and the fact that it is the biggest Italian harbour by tonnage of goods, makes it a crucial and peculiar case to focus on. The huge logistic structure, from the refuelling of ships and heavy transport to the mobility and the infrastructures like pipelines and fuel storage will require an extremely complex and holistic planning. Under this perspective, optimizing the billion euro investment is fundamental to achieve effective and durable results in a reasonable time. Hydrogen, bio-fuels, electricity should be integrated choosing the best target vehicle to substitute a sector dominated by oil-products. On top of that, the production, transport and storage of such energy carriers has to be planned and made most local and flexible as possible.

The heavy industry sector has a very high specific weight in a small region like FVG. Iron & steel in particular (but also paper and wood processing industries) contribute largely to the regional fossil fuels consumption and related emissions. Again, to build a strong cooperation between industries, regional authorities, research centres and universities is a key aspect to move along the most promising paths to decarbonize a sector that appears to be fossil fuel-bonded. Likewise, the harbour of Trieste, it is fundamental to understand how to better produce, transport and utilize alternative energy carriers, with a great focus on hydrogen. Moreover, waste heat from industrial processes is a freely available source of energy that has a great potential in the region's industrial areas. It can be used to supply heat to other processes (or also just as pre-heating) also with the aid of heat pumps. If the source of waste heat is located close to a residential area, DH solutions can be taken into consideration.

For what concerns the available resources in the region, biomass-based DH networks and forest management models appear to be two key measures for the development of the mountain areas of the region, which represent a very relevant share in terms of surface. The forest growth potential is highly underexploited, and the economic opportunity to develop local cooperatives that manage the forest and the heat supply through a RES DH can bring durable jobs and profits. Moreover, it is known how a well-planned and designed DH network can replace inefficient old burners and reduce local and global emissions.

## 4.4 Enabling and restraining factors

For each measure, strengths and weaknesses, opportunities and threats (SWOT) are evaluated and graded with a weight ranging from 1 (high weight = 3 points) to 3 (low weight = 1 point). Strengths and opportunities sum up to the total "Impact" of the priority, while weaknesses and threats are represented by the "Effort" parameter. In this section, the global evaluation of the Impact/Effort ratio will first be presented, and later a more detailed analysis of the SWOT characteristics of each measure will take place.

By plotting the final factors for Impact and Effort against each other, it is possible to compare the different priorities in terms of how challenging and/or rewarding they are. Each factor is calculated as the sum of the positive or negative SWOT scores over the maximum available points, e.g. 15 points over 4 measures is equal to 15/ (4*6) = 0,625.


**Figure 11: Impact to effort ratio**

By looking at the graph, it can be seen how the different priorities are all located in the same upper-right quadrant, which means great impact with great effort. Looking closer it can be seen that Sustainable Buildings, Sustainable Mobility and Industrial Efficiency present could have the same impact on the system, with a factor of 0.67. As expected, measures regarding the industry sector require the highest effort (0.83), as the sector present a notable inertia to changes and many processes are difficult to be decarbonized. Sustainability in buildings demands a relatively low effort (0.62), being a priority, which is already undergoing a notable transformation over the last years. Mobility stands in between the two aforementioned priorities (0.72), as technologies are closer to be market-ready than in industry but not yet as popular as innovations in the construction sector.

Bio energies is the priority that presents the best Impact to Effort ratio, with an estimated impact of 0.78 facing an effort of “only” 0.55. In fact, forestry and the cascade usage of wood resources is a well-known topic in the region and therefore does not require a lot of work in order to be optimized and thrive. On the other hand, the untapped potential of wood biomass and agriculture residues is huge and quite accessible to be exploited.

Last, the Smart Grids is the trajectory with the greatest potential (0.89), but requires as the same time a notable effort (0.67) in many fields in order to achieve results, as it comprehends multiple technologies, stakeholders and social aspects.

## 4.5 Challenges, estimation of efforts and impact

As previously mentioned, for each measure of each priority strengths, weaknesses, opportunities and threats have been evaluated and their weight graded from 1 (high) to 3 (low).

**1) Sustainable Buildings.**

Energy efficient retrofitting appears to be the strongest out of the four measures, both regarding Strengths and Opportunities. In fact, having already in place multiple incentives shows a clear political willingness to pursue this goal. Construction companies and market actors are already prepared for this challenge, high-quality standards and regulations have been developed and the first effects are expected to be seen on the very short-term. In particular the economic impact on the local level on construction companies, the supply chain and benefits for the public administration is a valuable strength, despite the difficult direct evaluation. The risks are relatively moderate, with low quality interventions and effects on local distribution grid that could be managed without major troubles. Eco-construction is an interesting topic especially with a long-term perspective. In fact, the little know-how and practices, lack of regulations and incentives make the costs and the uncertainties very high and risky. On the other hand, the opportunities for local businesses and supply chain could still attract public and private investments with a more forward-thinking perspective.

The greatest achievement obtainable from a large decentralized deployment of small-scale RES is surely the decarbonization of the energy system. On the bigger picture, energy security and lower dependency from external imports of commodities is surely appreciable, as well as the direct engagement of citizens and the strengthening of social awareness. On the negative side, the management of the infrastructures such as the distribution grid could get tricky for the operators. Risks of counterflows and over voltages will require large expenses to adequate the infrastructure and the control, but at the same time lower supply of electricity due to higher self-consumption will decrease the operator’s income. Last, demand side and monitoring appliances are a vast and difficult area to regulate and incentivize, despite the clear and immediate benefits that such measure could bring. The market will probably drive itself driven by profit and to foster social engagement might require some uneven stimulus towards some technologies. Moreover, it is difficult to predict the behaviour of private citizens, with the possibility that every energy saving will be followed by a rebound effect that counterbalances every improvement achieved.

| | ENERGY EFFICIENT RETROFITTING | WEIGHT |
|---|---|---|
| S | #Local circulation of private and public funds<br>#Short term results in energy saving<br>#Immediate economic and comfort benefits for citizens | 1 |
| W | #Unpredictable impact on local distribution grids (DH, gas, electricity) and the necessary interventions | 2 |
| O | #Favourable incentive schemes already in place<br>#Business opportunities for local construction companies | 1 |
| T | #Geographically uneven distribution of interventions<br>#Low quality interventions/materials driven by economical profit | 2 |
| | ECO-CONTRUCTIONS | WEIGHT |

| | | |
|---|---|---|
| S | #Dissemination of know-how<br>#Energy efficient and low-carbon buildings<br>#Local circulation of funds | 3 |
| W | #Little knowledge at current state<br>#High costs, low demand | 2 |
| O | #Creation of local material supply chain<br>#Business opportunities for local construction companies<br>#Opportunities to experiment new building techniques/architecture | 2 |
| T | #Little observance of quality and material standards without regulation<br>#Low implementation due to high costs | 2 |
| | **SMALL SCALE RES IN BUILDINGS** | **WEIGHT** |
| S | #Increased energy security<br>#Decarbonization<br>#Engagement of private citizens | 1 |
| W | #Unpredictable impact on local distribution grids (DH, gas, electricity) and the necessary interventions | 2 |
| O | #Positive economic impact on local RES production/supply/O&M<br>#Increasing awareness of citizens | 2 |
| T | #Wrong sizing and poor quality driven by profit<br>#Uneven geographical distribution | 2 |
| | **DEMAND SIDE SMART ENERGY DEVICES** | **WEIGHT** |
| S | #Immediate energy savings | 3 |
| W | #Relatively low impact<br>#Choices driven by cost/opportunity more than efficiency | 3 |
| O | #Raise social awareness | 3 |
| T | #Wrong behaviour could counterbalance savings<br>#Substitution of still efficient appliances | 2 |

**2) Sustainable Mobility.**

Transport sector is definitely one of the hardest decarbonization challenges. In fact, weaknesses and threats always score high values, making the possible opportunities look less appealing. In particular regarding terrestrial transport technical and economic barriers seem to counterbalance the social acceptance that already exist and the development opportunities connected to the new technology. Low distance autonomy, battery disposal issues, little existing infrastructure and high costs act against a quick spread of the EV technology, and the only tool that public administrations found at the moment is direct or indirect incentives.

For what concerns the maritime transport, the topic presents a relatively easy technical challenge, but put into a fair more complex circumstance. In fact, maritime drivetrains are in most cases already electric driven, with a generation unit to supply electricity. This easy substitution is for sure a great strength of the measure, abating substantially technology shift costs. Bio diesel could be also a short-term solution, as it requires even less structural interventions. The circumstances in which this technology shift should happen are much trickier. International ships travel across the world and often owner and operator differ, as well as the country in which the boat is registered. Who should bear the cost? And is it possible to make a shift happen in multiple harbours around the planet? This translates into new infrastructure for refuel and storage, as well as big changes in the supply chain. Again, it seems like weaknesses and especially threats outplay the opportunities, as long as some international entity imposes a stricter regulation.

Talking about alternative fuels, this might seem the measure that brings the most benefit with respect to the possible threats. Biomethane is an already tested technology, which when refined can also be injected into the existing gas grid. The electric infrastructure for EV charging can be easily improved. As opportunities, the whole bio-diesel and bio-methane supply chain as well as the hydrogen one can drive local investment in research and incentives and foster the local economy and create jobs. Moreover, having such a supply chain established on the local scale increases sensibly the energy security of the system. However, high implementation costs and the lack of a clear and effective strategy to use the available funds might jeopardize the process. A proper and careful use of public funds is necessary.

| | TERRESTRIAL TRANSPORT | WEIGHT |
|---|---|---|
| S | #EVs are socially accepted and spreading<br>#Simple infrastructure, to be implemented with small interventions | 2 |
| W | #Low distance autonomy of EV<br>#Higher vehicle cost<br>#Issue of battery disposal<br>#Low infrastructure in place | 2 |
| O | #Growth opportunity for biofuels production<br>#Job creation on maintenance & disposal | 3 |
| T | #High system cost<br>#Electric grid might not be ready yet for such load | 2 |
| | **MARITIME TRANSPORT** | **WEIGHT** |
| S | #Maritime drivetrains are already electric, technically simple substitution of generator<br>#Few harbours have an appropriate infrastructure or can be re-design in the short term<br>#Bio-diesel can be already introduced to a certain share | 2 |
| W | #Big and expensive infrastructure with environmental impact<br>#Expensive substitution of generator units<br>#Hydrogen and fully electric technologies not yet ready | 1 |
| O | #Growth opportunities for the regional biofuel industry<br>#Become international leader in the green maritime sector<br>#Infrastructure and bunkers can increase energy security | 2 |
| T | #Low willingness of private transport companies to face the investment<br>#Logistic, social and environmental acceptance of new infrastructures | 1 |
| | **ALTERNATIVE FUELS** | **WEIGHT** |
| S | #Bio methane tested technology, can be refined and injected in existing grid<br>#Electric infrastructure can be easily improved<br>#Hydrogen is promising and flexible | 1 |

| | | |
|---|---|---|
| W | #High costs of implementation<br>#High inertia of the system | 2 |
| O | #Job creation in bio-methane sector<br>#Added value to agriculture<br>#Increased energy security | 2 |
| T | #Mismanagement of money and incentives<br>#Wrong and chaotic implementation of infrastructures | 3 |

**3) Bio energies.**

Forest management models like LIDAR and other digital tools might seem to be just marginal tools but they can actually help unlock a smart end effective management of the forest resource. The abundancy of forests, and the possibility for businesses connected to the wood process chain are major benefits that should attract interest from public administrations and privates. The major threat is certainly the fragmentation of the forest property among several hundreds of private owners. In fact, such tiny pieces of forest might have low attractivity to forestry companies when alone, or could also represent an obstacle to the construction of a road to reach other forest areas. It is important to connect these little owners and build what can be called a forest-condominium, and give the management of the whole block to a company or a local cooperative. Overall, a part from this last social obstacle the pros largely outweigh the cons.

The proper exploitation of the forest resources is a fundamental aspect to the Biomass DH measure. The technology is well established and competitive, and the opportunities for a local supply chain development are concrete. The main obstacle is to attract investments from privates and use properly the public ones. In this sense, better financial tools are required. Social acceptance might also be a problem, but it is reasonable to think that after a couple of good practices have been realized in the area, doubts will fade away.

Last measure regards biomass plants. On one hand, it presents great strengths such as solid technologies, an existing gas grid and especially the great flexibility of operations. Moreover, the rural areas of lower Friuli offer a great availability of agricultural waste and manure. It can also represent a good opportunity for local cooperatives and create few jobs. On the other hand, without incentives it might not be economically competitive yet, so there is a great uncertainty depending on how these incentives are regulated. A wrong financial tool might in fact lead to speculations, bad sizing of the plants, usage of not local biomass, bad agriculture practices in order to obtain large amount of energy crops, and last the abandon of the plant when incentives expire.

| | BIOMASS DH PLANT AND GRIDS | WEIGHT |
|---|---|---|
| S | #Solid technology, standardized planning and O&M in some countries<br>#Competitive heat cost, efficient and $CO_2$ free | 1 |
| W | #High initial investment cost, especially regarding the grid. Better financial tools are required | 2 |

| | | |
|---|---|---|
| O | #Opportunity for the development of a local supply chain from the forest (private and public) to the plant management, job creation | 2 |
| T | #Social acceptance of a biomass plant<br>#Small owners' resistance to forest management projects | 3 |
| | BIOGAS PLANTS | WEIGHT |
| S | #Standardized technologies<br>#Local availability of resources<br>#Flexibility in plant size<br>#Existing gas grid | 1 |
| W | #Relatively expensive when refined for grid injection<br>#Expensive O&M | 2 |
| O | #Energy security<br>#Small decentralized plants and cooperatives, job creation<br>#Economic opportunity for local farmers | 2 |
| T | #Wrong incentives and regulations could lead to agriculture distortion | 2 |
| | FORESTRY MANAGEMENT MODELS | WEIGHT |
| S | #Resource abundance | 1 |
| W | #Difficulties to contact, connect and organize owners and target groups | 2 |
| O | #Local jobs and economic benefits | 2 |
| T | #Social opposition to forest exploitation | 3 |

**4) Industrial Efficiency.**

Hydrogen has created a notable hype as the fuel of the future. On one hand it certainly offers great benefits where it is applied, but it currently comes with deep weaknesses and high threats. In fact, extreme costs, new infrastructures (electrolysers, fuel cells, electric lines, hydrogen pipelines, boat and truck carriers …) are the main barriers to the development of such technology. Mover, the whole electricity to hydrogen to electricity process has a rather low efficiency, making questionable whether it is worth to build such a complex supply chain. On the benefits side, such energy density and zero local emissions could have a major impact on those economic sectors that currently present the hardest challenges for the decarbonization, namely industry and mobility.

Waste heat recovery instead is not a new technology raising doubts, but rather a recognized resource and many efforts have been made in order to exploit it wherever possible. The availability of it is surely the greatest advantage, and the challenge relies completely in finding the best and cheapest way to exploit it. Great opportunities for synergies and cooperation between industries themselves, industries and DH networks and universities and research centres are there to be built.

The flexibility of operations and the competitivity that could be achieved with hybrid and multi-energy systems represents a valid reason to pursue such measure. Again, technologies at their early stages, high costs, and difficulties to attract investments are the obstacles to such development. Cooperation with research institutes and international partners could boost this process.

| | HYDROGEN IN INDUSTRIAL PROCESSES | WEIGHT |
|---|---|---|
| S | #High energy density<br>#Zero local emissions | 1 |
| W | #Low efficiency in hydrogen production<br>#Expensive infrastructure | 1 |
| O | #Foster renewable energy generation by exploiting its surplus | 2 |
| T | #High costs<br>#Infrastructure planning | 1 |
| | **WASTE HEAT RECOVERY SYSTEMS** | **WEIGHT** |
| S | #Free available heat<br>#Proven technologies | 1 |
| W | #Implementation costs<br>#Often source and demand are located far apart | 2 |
| O | #Develop cooperation with universities and local stakeholders<br>#Boost DH networks around the region | 3 |
| T | #Difficulties in putting together multiple players from different sectors | 2 |
| | **HYBRID & MULTI-ENERGY SYSTEMS** | **WEIGHT** |
| S | #Flexibility of plant operations<br>#Energy security<br>#Lower emissions | 2 |
| W | #High costs<br>#Low maturity of technologies | 1 |
| O | #Cooperation with universities on innovative systems for industries | 3 |
| T | #Low willingness of stakeholders to invest in not mature technologies | 2 |

### 5) Smart Grids.

Energy Communities are expected to play a key role in the energy transition in the years to come. In fact, the benefits that such structure brings to all the players are notable, starting from lower costs of electricity, to the deployment of RES, to the engagement and awareness of citizens. Moreover, European and national funds have been allocated for the coming years. The threats are that the technical aspects have still to be refined and experience has to be developed. Lastly, the success of such measure highly depends on national regulations and bureaucracy.

Monitoring Systems and Demand Response mechanisms is probably the measure which has the easiest implementation. Monitoring systems are cheap and already largely diffused, and privates and utilities are starting to use the amount of data for optimization and load management. When storage technologies will be more mature and economically viable, the potential for this measure will grow exponentially.

Renewable energy integration as well has a great potential due to being accessible to a large share of the population. It ensures low cost of energy to the users, higher air quality and helps raising awareness. The main obstacle is the adaptation of the grid to such variable generation and load, as over voltages and congestions might compromise the success of it and cause expensive damages.

| | ENERGY COMMUNITIES | WEIGHT |
|---|---|---|
| S | #Private citizens and businesses are active players<br>#Lower final cost of energy<br>#Less infrastructures<br>#Incoming incentives | 1 |
| W | #Ownership of the grid<br>#Adaptation and management of the grid | 1 |
| O | #Engagement and awareness of citizens<br>#Increase of distributed RES generation<br>#Cooperate with universities for optimal design/strategy | 1 |
| T | #Bureaucracy difficulties<br>#Low initial engagement<br>#Grid constraints | 2 |
| | **MONITORING SYSTEMS/DEMAND RESPONSE** | **WEIGHT** |
| S | #Monitoring systems are cheap and easy to install<br>#Economic benefits for both producers and consumers<br>#Higher RES penetration | 1 |
| W | #Storage and demand response technologies are not mature yet | 3 |
| O | #Centralized databases with high accuracy and resolution<br>#Better forecasting and grid management | 1 |
| T | #Chaotic and not standardized way of monitoring the energy data, partial data sharing of some users | 2 |

| | RENEWABLE ENERGY INTEGRATION | WEIGHT |
|---|---|---|
| S | #Low energy cost to final users<br>#Engagement of citizens and industries<br>#Established technologies | 2 |
| W | #Grid constraints on existing infrastructure and operations | 2 |
| O | #Stronger cooperation with grid operators and planners<br>#Economic opportunity for local companies (prod, install, O&M) | 2 |
| T | #Chaotic and inefficient implementation without planning | 2 |

# 5. ACTION DEFINITION

This chapter lists several possible actions to be taken within each measure, in order to translate the concepts explained into practical deeds that will affect the respective sectors. For each of these actions, what is probably the greatest obstacle is to dedicate a share of public resources, both in terms of money and human work, and therefore the Regional Authority should commit to adopt a comprehensive planning and management programme. These deeds mainly work in two ways, first by promoting the development of certain trends, and second by avoiding and minimizing wrong practices. In this chapter, the actions will be catalogued by target area and not anymore by key priority, giving a different perspective of the needs and the possible synergies among some trajectories.

## 5.1 Energy efficiency

- Set up and implement into regulations **quality standards for energy retrofitting** interventions (KlimaHaus, Passivhaus, etc.). Define standards for materials to be used that guarantee effective performance in time and, where possible, use local and low-impact materials. Set as a necessary step to undertake an analysis of energy performance of the building before and after the intervention (APE certification). Keep the minimum efficiency improvement as a threshold, evaluate if it is worth to reward higher improvements;
- **APE certifications** (energy efficiency analysis and labels) should be promoted for all the existing buildings, both public and private, in order to perform first the most necessary interventions and to have a complete overview of the entire regional situation. Municipalities should lead the way by improving the efficiency in all the public buildings, starting from those with the highest demands (schools, hospitals, nursing homes, etc.);
- Interventions and energy efficiency certifications should be entered in a unique open-source **database**, with geo-referenced data. In such way, municipalities that need most interventions can be funded and studies and interventions on broader areas can be planned. These data can be used to have a more consistent knowledge of the system, to carry out trend studies and scenario simulations;
- Support the improvement of **labels for energy saving and smart appliances**, set up incentives for privates in order to substitute old ones, promote the use of smart home-systems that manage the house loads to have the smoothest operations for the grid;

## 5.2 Renewable energy supply

- Promote the diffusion of **small biomass and RES-based DH networks** for local heating supply of mountain areas, create a network of professionals and experts from all the interested sectors;
- Adopt a standardized **quality management system** (QM Holzheizwerke) and connect it to the financing tools. In such way the quality and management of such plants are

guaranteed on the long run and therefore also the use of public funds is justified and effective;

- Develop **ad hoc financial tools that support the initial investment mortgage for properly designed DH plants**, and are not strictly connected to the produced energy, which is a mechanism that could lead to speculations;
- Work on contracts and bureaucracy in order to allocate the **management of the forests and of the heat supply** (plant and DH grid) to local cooperatives for 15-20 years in a row. In such way local and durable job creation is ensured, with a positive effect on the local economy and against the depopulation of mountain areas;
- **Simplify financial regulations** and let public-financed plants supply privates and small companies as well. In fact, at the moment DH networks financed with public funds cannot supply privates and companies since it would be against free market competition for heat supply. Obviously, this fact limits the potential and effectiveness of such grids, as they can only supply public buildings and cannot densify the demand with all the private buildings along the network;
- Define **quality standards for biogas plants** regarding location choice, construction, operations, supply of agricultural waste and promotion of cooperatives that manage the plant and redistribute profits among the members;

## 5.3 Sustainable mobility

- Develop a **regional plan for EV charging infrastructure**. It is in fact important to have a comprehensive view of the infrastructure, in order to guarantee a proper service to EV owners, prevent redundancies and avoid to overburden certain sections of the electric grid. As good practice each municipality could install at least one charging area and substitute its vehicles;
- Develop a regional plan, as well as urban mobility plans in bigger cities, for **cycling paths**;
- Develop the **public transport** network and frequency with environmentally friendly vehicles (electric trains, methane buses etc.);
- Incentives **on substitution of old cars**, with low km/l efficiency and high particulate and NOx emissions. This is particularly important in urban areas where traffic problems and heating systems heavily affect the air quality and the health of the inhabitants;
- Create a cooperation between universities and relevant stakeholders (fuel suppliers, farmer cooperatives and associations, investors) for the **development and regulation of a biofuel supply chain**;
- Perform a detailed study of maritime routes, ships and refuels. Develop a **project for harbour infrastructures** such as biofuels refuelling and electrical charging, depending on the target ship;
- Obtain **commitment from maritime companies to convert** certain ships for defined routes to alternative fuels, and get signed contracts for a minimum amount of refuelling of these fuels at the harbour, in order to set up an adequate supply chain and refuelling station;

## 5.4 Sustainable infrastructure and spatial development

- **Regulate agriculture of energy crops**. Identify wrong agriculture practices for pure energy production and only subsidize plants which operate following the most sustainable principles. This will ensure to produce biogas as by-product and without affecting the agricultural sector;
- Facilitate the creation of new approaches to **forest management**. A priority should be to recover small and fragmented forest land private properties by promoting their aggregation and enhancing the economic value of the natural resources making use of advanced precision forestry technologies;
- Develop a **green hydrogen pilot plant** funded by the region in order to lead the way. It is most likely going to be an on-site production, storage and use. Industry or mobility seem to be the most promising sectors, but the ideal site should be selected carefully;
- Define a **regional hydrogen strategy**. Whether to focus on self-production for industries, to start planning transport and storage infrastructures like pipelines, analyse sectors and geographical areas with the highest production and end-use potential;
- **Simplify on both regulatory and technical level the creation and management of energy communities**. This new concept allows private citizens and companies to play an active role in the energy system and benefit from it. Although it will not represent a major earning, making citizens accountable for their production and consumption can lead to new RES installations and a better-informed consumption behaviour;
- Study with operators and universities interventions for a more **advanced and resilient grid.** The electric system will in fact undergo major changes, with increasing distributed generation and changes in consumption patterns. It will be very important to adapt the grid to avoid blackouts and other operational issues, as well as curtailment of RES;
- Build a detailed open-source **database of all waste heat sources** and their characteristics. In such way these available data can be used in the future to realize energy efficiency interventions and synergies among processes;

## 5.5 Catalysing factors: awareness, education, information

- Commit to couple the green and **digital transformation** where digitalisation is seen as a driver of change towards competitiveness and a fit for all relevant EU policies;
- Promote the creation of **local cooperatives that manage small-scale power plants**. From farmers-citizens cooperatives with biogas plants and methane/electricity production, to DH networks managed by forestry companies led cooperatives, to small- and mini-hydro, to collectively owned PV plants over large buildings;
- **Cooperate with universities, stakeholders and research centres** for hydrogen, waste heat and multi-energy systems solutions in industry and logistics;
- **Standardized data collection** of monitoring devices, establish centralized and open datasets and set up incentives for **data sharing**;

# 6. SCENARIOS

Having defined all the measures and actions that could be set up in the respective sectors and having weighted pros and cons, their hypothetical impact over the system should still be evaluated. It is a good practice to simulate the effect of measures over time by building and simulating several scenarios. Analysing and comparing the results of different scenarios is an extremely useful support for decision-makers, in order to consider which measures to focus on, what parameters should be modified (diminished or increased) and over which time frame to act. Within the PROSPECT2030 project, 3 main scenarios have been developed by each partner in order to see the progression of the selected indicators over time. In particular the scenarios will be referring to 2025 (short-term), 2030 (mid-term) and 2040 (long-term).

For each scenario, a general description of the measures in place, the required costs in terms of investments in generation capacity, primal and final consumption by sector and energy vector and a Sankey diagram are developed and analysed in the following chapters.

## 6.1 Overview on main actions and measures on the time scale

In the following table, measures are classified according to the time they should be elaborated and implemented to obtain the expected results. This does not mean that they should be applied only within the selected timeframe. They should instead periodically be updated for what concerns the techniques, goals raised and measures adjusted. This classification mainly gives an idea of which measures are more urgent and which need some more time for technologies and knowledge to be mature. For what concerns the long-term scenario, all the listed measures should already be in place and be adapted and improved step-by-step according to the actual status of the system.

| SUSTAINABLE BUILDINGS | SHORT TERM | MID TERM | LONG TERM |
|---|---|---|---|
| ENERGY EFFICIENT RETROFITTING | X | | |
| ECO-CONSTRUCTIONS | | X | |
| SMALL SCALE RES INTEGRATION | X | | |
| DEMAND SIDE SMART ENERGY DEVICES | X | | |
| **SUSTAINABLE MOBILITY** | | | |
| TERRESTRIAL TRANSPORT | X | | |
| MARITIME TRANSPORT | | X | |
| ALTERNATIVE FUELS | | X | |
| **BIOENERGIES** | | | |
| BIOMASS DH PLANTS | X | | |
| BIOGAS PLANTS | | X | |
| FORESTRY MANAGEMENT MODELS | X | | |
| **INDUSTRIAL EFFICIENCY** | | | |
| HYDROGEN IN INDUSTRIAL PROCESSES | | X | |
| WASTE HEAT RECOVERY | X | | |
| HYBRID SOLUTIONS/MULTIENERGY SYSTEMS | | X | |
| **SMART GRIDS** | | | |
| ENERGY COMMUNITIES | X | | |
| MONITORING SYSTEMS/DEMAND RESPONSE | X | | |
| RENEWABLE ENERGY GENERATION | X | | |

## 6.2 Scenario 2025

The urgency of a drastic change in resources consumption and carbon emissions makes fundamental to implement immediately most of the measures evaluated. It is unlikely to achieve major emission reductions in such a little timespan, but it is very important in order to build up a more resilient and effective regulation towards mid- and long-term scenarios.

### 6.2.1 General description: Actions and measures in the scenario

As previously said most measures can already be activated, maybe leaving initially a certain degree of freedom in order to let the market adapt. Energy efficient retrofitting, as it is an already ongoing process, can be intensified and made more efficient with respect to the funds invested.

Same for small RES integration and demand side energy devices. Regarding the transport sector, only terrestrial transport can boast green technologies that are costly and technically competitive, leaving for future scenarios the measures on maritime transport and alternative fuels.

For what concerns bio energies, forest management models and biomass-based DH networks are measures that can have an immediate impact and should move along together. In the industrial sector, it is possible to find several good practices of waste heat recovery all over the world. The sources should be analysed and exploited for other processes, directly or with the aid of heat pumps.

Lastly, regarding the smart grid trajectory, all the measures can be implemented even if at different levels of effectiveness. Some pilot projects might be necessary at first but there is surely space for results before 2025, so that the whole process can be sped up towards 2030.

### 6.2.2 State of energy efficiency, renewable energy supply, mobility, infrastructure and spatial development

**Energy efficiency**

On the regional level, there are about 308.000 residential buildings, of which about 42.000 units are holiday houses. Of this number, about 22% were built before 1975, 28% between 1975 and 1990, 15% in the 90s and about 35% after year 2000. According to these numbers, it is clear that focusing on energy retrofitting of buildings is fundamental in order to achieve the intended goals.

The total gross residential area of all the buildings is above 82.000.000 square meters, while the rest of the gross floor area which is not indicated as residential counts for about 20.500.000 square meters. The average gross residential area per building is therefore 267 square meters, and the average consumption is 124 kWh per square meter (considering also the holiday houses, which consumption is much lower than primary houses). The total combined yearly heat consumption is 10.397 GWh.

Over the 2016-2025 period the total heat demand of the residential sector is expected to decrease by about 15%, which means slightly above 1,5% yearly change. In the service sector the expected change stops at 10% over the scenario period.

**Renewable energy supply**

Regarding the renewable energy supply, on the short and mid-term the main trends expected to have an impact on the system are:

- **Replacement of oil-fired boilers and old gas boilers.** In the short term this shift to renewable generation and heat pumps is expected to cover 5% (each) of the previous oil products and gas demand;
- **PV generation expansion.** Electrification of end uses (e.g. heat pumps), incentives on small plants and energy communities will surely boost the installation of small PV. The production from this source is expected to increase by 266%, which means over 1.2 GW of PV will be installed before 2025;

- **Growth of DH systems.** Few new DH grids are expected to be built, and the existing ones to be expanded, operated in a more efficient way and with higher RES integration;

**Mobility**

On the short term there are no major changes expected to happen in the transport sector. This time should be used to plan in a detailed way new infrastructure projects and a regional strategy for the coming years.

**Infrastructure and spatial development**

As well as for the mobility section, this time frame should be used to select, plan and design big infrastructure projects such as green harbours, hydrogen valleys, industrial synergies etc.

### 6.2.3 Required investments

All this transition process comes with expenses from the public administration, mainly in the form of investment incentive or remuneration of the single renewable kWh produced. In this section the public costs of energy efficiency interventions and of renewable energy supply are estimated. Public investments in mobility and infrastructure are very hard to estimate, as currently there is no strategy tackling this sector and costs are highly depending on the type of transport (cargo or passenger, rail maritime or wheel, etc.).

Considering the public cost of investments in energy efficiency in terms of Eur/kWh of saved energy, the average for Italy is equal to 0,8 cent/kWh (taken from an EU multiple-year analysis). In this way it is pretty simple to estimate the cost for public authorities, having already calculated the estimated energy savings. In fact, considering 1352 GWh of saved energy in the short-term scenario, the total public costs of incentives result about 1.1 billion euros, which is equal to a yearly expense of 122 million euros.

| SHORT TERM | Investment (€) | Feed-in remuneration (€) | Investment incentive (€) |
|---|---|---|---|
| PV | 1.336.230.208 | 43.875.040 | 195.456.194 |
| BIOGAS | 73.753.512 | 8.742.720 | 0 |
| SOLID BIOMASS | 287.027.892 | 59.693.955 | 0 |
| HYDRO | 0 | 0 | 0 |
| HP & ST | 3.084.307 | 0 | 1.991.727 |
| total | 1.700.095.921 | 112.311.715 | 197.447.921 |

**Table 3: total investments and public costs of RES generation – short term**

Table 3 depicts the estimated costs for public authorities related to the increase renewable energy supply. As it can be seen, PV represents the leading technology for the short-term period, with over 1.3 billion of investments in the region, of which 195 million covered by investments incentives. Besides PV, solid biomass, especially for heat generation, is expected to require 287 million euros of investment, biogas 74 million and heat pumps and solar thermal about 3 million. PV, biogas and solid biomass have also a feed-in tariff on the produced energy: this accounts for almost 60 million for the latter one, almost 9 million for biogas and almost 44 million for photovoltaic. Altogether, incentives on investments and on production, the estimated social cost is around 310 million euros for the 2016-2020 period, or 35 million per year.

### 6.2.4 Renewable energy in supply and consumption

The following table shows the variation in electricity production by energy source between the baseline 2016 and the 2025 scenario. These variations were retrieved from the EUCO16 reference scenarios, considering only the energy sources that can actually be developed within the regional territory (i.e. excluding wind, geothermal, marine energy). PV exponential growth (+266%) is the most significant figure, bringing the production from 520 GWh to 1904 GWh, almost 4 times higher. Biomass and biofuels grow consistently as well with +36%, but since the currently installed capacity is still limited, the actual increase in generation is still marginal with respect to the total regional generation. Hydropower will have a slight decrease due to decommisioning of some old plants and since a higher minimum water flow in rivers has to be guaranteed for environmental reasons. The construction of new mini hydro does not seem to counterbalance the trend on the short-term. Regarding fossil fuels, coal consumption is not modified on the short-term because of its mainly industrial use. As already said in this report, heavy industry will need time and considerable investments to overcome this dependency. Gas, which is currently the most important source for electricity generation in FVG and Italy, will still be primal but with a lower share of the total generation. In fact, in the baseline scenario fossil fuel electrical generation accounts for about 66% of the total production, while in the short term this percentage decreases to 47% (Tables 4 & 5).

| Electricity generation<br>Source | Short term change% | Baseline value [MWh] | Short term [MWh] |
|---|---|---|---|
| Hydro | -3,0% | 1.588.500 | 1.540.845 |
| Solar photovoltaic | 266,0% | 520.200 | 1.903.932 |
| Primary solid biofuels | 36,0% | 91.400 | 124.304 |
| Biogases (incl. sewage-gas) | 36,0% | 390.300 | 530.808 |
| Waste (renewable) | 36,0% | 450.012 | 612.016 |
| Liquid biomass | 36,0% | 260.600 | 354.416 |
| Solid fossil | 0,0% | 2.420.900 | 2.420.900 |
| Gaseous fossil | -11,0% | 5.268.100 | 4.688.609 |

**Table 4: Change in electricity generation by source over the three scenarios**

Even if the results of the electricity generation look already promising, for what concerns the heat generation sector the challenge surely looks thougher. There is an exponential growth of heat pumps installations, which were basically negligible in 2016. This increases the electricity demand but does not really substitute the gas demand for space heating and hot water, and especially does not affect the overall sector which is dominated by thermal processes. In fact, the fossil fuel share in this sector only decreases from 80,7% to 79% (Tables 4 &5).

| Regional demand pool (GWh) | Demand | Internal supply | Internal renewable | Import | Export | Import renewable | Total renewable | Renewable % | Fossil % |
|---|---|---|---|---|---|---|---|---|---|
| **Heat and thermal process** | 21.181 | 238 | 17 | 20.944 | - | 4.071 | 4.088 | 19,3% | 80,7% |
| **Electricity** | 9.790 | 9.790 | 3.301 | - | 1.200 | - | 3.301 | 33,7% | 66,3% |
| **Alternative & transport fuels** | 6.313 | - | - | 6.313 | - | 255 | 255 | 4,0% | 96,0% |

**Table 5: Baseline overall energy balance**

| Regional demand pool (GWh) | Demand | Internal supply | Internal renewable | Import | Export | Import renewable | Total renewable | Renewable % | Fossil % |
|---|---|---|---|---|---|---|---|---|---|
| **Heat and thermal process** | 19.225 | 502 | 305 | 18.723 | - | 3.729 | 4.034 | 21,0% | 79,0% |
| **Electricity** | 9.538 | 9.538 | 5.066 | - | 2.638 | - | 5.066 | 53,1% | 46,9% |
| **Alternative & transport fuels** | 5.307 | - | - | 5.307 | - | 214 | 214 | 4,0% | 96,0% |

**Table 6: Short-term overall energy balance**

Both for the baseline and the short-term scenarios, there is no need for electricity import into the regional system. Regarding transport fuels, the share fossil fuel-renewables remains unchanged to 96%-4% (Tabes 4 & 5), but the overall consumption shows a decrease of about 16%.

The following graphs depict the progress made in renewable generation over all the sectors in the short-term scenario against the current baseline scenario, based on 2016 data.


**Figure 12: Share of renewables, baseline vs short-term**

### 6.2.5 Primary energy in supply and consumption

Considering primary energy consumption, the two following tables depict the situation for both baseline and short-term scenarios. In 2016, electricity is the primal vector with more than 28 TWh, which is 48% of the total primal energy demand, equal to 58 TWh. Second and third energy vectors are NG (12 TWh) and crude oil products (9 TWh), while renewables account for 4 TWh.

| **Estimation of regional primary energy demand (MWh)** | Total | Solid fossil fuels | Crude oil and petroleum products | Gas | Renewable energies | Non renewable wastes | Electricity | Derived heat |
|---|---|---|---|---|---|---|---|---|
| **Primary energy consumption** | **58.157.550** | **1.004.300** | **9.443.546** | **12.364.971** | **4.343.000** | **12.800** | **28.581.956** | **2.406.977** |
| Agriculture, forestry and fishing | 862.198 | - | 510.116 | - | - | - | 352.082 | - |
| Industry (without construction), energy, water sewage etc | 25.882.063 | 1.004.300 | 1.139.550 | 4.974.900 | 236.000 | 12.800 | 16.369.164 | 2.145.349 |
| Construction | 174.225 | - | - | 68.250 | - | - | 105.975 | - |
| Transport | 8.199.758 | - | 6.320.490 | 158.721 | 255.000 | - | 1.465.547 | - |
| Services | 9.615.638 | - | 315.650 | 2.696.400 | 227.000 | - | 6.376.588 | - |
| Residential | 13.423.669 | - | 1.157.740 | 4.466.700 | 3.625.000 | - | 3.912.601 | 261.628 |

**Table 7: Primal energy consumption by sector and energy vector – baseline**

In Table 5, the development of the system in the short-term scenario can be compared with the current situation. The total primal energy demand decreases of about 3 TWh (4-5%), mainly due to a net reduction in oil products and NG (-1.5 TWh each). The decrease in oil products depends on the reduction of transport demand and in the substitution of oil boilers in residential sector, while NG gets substituted by electricity in the residential end uses. On the other hand, electricity demand increases slightly in all areas, with a clear advancement in the transport sector. Solid fossil fuels, non-renewable waste and derived heat remain basically unchanged. Regarding sectorial total primary demand, transport, services and residential sectors decrease their consumption by about 1 TWh, while industry and agriculture remain constant.

| Short term primary consumption | Solid fossil fuels | Crude oil and petroleum products | Gas | Renewable energies | Non renewable wastes | Electricity | Derived heat & grid bound thermal system | Total |
|---|---|---|---|---|---|---|---|---|
| Agriculture, forestry and fishing | - | 489.916 | 9.811 | - | - | 355.995 | - | 855.722 |
| Industry (without construction), | 984.214 | 1.116.759 | 4.875.402 | 231.280 | 12.544 | 16.551.114 | 2.102.442 | 25.873.755 |
| Construction | - | - | 66.885 | - | - | 107.153 | - | 174.038 |
| Transport | - | 5.209.221 | 235.721 | 214.455 | - | 1.833.200 | - | 7.492.598 |
| Services | - | 255.677 | 2.284.764 | 333.067 | - | 6.082.662 | - | 8.956.169 |
| Residential | - | 885.671 | 3.417.026 | 3.470.016 | - | 4.094.899 | 222.384 | 12.089.995 |
| **Total** | **984.214** | **7.957.244** | **10.889.610** | **4.248.818** | **12.544** | **29.025.023** | **2.324.826** | **55.442.277** |

**Table 8: Primal energy consumption by sector and energy vector - short term scenario**

## 6.2.6 Final energy consumption and GHG emissions

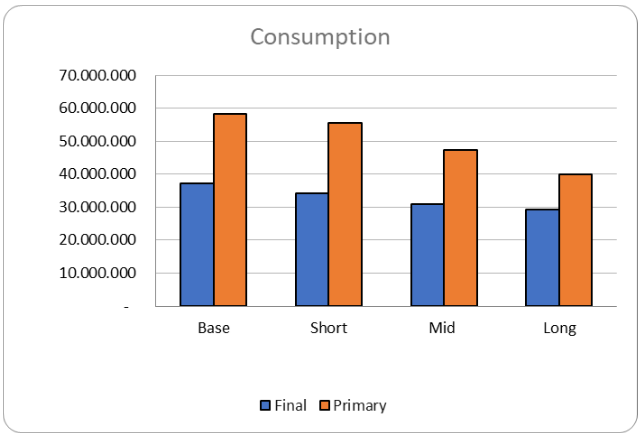



**Figure 13: Primary and final consumption by scenario**

Last, final consumption has to be analysed. Primary energy demand can in fact differ a lot from final demand, due to the efficiencies of conversions and the different energy type involved in the end use (heat, electricity, chemical). As it can be seen in figure 13, on the mid- and long-term primary energy decreases faster than the final energy demand, which means that the conversion processes are more efficient. In particular, growing renewable electricity generation reduces the need for thermal processes for electricity generation, which usually have quite low efficiency.

Looking at the final demand by sector and energy vector (Tables 8 & 9), it can be seen that the total final demand decreases by 3 TWh on the short-term, just like for the primary energy demand. This means that there is no real efficiency improvement but only a consumption reduction. Again, the reduction affects mainly NG and oil products. For what concerns the sectors, just like for primary consumption, transport, services and residential drive the consumption down.

| **Estimation of regional final energy demnand (MW** | Total | Solid fossil fuels | Crude oil and petroleum products | Gas | Renewable energies | Non renewable wastes | Electricity | Derived heat |
|---|---|---|---|---|---|---|---|---|
| 2016 | | | | | | | | |
| **Final energy consumption** | **37.284.858** | **913.000** | **8.825.744** | **11.776.163** | **4.343.000** | **32.000** | **9.790.300** | **1.604.651** |
| Agriculture | 597.344 | - | 476.744 | - | - | - | 120.600 | - |
| Industry | 14.021.233 | 913.000 | 1.065.000 | 4.738.000 | 236.000 | 32.000 | 5.607.000 | 1.430.233 |
| Construction | 101.300 | - | - | 65.000 | - | - | 36.300 | - |
| Transport | 6.815.163 | - | 5.907.000 | 151.163 | 255.000 | - | 502.000 | - |
| Services | 5.274.200 | - | 295.000 | 2.568.000 | 227.000 | - | 2.184.200 | - |
| Residential | 10.475.619 | - | 1.082.000 | 4.254.000 | 3.625.000 | - | 1.340.200 | 174.419 |

**Table 9: Final energy consumption by sector and energy vector - baseline**

| Short term scenario - SHIFT & CHANGE | Solid fossil fuels | Crude oil and petroleum products | Gas | Renewable energies | Non renewable wastes | Electricity | Derived heat & grid bound thermal system | Total |
|---|---|---|---|---|---|---|---|---|
| Agriculture, forestry and fishing | - | 457.865 | 9.344 | - | - | 116.982 | - | 584.191 |
| Industry (without construction), | 894.740 | 1.043.700 | 4.643.240 | 231.280 | 31.360 | 5.438.790 | 1.401.628 | 13.684.738 |
| Construction | - | - | 63.700 | - | - | 35.211 | - | 98.911 |
| Transport | - | 4.868.431 | 224.497 | 214.455 | - | 602.400 | - | 5.909.783 |
| Services | - | 238.950 | 2.175.966 | 333.067 | - | 1.998.797 | - | 4.746.780 |
| Residential | - | 827.730 | 3.254.310 | 3.470.016 | - | 1.345.607 | 148.256 | 9.045.919 |
| **Total** | **894.740** | **7.436.676** | **10.371.057** | **4.248.818** | **31.360** | **9.537.787** | **1.549.884** | **34.070.322** |

**Table 10: Final energy consumption by sector and energy vector - short term scenario**

Talking about carbon emissions, industry accounts for more than half of all the regional emissions. In fact, out of 11.6 million tons of $CO_2$ emitted in 2016, 5.3 are directly linked to this sector. Transport, services and residential account for around 2 million tons each. Looking at the emissions related to the different energy vectors, electricity leads the ranking with 6.5 million tons of $CO_2$, followed by NG and oil products at 2.3 million tons each.

| Estimation of regional energy CO2 emissions (t/a) | Total | Solid fossil fuels | Crude oil and petroleum products | Gas | Renewable energies | Non renewable wastes | Electricity | Derived heat |
|---|---|---|---|---|---|---|---|---|
| 2016 | | | | | | | | |
| **Final energy consumption** | **11.636.815** | **322.289** | **2.303.519** | **2.378.785** | **65.025** | **10.656** | **6.556.541** | - |
| Agriculture, forestry and fishing | 205.196 | - | 124.430 | - | - | - | 80.766 | - |
| Industry (without construction), energy, water sewage etc | 5.322.981 | 322.289 | 277.965 | 957.076 | - | 10.656 | 3.754.995 | - |
| Construction | 37.440 | - | - | 13.130 | - | - | 24.310 | - |
| Transport | 1.973.475 | - | 1.541.727 | 30.535 | 65.025 | - | 336.188 | - |
| Services | 2.058.485 | - | 76.995 | 518.736 | - | - | 1.462.754 | - |
| Residential | 2.039.239 | - | 282.402 | 859.308 | - | - | 897.529 | - |

**Table 11: $CO_2$ emissions by sector and energy vector - baseline**

In the short-term scenario, as previously analysed, the major changes are a reduction in transport demand and a substitution of oil products and gas with electricity and renewables in residential and services sectors. As expected, also the variations regarding emissions follow these changes, with about 0.2-0.3 million tons saved for each of the mentioned sectors.

| Short term - carbon emissions | Solid fossil fuels | Crude oil and petroleum products | Gas | Renewable energies | Non renewable wastes | Electricity | Derived heat & grid bound thermal | Total |
|---|---|---|---|---|---|---|---|---|
| Agriculture, forestry and fishing | - | 119.503 | 1.888 | - | - | 77.657 | - | 199.048 |
| Industry (without construction), | 315.843 | 272.406 | 937.934 | - | 10.443 | 3.610.485 | - | 5.147.111 |
| Construction | - | - | 12.867 | - | - | 23.374 | - | 36.242 |
| Transport | - | 1.270.661 | 45.348 | 54.686 | | 399.897 | | 1.770.592 |
| Services | - | 62.366 | 439.545 | - | - | 1.326.881 | - | 1.828.792 |
| Residential | - | 216.038 | 657.371 | - | - | 893.267 | - | 1.766.676 |
| **Total** | **315.843** | **1.940.973** | **2.094.953** | **54.686** | **10.443** | **6.331.562** | - | **10.748.460** |

**Table 12: $CO_2$ emissions by sector and energy vector – short-term scenario**

### 6.2.7 Sankey diagrams

Figure 14 shows the Sankey diagram of the final use of each energy vector in each sector. As already seen in the tables before, there is no major change yet with respect to the baseline numbers. Industry captures all the solid fuels and most of heat, electricity and gas, while transport accounts for most of the oil products. Residential is the second sector by demand magnitude and relies on renewables (for which represents the main end use) and gas, and for a minor share on electricity and oil products.

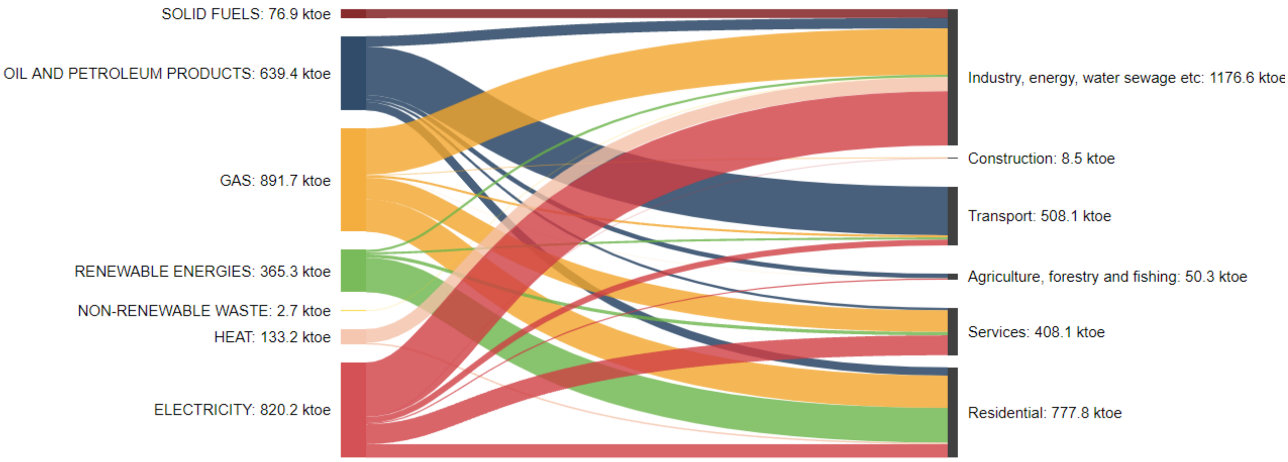



**Figure 14: short-term Final use Sankey diagram**

In graph 15 emissions are also represented in a Sankey diagram and divided by sector. Regarding fossil fuels, emissions just follow the same pattern as the final energy used saw in the previous graph. By removing renewable energy and heat from the left side of the graph, the residential sector's emissions get reduced and become similar o those of the service sector. Moreover, electricity carries the CO2 produced in the generation process, and therefore are more consistent than in the final use graph.

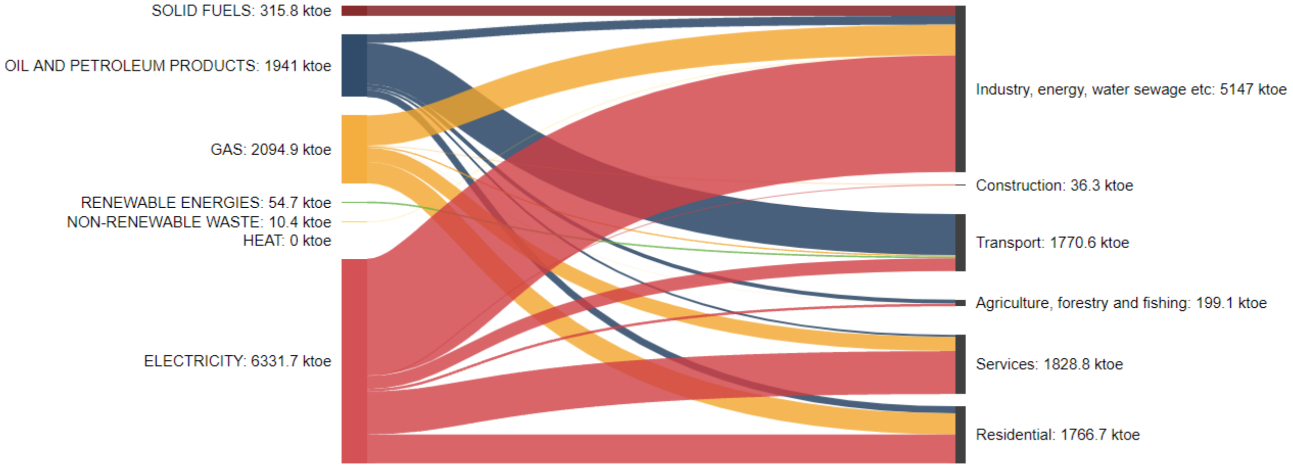



**Figure 15: short-term emissions Sankey diagram**

esides the decrease of overall energy consumption, it is interesting how the energy mix shifts from one vector to another over the selected time frame. In figure 16 the minor changes happening in the short-term scenario can be seen. In particular the beginning of a shift of gas (and a smaller share oil products) towards renewable energies and heat pumps can be appreciated.

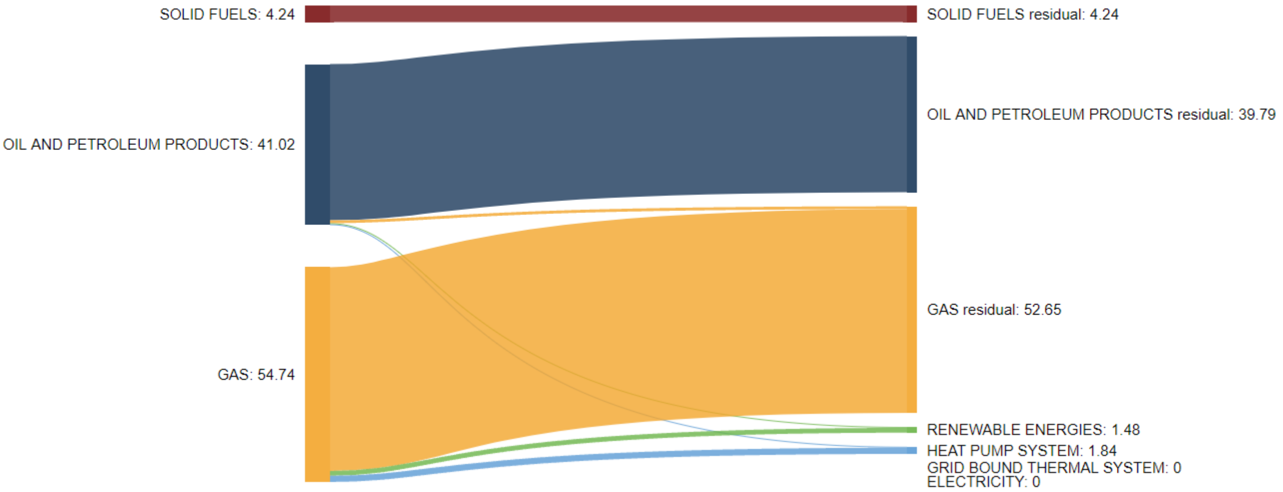



**Figure 16: short-term fuel shift Sankey diagram**

## 6.3 Scenario 2030

If 2025 scenario does not bring major changes in consumption patterns, 2030 should start showing the results of a 10-year green policy effort. In fact, by 2030 it is expected that the missing measures are implemented, and the old ones are adjusted, updated and intensified. The year 2030 is a milestone to see if the efforts are sufficient and the system is moving towards the expected goals.

### 6.3.1 General description: Actions and measures in the scenario

Regarding the sustainable buildings trajectory, energy efficient retrofitting is expected to have achieved notable results and reduced the heating demand of all public buildings and a large share of residential ones. The integration of RES (in particular the combination PV + Heat Pump) into new and existing buildings will also be common, coupled with smart systems for the building energy management. In addition to this, eco constructions will be more mature from a regulatory and economic point of view.

One of the areas where major changes will happen in the mid-term is surely mobility. Terrestrial transport might already see a consistent share of EVs, while the total demand for private vehicle transport is expected to decrease due to remote working and alternative urban mobility solutions. The first applications will take place in the maritime transport and in the alternative fuel production and supply chain. In fact, interventions on large infrastructures, like the Trieste harbour, will require years to be implemented, but by 2030 it is expected that a relevant number of ships and terrestrial harbour operations will be electric or fuelled by biodiesel or hydrogen (the latter ones more likely in the prototype phase).

Regarding the bio-energies sector, a new generation (after the 2011-2012 one) of small-scale biogas plants is expected to be established, following sustainable agriculture practices, both for cogeneration and biogas production.

If 2025 left the industrial sector basically unchanged, by 2030 the first steps towards a more sustainable industry should already be in place, laying the ground for the structural changes to come. In particular, the first hybrid systems and synergies should take shape, and hydrogen could start to be a viable and interesting solution for many processes.

Last, energy communities will be numerous, monitoring systems diffused and this large availability of real-time data will help smart grids to be efficient and resilient, and the integration of distributed RES will achieve higher shares and lower curtailments.

### 6.3.2 State of energy efficiency, renewable energy supply, mobility, infrastructure and spatial development

**Energy efficiency**

At regional level, there are about 308.000 residential buildings, of which about 42.000 units are holiday houses. Of this number, about 22% were built before 1975, 28% between 1975 and 1990, 15% in the 90s and about 35% after year 2000. According to these numbers, it is clear that focusing on energy retrofitting of buildings is fundamental in order to achieve the intended goals.

After the short-term scenario effects, the average consumption is 105 kWh per square meter (still considering also the holiday houses, which consumption is much lower than primary houses). The total combined yearly heat consumption is now 9.045 GWh.

After the 2016-2025 effort, techniques and business plans are supposed to be well established and effective. Therefore, in the period 2025-2030 the residential sector is expected to see an additional decrease of 15% with respect to the baseline value, for a total of -30% in 14 years. Also, in the services sector an additional 10% in heat savings is forecasted, which means 20% cumulative in the mid-term.

**Renewable energy supply**

Regarding the renewable energy supply, in the short and mid-term the main trends expected to have an impact on the system are:

- **Replacement of oil-fired boilers and old gas boilers.** In the mid-term this shift to renewable generation and heat pumps is expected to cover 20% (each) of the previous oil products and gas demand;

- **PV generation expansion.** Electrification of end uses (e.g. heat pumps), incentives on small plants and energy communities will surely boost the installation of small PV. The production from this source is expected to increase by 33% with respect to 2025, which means over 400 MW of PV will be installed in the 2025-2030;

- **Growth of DH systems.** Finally, a relevant number of new DH grids are expected to be built, and the existing ones to be expanded, and integrated with a higher share of RES;

**Mobility**

In the mid-term, a net reduction of 27.5% of transport fuel is expected, partially balanced by a 100% growth of electricity demand of the same sector. Moreover, a shift from oil products to gas (6%) and electricity (5%) is expected.

**Infrastructure and spatial development**

This time frame is intended to actually start building the infrastructure projects selected in the previous period and start collecting data on their operations.

### 6.3.3 Required investments

Again, public investments in mobility and infrastructure are very hard to estimate and therefore neglected here, as currently there is no strategy tackling this sector and costs are highly depending on the type of transport (cargo or passenger, rail maritime or wheel, etc.).

Considering the public cost of investments in energy efficiency in terms of Eur/kWh of saved energy, the average for Italy is equal to 0,8 cent/kWh (taken from an EU multiple-year analysis). In this way it is pretty simple to estimate the cost for public authorities, having already calculated the estimated energy savings. In fact, considering 1560 GWh of saved energy in the short-term scenario, the total public costs of incentives result about 1.2 billion euros, which is equal to a yearly expense of 249 million euros.

| MID TERM | Investment (€) | Feed-in remuneration (€) | Investment incentive (€) |
|---|---|---|---|
| PV | 606.728.889 | 36.438.947 | 88.748.869 |
| BIOGAS | 55.724.876 | 6.605.611 | 0 |
| SOLID BIOMASS | 216.865.519 | 42.266.771 | 0 |
| HYDRO | 92.832.616 | 6.512.215 | 0 |
| HP & ST | 10.630.403 | 0 | 6.864.706 |
| total | 982.782.303 | 91.823.544 | 95.613.575 |

**Table 12: total investments and public costs of RES generation – mid-term**

Table 12 shows the estimated costs for public authorities related to the increase in renewable energy supply. Again, PV represents the leading technology but this time with a smaller lead with respect to the other technologies. Out of the 600 million of investments in the region, 88 million will be covered by investments incentives. Besides that, solid biomass, especially for heat generation, is expected to require 217 more million euros of investment, biogas 55 million and heat pumps and solar thermal about 10 more million. In the mid-term scenario hydropower grows again, after a first scenario decrease. This increase and repowering of hydro is expected to require more than 92 million euros. PV is estimated to cost 36 million in feed-in tariff, 6 million for biogas, 42 for solid biomass and 6 for hydro. Summing everything, incentives on investments and on production, the estimated social cost is around additional 187 million euros for the 2025-2030 period on top of the short-term scenario, or 37 million per year.

### 6.3.4 Renewable energy in supply and consumption

As for the previous scenario, the following table shows the variation in electricity production by energy source between the baseline 2016, 2025 scenario and the 2030 scenario, based on the EUCO16 report. Hydro, after a little decrease in 2025, grows again thanks to the repowering and mini-hydro installations. PV keeps growing, and even if +33% might seem low compared to the previous +266%, it is a notable addiction since it is referred to the short-term absolute value. In fact the total production reaches over 2.5 TWh of production, about five times the baseline one. Biofuels continue their steady growth, accounting for almost 2 TWh summing up all the 4 categories in the table. Regarding fossil fuels, the impact of the first measures on the industrial sector shows a clear reduction of about a third in coal use. Natural gas, after a relative decrease on the short-term, sees a cut of almost 1 TWh in electricity generation with respect to the previous scenario.

| Electricity generation<br>Source | Mid-term change% | Baseline value [MWh] | Short term [MWh] | Mid-term [MWh] |
|---|---|---|---|---|
| Hydro | 5,0% | 1.588.500 | 1.540.845 | 1.617.887 |
| Solar photovoltaic | 33,0% | 520.200 | 1.903.932 | 2.532.230 |
| Primary solid biofuels | 20,0% | 91.400 | 124.304 | 149.165 |

| | | | | |
|---|---|---|---|---|
| Biogases (incl. sewage-gas) | 20,0% | 390.300 | 530.808 | 636.970 |
| Waste (renewable) | 20,0% | 450.012 | 612.016 | 734.420 |
| Liquid biomass | 20,0% | 260.600 | 354.416 | 425.299 |
| Solid fossil | -34,0% | 2.420.900 | 2.420.900 | 1.597.794 |
| Gaseous fossil | -20,0% | 5.268.100 | 4.688.609 | 3.750.887 |

**Table 13: Electricity generation development in mid-term scenario**

Considering electricity generation only, in table 13 it can be seen that renewable generation covers over 63% of 9.6 TWh, i.e. the final demand (it was 34% in the baseline and 53% in the short-term scenario). Improvements are made also in the heat and thermal process sector and in the transport fuel sectors, even if they appear marginal compared to a total decarbonization of the system. In fact, in the heat and thermal processes the renewable percentage improves by almost 7%, and by 2,2% in the transport fuels. More relevant than the change of shares, it is the change in total demand. In fact, heat and thermal process demand decreases by 2.5 TWh (-12,6%) and transport fuel demand by 1 TWh (-17,9%), while electricity consumption actually increases by 0,1 TWh (+1%).

| Regional demand pool (GWh) | Demand | Internal supply | Internal renewable | Import | Export | Import renewable | Total renewable | Renewable % | Fossil % |
|---|---|---|---|---|---|---|---|---|---|
| **Heat and thermal process** | 16.801 | 1.473 | 1.283 | 15.327 | - | 3.332 | 4.614 | 27,5% | 72,5% |
| **Electricity** | 9.620 | 9.620 | 6.096 | - | 1.825 | - | 6.096 | 63,4% | 36,6% |
| **Alternative & transport fuels** | 4.358 | - | - | 4.358 | - | 270 | 270 | 6,2% | 93,8% |

**Table 14: Mid-term overall energy balance**

The overall share of renewables in the system, compared to the previous scenario, can be seen in the pie charts of figure 17.

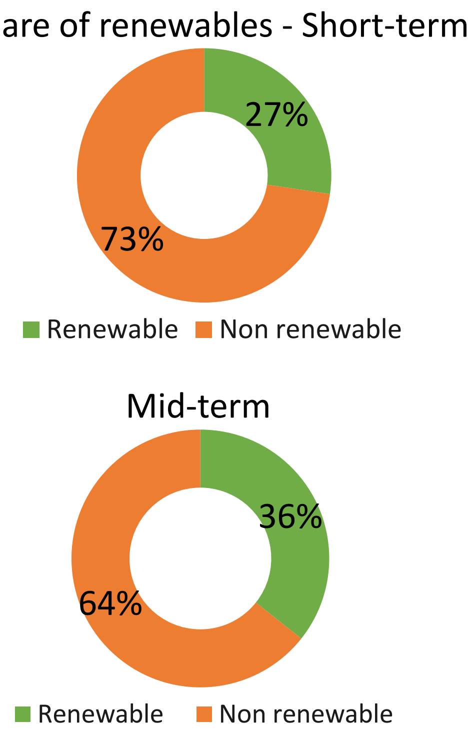



**Figure 17: overall share of renewables comparison between short and mid-term scenarios**

### 6.3.5 Primary energy in supply and consumption

Regarding primary energy consumption, the mid-term scenario results (tab 15) are here compared to the short-term scenario (tab 14). It can be seen how the total consumption drops significantly, going from 55.4 TWh down to 47.4 TWh (-14.5%) in just 5 years of measures. This is notable considering that in the previous scenario the cut only accounts for 3 TWh, but the mid-term decrease is also due to the measures implemented in the previous scenario and then improved. In particular, oil products consumption drops from 8 TWh to 6 TWh (-25%), natural gas from 10.9 TWh to 8.7 TWh (-27%) and electricity from 19 TWh to 24.6 TWh (-15.5%).

| **Short term primary consumption** | Solid fossil fuels | Crude oil and petroleum products | Gas | Renewable energies | Non renewable wastes | Electricity | Derived heat & grid bound thermal system | Total |
|---|---|---|---|---|---|---|---|---|
| Agriculture, forestry and fishing | - | 489.916 | 9.811 | - | - | 355.995 | - | 855.722 |
| Industry (without construction), | 984.214 | 1.116.759 | 4.875.402 | 231.280 | 12.544 | 16.551.114 | 2.102.442 | 25.873.755 |
| Construction | - | - | 66.885 | - | - | 107.153 | - | 174.038 |
| Transport | - | 5.209.221 | 235.721 | 214.455 | - | 1.833.200 | - | 7.492.598 |
| Services | - | 255.677 | 2.284.764 | 333.067 | - | 6.082.662 | - | 8.956.169 |
| Residential | - | 885.671 | 3.417.026 | 3.470.016 | - | 4.094.899 | 222.384 | 12.089.995 |
| **Total** | **984.214** | **7.957.244** | **10.889.610** | **4.248.818** | **12.544** | **29.025.023** | **2.324.826** | **55.442.277** |

**Table 16: Primal energy consumption by sector and energy vector – short term scenario**

On the other hand, renewable energy demand is the only vector to increase, while solid fossil fuels, waste and derived heat remain basically unvaried. Looking at the different sectors, industry finally shows a net decrease in primary energy consumption of 3.6 TWh, summing saving on oil products (0.2 TWh), gas (0.4 TWh) and electricity (3 TWh). Other sectors achieving major savings are residential and services. Residential sector decreases its primal demand by 2.4 TWh (-19.8%), with a clear cut of oil products (-0.4 TWh or – 50%), gas (-1.2 TWh or -38%) and electricity (-0.7 TWh or -20%). The same energy vectors see a decrease also in the services sector, but with a major contribution of electricity consumption equal -1.7 TWh (-28%) out of -2.1 TWh of total cut.

Interesting is to have a look at the transport sector, here in fact the total demand slightly increases, but there is a major shift from oil products to other sources, primarily electricity. Electrification of transport makes the electricity demand of this sector almost double, going from 1.8 TWh to 3.1 TWh within 5 years. Gas and renewable energies also contribute to the decarbonization of the sector even if they account for a total of 0.6 TWh. Oil products, which accounted for 6.3 TWh in 2016 and 5.2 TWh in 2025, accelerated the trend reaching 4 TWh in 2030.

| **Mid term primary consumption** | Solid fossil fuels | Crude oil and petroleum products | Gas | Renewable energies | Non renewable wastes | Electricity | Derived heat & grid bound thermal system | Total |
|---|---|---|---|---|---|---|---|---|
| Agriculture, forestry and fishing | - | 445.842 | 28.533 | 9.058 | - | 283.601 | - | 767.034 |
| Industry (without construction), | 954.085 | 876.884 | 4.407.035 | 531.345 | 12.160 | 13.380.283 | 2.068.434 | 22.230.225 |
| Construction | - | - | 64.838 | - | - | 85.363 | - | 150.200 |
| Transport | - | 3.986.649 | 379.479 | 270.527 | - | 3.069.585 | - | 7.706.239 |
| Services | - | 189.390 | 1.688.971 | 553.951 | - | 4.406.291 | - | 6.838.603 |
| Residential | - | 486.251 | 2.126.149 | 3.520.360 | - | 3.364.022 | 183.140 | 9.679.922 |
| **Total** | **954.085** | **5.985.015** | **8.695.005** | **4.885.240** | **12.160** | **24.589.145** | **2.251.573** | **47.372.223** |

**Table 17: Primal energy consumption by sector and energy vector – mid-term scenario**

### 6.3.6 Final energy consumption and GHG emissions

As the primary energy demand decreases by 8 TWh in the 2025-2030 timeframe, this trend is clearly driven by a cut in final consumptions. Nevertheless, by looking at the final energy demand tables 16 and 17 it can be seen how this cut is only equal to 3.3 TWh, leaving the remaining 4.7 TWh as a result of electrification and efficiency improvements.

| Short term scenario - SHIFT & CHANGE | Solid fossil fuels | Crude oil and petroleum products | Gas | Renewable energies | Non renewable wastes | Electricity | Derived heat & grid bound thermal system | Total |
|---|---|---|---|---|---|---|---|---|
| Agriculture, forestry and fishing | - | 457.865 | 9.344 | - | - | 116.982 | - | 584.191 |
| Industry (without construction), | 894.740 | 1.043.700 | 4.643.240 | 231.280 | 31.360 | 5.438.790 | 1.401.628 | 13.684.738 |
| Construction | - | - | 63.700 | - | - | 35.211 | - | 98.911 |
| Transport | - | 4.868.431 | 224.497 | 214.455 | - | 602.400 | - | 5.909.783 |
| Services | - | 238.950 | 2.175.966 | 333.067 | - | 1.998.797 | - | 4.746.780 |
| Residential | - | 827.730 | 3.254.310 | 3.470.016 | - | 1.345.607 | 148.256 | 9.045.919 |
| **Total** | **894.740** | **7.436.676** | **10.371.057** | **4.248.818** | **31.360** | **9.537.787** | **1.549.884** | **34.070.322** |

**Table 18: Final energy consumption by sector and energy vector - short term scenario**

As seen in primary energy consumption, oil products (-1.8 TWh) and natural gas (-2.1 TWh) are the vectors that are subject to the major cut, while renewables (+0.6 TWh) and electricity (+0.1 TWh) increase. Looking at the sectors, industry lowers its oil products and natural gas demand and increases the share of renewables. Services cuts 0.5 TWh of gas and also 0.2 TWh of electricity, while adding +0.2 TWh of renewables. Transport doubles its electricity demand (+0.6 TWh) and cuts 1.1 TWh of oil products. Services also achieve notable cuts in gas (-0.6 TWh) and electricity (-0.3 TWh). Last, residential is the sector that shows the largest reduction in final consumption, equal to -1.6 TWh total. Gas demand is reduced by over 1.2 TWh and oil products by 0.4 TWh, while the consumption of other energy vectors remains basically unchanged.

| Mid term scenario - SHIFT & CHANGE | Solid fossil fuels | Crude oil and petroleum products | Gas | Renewable energies | Non renewable wastes | Electricity | Derived heat & grid bound thermal system | Total |
|---|---|---|---|---|---|---|---|---|
| Agriculture, forestry and fishing | - | 416.674 | 27.174 | 9.058 | - | 110.952 | - | 563.859 |
| Industry (without construction), | 867.350 | 819.518 | 4.197.176 | 531.345 | 30.400 | 5.234.708 | 1.378.956 | 13.059.452 |
| Construction | - | - | 61.750 | - | - | 33.396 | - | 95.146 |
| Transport | - | 3.725.840 | 361.408 | 270.527 | - | 1.200.900 | - | 5.558.675 |
| Services | - | 177.000 | 1.608.544 | 553.951 | - | 1.723.854 | - | 4.063.348 |
| Residential | - | 454.440 | 2.024.904 | 3.520.360 | - | 1.316.091 | 122.093 | 7.437.888 |
| **Total** | **867.350** | **5.593.472** | **8.280.957** | **4.885.240** | **30.400** | **9.619.901** | **1.501.049** | **30.778.369** |

**Table 19: Final energy consumption by sector and energy vector – mid-term scenario**

Looking at carbon emissions, the measures implemented during the selected period achieve a cut of 2.4 million tonnes of $CO_2$, which means -23% with respect to the short-term scenario. Industry shows the largest decrease with over 1.1 million tonnes (-22,5%), followed by services with 0.6 million tonnes (-33%) and residential also with 0.6 million tonnes (-33%). The transport sector is the only sector that basically does not reduce its emissions, with just -3% of the 1.7 million tonnes that the sector emits.

| Short term - carbon emissions | Solid fossil fuels | Crude oil and petroleum products | Gas | Renewable energies | Non renewable wastes | Electricity | Derived heat & grid bound thermal | Total |
|---|---|---|---|---|---|---|---|---|
| Agriculture, forestry and fishing | - | 119.503 | 1.888 | - | - | 77.657 | - | 199.048 |
| Industry (without construction), | 315.843 | 272.406 | 937.934 | - | 10.443 | 3.610.485 | - | 5.147.111 |
| Construction | - | - | 12.867 | - | - | 23.374 | - | 36.242 |
| Transport | - | 1.270.661 | 45.348 | 54.686 | | 399.897 | | 1.770.592 |
| Services | - | 62.366 | 439.545 | - | - | 1.326.881 | - | 1.828.792 |
| Residential | - | 216.038 | 657.371 | - | - | 893.267 | - | 1.766.676 |
| **Total** | **315.843** | **1.940.973** | **2.094.953** | **54.686** | **10.443** | **6.331.562** | **-** | **10.748.460** |

**Table 20: $CO_2$ emissions by sector and energy vector – short term**

Analysing the scenario emission according to the energy vector, the greatest reduction occurs in the electricity related emissions, decreasing from 6.3 to 4.8 million tonnes (-24%) in just five years, with the major contribution from the industrial sector. Gas and oil products emissions are also diminished, both by about 0.5 million tonnes, with services and residential affecting gas consumption and transport affecting the oil products demand.

| Mid term - carbon emissions | Solid fossil fuels | Crude oil and petroleum products | Gas | Renewable energies | Non renewable wastes | Electricity | Total |
|---|---|---|---|---|---|---|---|
| Agriculture, forestry and fishing | - | 108.752 | 5.489 | - | - | 55.433 | 169.674 |
| Industry (without construction), | 306.175 | 213.894 | 847.830 | - | 10.123 | 2.615.308 | 3.993.330 |
| Construction | - | - | 12.474 | - | - | 16.685 | 29.158 |
| Transport | - | 972.444 | 73.005 | 68.984 | | 599.981 | 1.714.414 |
| Services | - | 46.197 | 324.926 | - | - | 861.253 | 1.232.376 |
| Residential | - | 118.609 | 409.031 | - | - | 657.531 | 1.185.171 |
| **Total** | **306.175** | **1.459.896** | **1.672.753** | **68.984** | **10.123** | **4.806.191** | **8.324.123** |

**Table 21: $CO_2$ emissions by sector and energy vector – mid-term**

### 6.3.7 Sankey diagrams

Figure 18 shows the Sankey diagram of the final use of each energy vector in each sector. With respect to the short-term scenario, the gas flows are reduced, especially in the residential sector. Oil products also see their contribution in each sector diminished, while electricity increases in the transport final use. Renewables increase slightly, while heat remains unvaried and mainly contributing in the industrial sector.

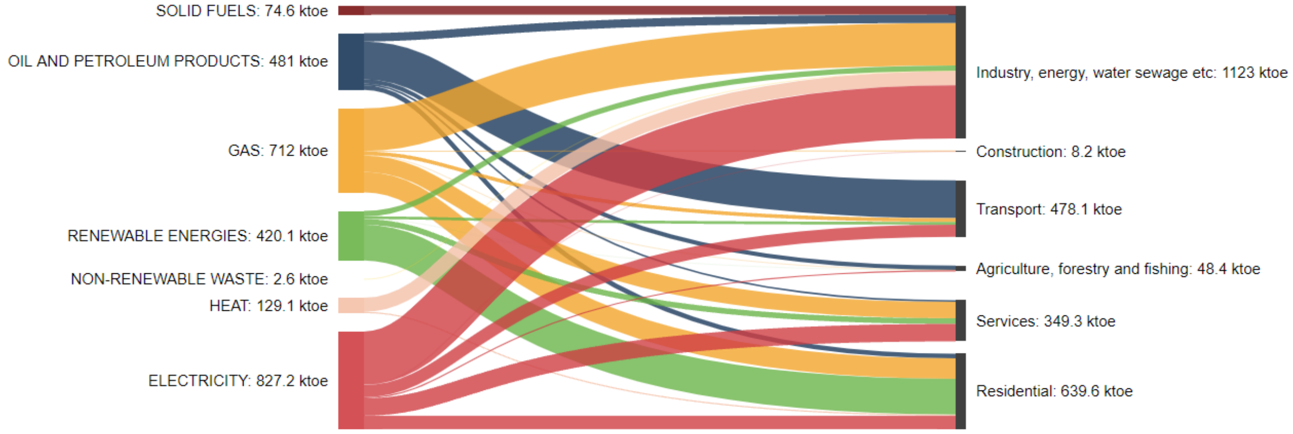



**Figure 18: mid-term Final use Sankey diagram**

In graph 19 emissions are also represented in a Sankey diagram and divided by sector. Regarding fossil fuels, emissions just follow the same pattern as the final energy used saw in the previous graph. Basically, all sectors but transport reduce their emissions consistently, and all see the share of electricity-related emissions increase due to electrification of end-uses.

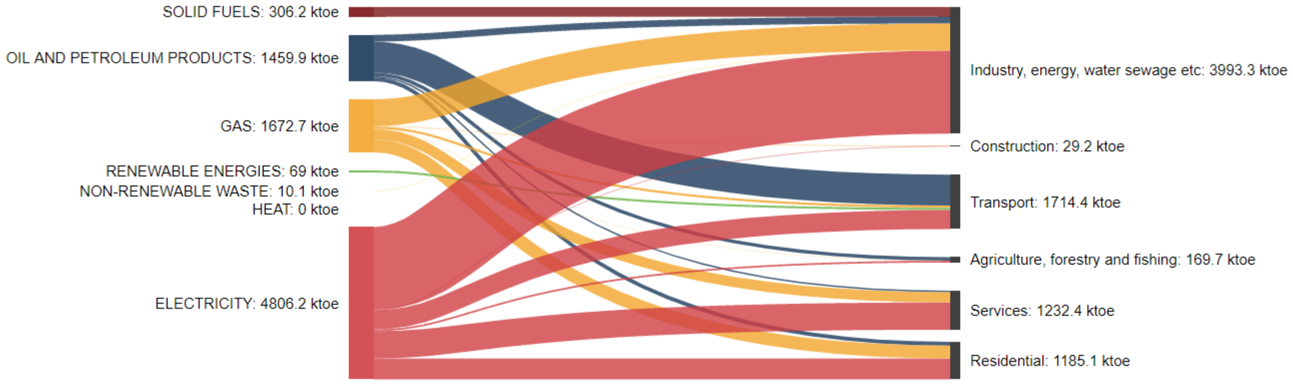



**Figure 19: mid-term emissions Sankey diagram**

Besides the decrease of overall energy consumption, it is interesting how the energy mix shifts from one vector to another over the selected time frame. In figure 20 it can be seen how heat pumps and renewable energies, which accounted for an almost negligible fraction in the previous scenario, are now a relevant part of the energy mix. Gas consumption is partially replaced by heat pumps, renewable energies and grid bound heat, while oil products shift to gas, renewable energy, heat pumps and electricity.

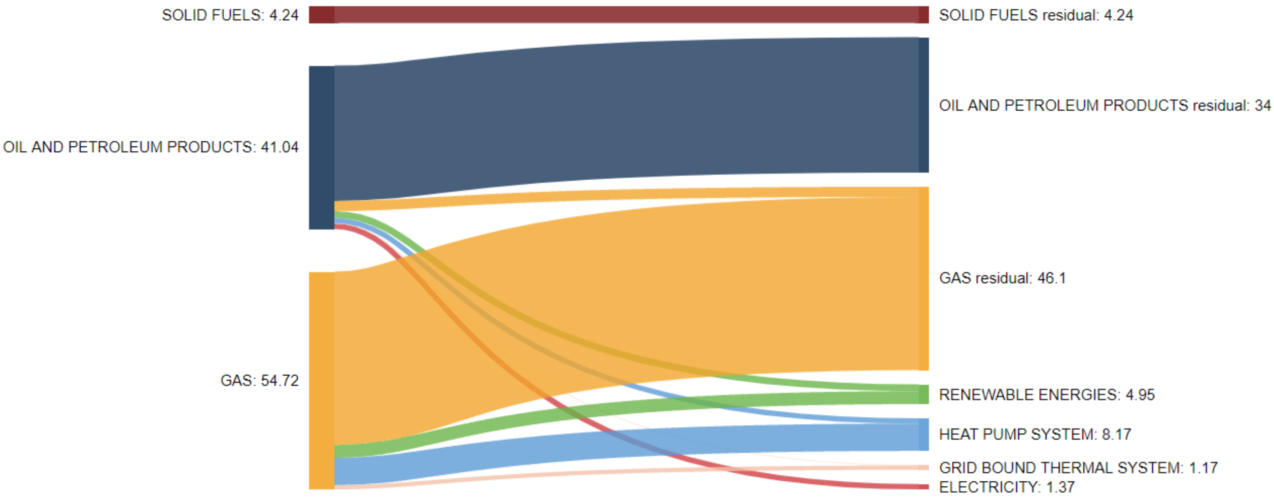



**Figure 20: mid-term fuel shift Sankey diagram**

## 6.4 Scenario 2040

Beyond 2030 it is hard to elaborate accurate scenarios, as the uncertainties about available technologies, effectiveness of the selected measures, politics, energy markets are often unpredictable. Despite this, it makes sense to build a most reasonable development scenario that follows and improves 2030 trends. Technology development is expected to have major effect on efficiency, both in production and consumption. Within the 10-year time span the energy system is expected to be subject to structural changes, a deep decarbonization that makes possible the carbon neutral goal that many countries set for 2050.

### 6.4.1 General description: Actions and measures in the scenario

As previously explained in the chapter, there are no specific measures set for 2040. This is because this document wants to focus on how to set a positive trend in the next decade, and make a simple projection of how the system could develop if effective measures are developed within the first two scenario's time frames.

The sustainable buildings trajectory is expected to have exploited most of its potential, having retrofitted basically all buildings that did not undergo interventions within the last 10 years. Focus will be put on the sustainability of the materials, from the extraction and processing to the geographical origin. Small scale renewables, with heat pumps and storage systems should be a standard in most buildings, for the highest self-consumption rates that can be achieved.

Mobility will be structurally different from today, with high electrification of light and heavy vehicles but especially with a great decrease of daily transport demand and a shift from car-transport to other more sustainable solutions, especially in urban context. If terrestrial mobility is already changing today, by 2040 it will be possible to finally see changes in fuel and strategies both in maritime transport and aviation, with biofuels, hydrogen and electricity substituting a relevant fossil fuel share of the sector.

In the bio-energies sector, the expectation is that technologies and trends established by 2030 become the standards over the entire region. Biomass-driven DH networks, biogas plants that use only agricultural waste and the correct exploitation of forest that keep profits at a local scale.

As for maritime transport, industry will not change much before 2030. High costs and technologies that are not yet market ready will cease to be obstacles and the sector will take a new direction by 2040. Hydrogen, alternative fuels, power-to-x technologies that currently are only pilot projects will become economically competitive, and past experiences will boost the change. In this way the most-emitting sector of the region will not only stop being a burden, but an economic opportunity of development while pursuing sustainability.

Last, regarding smart grids, it is almost impossible to forecast the development of such technologies, management systems and legislations, but the future grid is expected to be based on local production and exchange of energy, with minor energy transport and curtailments, while able to avoid over-voltages and to react quickly to changes in the energy consumptions.

### 6.4.2 State of energy efficiency, renewable energy supply, mobility, infrastructure and spatial development

**Energy efficiency**

At the regional level, there are about 308.000 residential buildings, of which about 42.000 units are holiday houses. Of this number, about 22% were built before 1975, 28% between 1975 and 1990, 15% in the '90s and about 35% after year 2000. According to these numbers, it is clear that focusing on energy retrofitting of buildings is fundamental in order to achieve the intended goals.

After the mid-term scenario effects, the average consumption is 87 kWh per square meter (still considering also the holiday houses, which consumption is much lower than primary houses). The total combined yearly heat consumption is now 7.485 GWh.

In the period 2030-2040 a final push is expected to bring the residential sector efficiency to an higher level. This means an additional decrease of 15% with respect to the baseline value, for a total of -45% in 24 years. Also, in the services sector an additional 15% in heat savings is forecasted, which means 35% cumulative on the long-term.

After the long-term scenario effects, the average consumption is 74 kWh per square meter (still considering also the holiday houses, which consumption is much lower than primary houses). The total combined yearly heat consumption is now 6.238 GWh.

**Renewable energy supply**

Regarding the renewable energy supply, on the long-term new technologies might take over the sector, but a continuous growth of the previous trends can be supposed:

- **Replacement of gas boilers.** In the long-term this shift to renewable generation and heat pumps are expected to cover respectively 50% and 40% of the previous oil products consumption, and 20% and 50% of the original gas demand;

- **PV generation expansion.** Electrification of end uses (e.g. heat pumps), incentives on small plants and energy communities will surely boost the installation of small PV. The production from this source is expected to increase by 61% with respect to 2030, which means over 1.2 GW of PV will be installed in the 2030-2040;

- **Growth of DH systems.** DH grids are now established and relatively diffused technologies, accounting for about 5% of the original gas demand;

**Mobility**

In the mid-term, a net reduction of 50.7% of transport fuel is expected, partially balanced by a 400% growth of electricity demand of the same sector. Moreover, a shift from oil products to gas (10%) and electricity (20%) is expected.

**Infrastructure and spatial development**

This time frame is intended to perform analysis with the collected data, optimize the operations of such infrastructures, integrate larger systems with renewables and adjust current and future projects.

### 6.4.3 Required investments

Also, for last scenario public investments in mobility and infrastructure are neglected, as currently there is no strategy tackling this sector and costs are highly depending on the type of transport (cargo or passenger, rail maritime or wheel, etc.).

Considering the public cost of investments in energy efficiency in terms of Eur/kWh of saved energy, the average for Italy is equal to 0,8 cent/kWh (taken from an EU multiple-year analysis). In this way it is pretty simple to estimate the cost for public authorities, having already calculated the estimated energy savings. In fact, considering additional 1607 GWh of saved energy in the short-term scenario, the total public costs of incentives result about 1.3 billion euros, which is equal to a yearly expense of 128 million euros.

| LONG TERM | Investment (€) | Feed-in remuneration (€) | Investment incentive (€) |
|---|---|---|---|
| PV | 1.491.633.782 | 89.584.600 | 218.187.749 |
| BIOGAS | 193.922.568 | 22.987.525 | 0 |
| SOLID BIOMASS | 754.692.005 | 156.955.306 | 0 |
| HYDRO | 77.979.397 | 5.470.260 | 0 |
| HP & ST | 24.342.148 | 0 | 15.741.702 |
| total | 2.542.569.900,12 € | 274.997.691,26 € | 233.929.450,92 € |

Table 22: total investments and public costs of RES generation – long-term

Table 22 shows the estimated costs for public authorities related to the increase renewable energy supply. Also in the last scenario PV is the leading technology in regional investments. Out of the 2.5 billion of investments in the RES sector, 1.5 focus on photovoltaic, of which 218 million from public funds. Solid biomass is expected to require 755 more million euros of investment, biogas 194 million, hydro 78 million and heat pumps and solar thermal about 24 more million. Regarding the feed-in tariff costs, PV is estimated to require 90 million, 23 million for biogas, 157 for solid biomass and additional 5 for hydro. Summing everything, incentives on investments and on production, the estimated social cost is around additional 509 million euros for the 2030-2040 period on top of the previous scenarios, equal to 50 million per year.

### 6.4.4 Renewable energy in supply and consumption

Table 20 depicts the expected development of the electricity generation sector. As the reference time frame accounts for 10 years instead of 5 as it was for the 2030 scenario, this has to be considered when analysing the occurring variations. Photovoltaics shows a notable increase in generation, becoming the first electricity source at regional level with 36.7% of the total generation. The increase of 61% on the mid-term scenario brings the PV production to 4.1 TWh, which is about eight times the baseline value and more than double the short-term one. Biofuels keep increasing at a steady rate, and all together account for about 3 TWh (27.7%). Hydro shows a slight increase probably due to efficiency improvements, but overall there is no variation on the impact on the system. Fossil fuels are probably the ones that are affected the most during this period. Coal is expected to be phased out completely, while natural gas is subject to a major cut of -40% with respect to the previous scenario.

| Electricity generation<br>Source | Long-term change% | Baseline value [kWh] | Short term [kWh] | Mid-term [kWh] | Long-term [kWh] |
|---|---|---|---|---|---|
| Hydro | 4,0% | 1.588.500 | 1.540.845 | 1.617.887 | 1.682.603 |
| Solar photovoltaic | 61,0% | 520.200 | 1.903.932 | 2.532.230 | 4.076.890 |
| Primary solid biofuels | 58,0% | 91.400 | 124.304 | 149.165 | 235.680 |
| Biogases (incl. sewage-gas) | 58,0% | 390.300 | 530.808 | 636.970 | 1.006.412 |
| Waste (renewable) | 58,0% | 450.012 | 612.016 | 734.420 | 1.160.383 |
| Liquid biomass | 58,0% | 260.600 | 354.416 | 425.299 | 671.973 |
| Solid fossil | -100,0% | 2.420.900 | 2.420.900 | 1.597.794 | 0 |
| Gaseous fossil | -40,0% | 5.268.100 | 4.688.609 | 3.750.887 | 2.250532 |

Table 23: Electricity generation development in long-term scenario

Looking at the electricity balance, it can be seen that for the first time the system needs to import electricity from outside, namely 1.8 TWh, equal to almost 14% of the electricity demand. This is also because the electricity demand increases from 9.6 TWh of the mid-term scenario to 12.9 TWh (+34%), while the overall generation remains about the same. Despite this, the share of renewables keeps increasing, reaching 82.5% of the final demand. Looking at the whole energy system, the renewables share also improves for what concerns heat and thermal processes. In fact, the percentage grows from 27,5% of the mid-term to 40%, more than double the baseline value. The internal supply also more than doubles from the previous scenario, but what makes the renewable percentage grow the most is surely the reduction in demand, which goes from 16.8 TWh to 13.8

TWh. Last, regarding transport fuels, demand also reduces drastically (-42%) and therefore the renewables share reaches 10.7% of the total.

| Regional demand pool (GWh) | Demand | Internal supply | Internal renewable | Import | Export | Import renewable | Total renewable | Renewable % | Fossil % |
|---|---|---|---|---|---|---|---|---|---|
| Heat and thermal process | 13.761 | 3.274 | 3.041 | 10.514 | - | 2.461 | 5.502 | 40,0% | 60,0% |
| Electricity | 12.876 | 11.084 | 8.834 | 1.792 | - | 1.792 | 10.626 | 82,5% | 17,5% |
| Alternative & transport fuels | 2.524 | - | - | 2.524 | - | 271 | 271 | 10,7% | 89,3% |

**Table 24: Long-term overall energy balance**

In figure 15 it can be seen how the overall renewable share, also thanks to the cut in final demand, increases by 20%, from 36% to 56%.

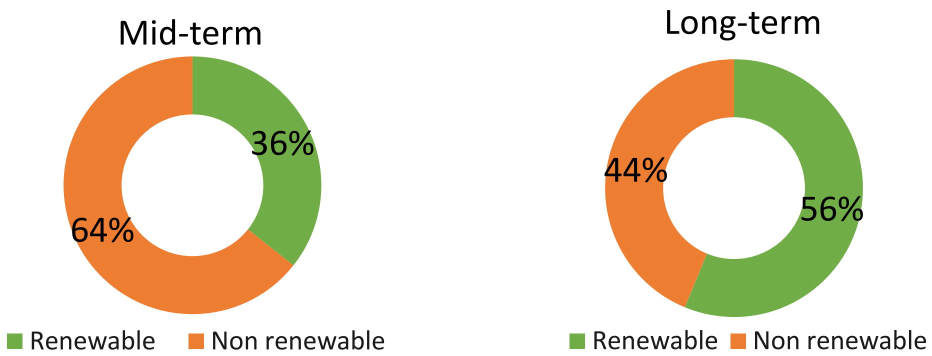



**Figure 21: overall share of renewables comparison between short and mid-term scenarios**

## 6.4.5 Primary energy in supply and consumption

Analysing the primary energy consumption of the region in the last two scenarios, one can appreciate once more the notable decrease of the overall consumption. This goes from 47.4 TWh to 39.9 TWh, equal to -16%. The sector achieving the largest reduction is also the most energy-intensive: industry. Its primary consumption decreases from 22.2 TWh to 17.2 TWh, mainly due to a reduction in electricity consumption (-31%) and natural gas (-16%). Services and residential sectors move along each other with about -2.5 TWh each, equal to -37% for services and -26% for residential. In the services sector natural gas consumption is halved, while electricity demand is reduced by 1.8 TWh out of the 4.4 TWh (-59%) of the mid-term scenario. In the residential sector, gas consumption is cut from 2.1 TWh down to 0.6 TWh (-71%) and electricity from 3.4 TWh to 2.5

TWh (-26%). For both the sectors, oil products demand is minimized. Differently from all the other trends, transport keeps increasing its primary consumption, going from 7.7 TWh in the mid-term to 10.5 TWh in the long-term scenario. Despite this increase in absolute numbers, oil products get cut from 4 TWh down to 2 TWh (-50%), and gas and renewables remain unchanged. The biggest change lies in the electricity demand, which more than doubles going from 3.1 TWh to 7.8 TWh (+154%).

| **Mid term primary consumption** | Solid fossil fuels | Crude oil and petroleum products | Gas | Renewable energies | Non renewable wastes | Electricity | Derived heat & grid bound thermal system | Total |
|---|---|---|---|---|---|---|---|---|
| Agriculture, forestry and fishing | - | 445.842 | 28.533 | 9.058 | - | 283.601 | - | 767.034 |
| Industry (without construction), | 954.085 | 876.884 | 4.407.035 | 531.345 | 12.160 | 13.380.283 | 2.068.434 | 22.230.225 |
| Construction | - | - | 64.838 | - | - | 85.363 | - | 150.200 |
| Transport | - | 3.986.649 | 379.479 | 270.527 | - | 3.069.585 | - | 7.706.239 |
| Services | - | 189.390 | 1.688.971 | 553.951 | - | 4.406.291 | - | 6.838.603 |
| Residential | - | 486.251 | 2.126.149 | 3.520.360 | - | 3.364.022 | 183.140 | 9.679.922 |
| **Total** | **954.085** | **5.985.015** | **8.695.005** | **4.885.240** | **12.160** | **24.589.145** | **2.251.573** | **47.372.223** |

**Table 25: Primal energy consumption by sector and energy vector – mid-term scenario**

Looking at the single energy vectors, oil products primary demand gets reduced from 6 TWh to 3.2 TWh (-47%), mainly driven from the transport sector. Gas demand is also reduced by 3.1 TWh (-36%), and electricity by 2.1 TWh (-9%). With respect to the baseline scenario, oil products are reduced by 6.3 TWh, gas by 6.8 TWh, electricity by 6.2 TWh for an overall balance of more than 18 TWh saved each year (-33.9%).

| **Long term primary consumption** | Solid fossil fuels | Crude oil and petroleum products | Gas | Renewable energies | Non renewable wastes | Electricity | Derived heat & grid bound thermal system | Total |
|---|---|---|---|---|---|---|---|---|
| Agriculture, forestry and fishing | - | 381.567 | 44.051 | 20.977 | - | 193.212 | - | 639.807 |
| Industry (without construction), | 883.784 | 601.682 | 3.699.142 | 827.772 | 11.264 | 9.248.555 | 1.958.197 | 17.230.396 |
| Construction | - | - | 60.060 | - | - | 58.156 | - | 118.216 |
| Transport | - | 2.025.401 | 377.910 | 271.323 | - | 7.799.749 | - | 10.474.382 |
| Services | - | 82.069 | 801.733 | 888.541 | - | 2.597.598 | - | 4.369.940 |
| Residential | - | 63.676 | 614.171 | 3.764.876 | - | 2.525.210 | 143.895 | 7.111.828 |
| **Total** | **883.784** | **3.154.395** | **5.597.067** | **5.773.488** | **11.264** | **22.422.480** | **2.102.092** | **39.944.570** |

**Table 26: Primal energy consumption by sector and energy vector – long-term scenario**

### 6.4.6 Final energy consumption and GHG emissions

In the short-term scenario, the reduction in primary consumption was mainly driven by the reduction in the final demand. In the mid-term scenario it was due a combination of final demand reduction, electrification and efficiency improvements. In the long-term scenario this trend is even more clear, of the 7.5 TWh of reduction in primary consumption, only 1.6 TWh are related to a direct reduction of the final demand.

| Mid term scenario - SHIFT & CHANGE | Solid fossil fuels | Crude oil and petroleum products | Gas | Renewable energies | Non renewable wastes | Electricity | Derived heat & grid bound thermal system | Total |
|---|---|---|---|---|---|---|---|---|
| Agriculture, forestry and fishing | - | 416.674 | 27.174 | 9.058 | - | 110.952 | - | 563.859 |
| Industry (without construction), | 867.350 | 819.518 | 4.197.176 | 531.345 | 30.400 | 5.234.708 | 1.378.956 | 13.059.452 |
| Construction | - | - | 61.750 | - | - | 33.396 | - | 95.146 |
| Transport | - | 3.725.840 | 361.408 | 270.527 | - | 1.200.900 | - | 5.558.675 |
| Services | - | 177.000 | 1.608.544 | 553.951 | - | 1.723.854 | - | 4.063.348 |
| Residential | - | 454.440 | 2.024.904 | 3.520.360 | - | 1.316.091 | 122.093 | 7.437.888 |
| **Total** | **867.350** | **5.593.472** | **8.280.957** | **4.885.240** | **30.400** | **9.619.901** | **1.501.049** | **30.778.369** |

**Table 27: Final energy consumption by sector and energy vector - short term scenario**

Analysing final consumptions, oil products demand decreases by 2.7 TWh (-48%) and gas demand by 3 TWh (-36%). Renewables keep increasing (+0.9 TWh, i.e. +18%) and electricity gains a major share of the overall system consumptions, going from 9.6 TWh of the mid-term scenario to 12.9 TWh (+34%). Out of the 29.2 TWh of total final demand, it means that more than 44% of the system energy consumption is electrified.

Looking at the different sectors, industry shows a reduction of 0.7 TWh as a sum of gas and oil products cuts. Services consumption decreases by 0.9 TWh, while residential's one by 1.4 TWh. Notable in both sectors is the reduction in gas demand and the minimization of oil products' use. Transport is the only sector which actually increases the final consumption, with an overall +1.4 TWh that follows the +3.3 TWh consumption in electricity.

| Long term scenario - SHIFT & CHANGE | Solid fossil fuels | Crude oil and petroleum products | Gas | Renewable energies | Non renewable wastes | Electricity | Derived heat & grid bound thermal system | Total |
|---|---|---|---|---|---|---|---|---|
| Agriculture, forestry and fishing | - | 356.605 | 41.953 | 20.977 | - | 110.952 | - | 530.487 |
| Industry (without construction), | 803.440 | 562.320 | 3.522.992 | 827.772 | 28.160 | 5.310.976 | 1.305.465 | 12.361.125 |
| Construction | - | - | 57.200 | - | - | 33.396 | - | 90.596 |
| Transport | - | 1.892.898 | 359.914 | 271.323 | - | 4.479.000 | - | 7.003.135 |
| Services | - | 76.700 | 763.555 | 888.541 | - | 1.491.669 | - | 3.220.464 |
| Residential | - | 59.510 | 584.925 | 3.764.876 | - | 1.450.100 | 95.930 | 5.955.341 |
| **Total** | **803.440** | **2.948.033** | **5.330.540** | **5.773.488** | **28.160** | **12.876.093** | **1.401.395** | **29.161.148** |

**Table 28: Final energy consumption by sector and energy vector – mid-term scenario**

Last, carbon emissions are analysed. A relevant overall reduction is achieved over the 2030-2040 period, with over 3.7 million tonnes saved from the previous' scenario 8.3 million tonnes (-45%). Industry contributes for 1.9 million tonnes (-47%), services and residential for 0.8 million tonnes each (-64% and -66%), and transport for 0.3 million tonnes (-15%).

| Mid term - carbon emissions | Solid fossil fuels | Crude oil and petroleum products | Gas | Renewable energies | Non renewable wastes | Electricity | Total |
|---|---|---|---|---|---|---|---|
| Agriculture, forestry and fishing | - | 108.752 | 5.489 | - | - | 55.433 | 169.674 |
| Industry (without construction), | 306.175 | 213.894 | 847.830 | - | 10.123 | 2.615.308 | 3.993.330 |
| Construction | - | - | 12.474 | - | - | 16.685 | 29.158 |
| Transport | - | 972.444 | 73.005 | 68.984 | | 599.981 | 1.714.414 |
| Services | - | 46.197 | 324.926 | - | - | 861.253 | 1.232.376 |
| Residential | - | 118.609 | 409.031 | - | - | 657.531 | 1.185.171 |
| **Total** | **306.175** | **1.459.896** | **1.672.753** | **68.984** | **10.123** | **4.806.191** | **8.324.123** |

**Table 29: $CO_2$ emissions by sector and energy vector – short term**

Looking at the emissions by energy vector, these are halved for oil products and reduced by 35% regarding natural gas, combining for a reduction of 1.3 million tonnes of avoided carbon dioxide. The biggest cut relies anyway on the electricity-related emissions, which are cut from 4.8 million tonnes down to 2.3 million tonnes.

| Long term - carbon emissions | Solid fossil fuels | Crude oil and petroleum products | Gas | Renewable energies | Non renewable wastes | Electricity | Derived heat & grid bound thermal | Total |
|---|---|---|---|---|---|---|---|---|
| Agriculture, forestry and fishing | - | 93.074 | 8.475 | - | - | 20.319 | - | 121.868 |
| Industry (without construction), | 283.614 | 146.766 | 711.644 | - | 9.377 | 972.622 | - | 2.124.023 |
| Construction | - | - | 11.554 | - | - | 6.116 | - | 17.670 |
| Transport | - | 494.046 | 72.703 | 69.187 | | 820.258 | | 1.456.195 |
| Services | - | 20.019 | 154.238 | - | - | 273.176 | - | 447.432 |
| Residential | - | 15.532 | 118.155 | - | - | 265.563 | - | 399.250 |
| **Total** | **283.614** | **769.437** | **1.076.769** | **69.187** | **9.377** | **2.358.053** | **-** | **4.566.438** |

**Table 30: $CO_2$ emissions by sector and energy vector – mid-term**

### 6.4.7 Sankey diagrams

Figure 22 shows the Sankey diagram of the final use of each energy vector in each sector. With respect to the mid-term scenario, electricity final use becomes the main energy vector in almost every sector, with the exception of the residential one where direct renewable energy production grows and covers most of the final consumption. Oil products are halved, and replaced by electricity in the mobility sector.

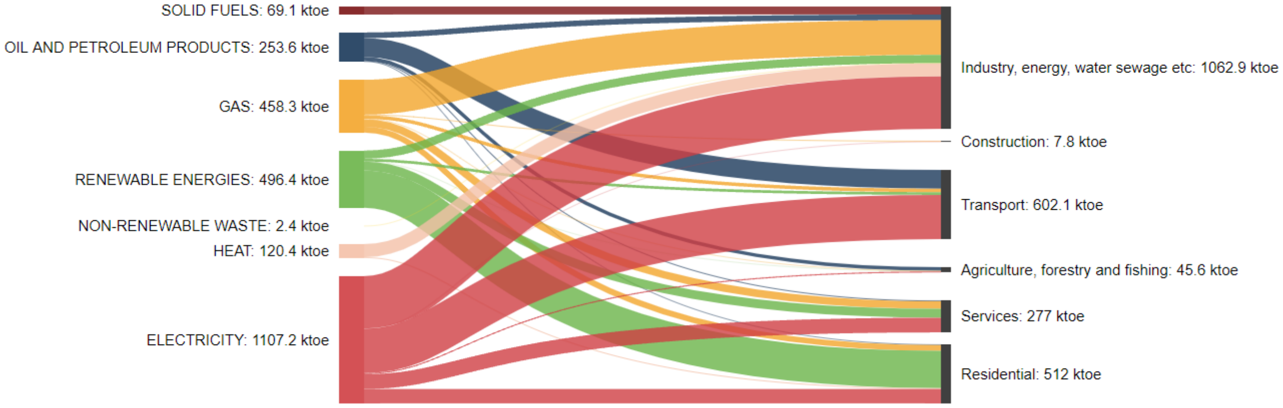



**Figure 22: long-term Final use Sankey diagram**

In graph 23 emissions are also represented in a Sankey diagram and divided by sector. Since also the national energy mix of electricity production becomes greener, the proportion of electricity-related emissions is reduced. All sectors reduce the carbon emissions, in particular industry, services and residential.

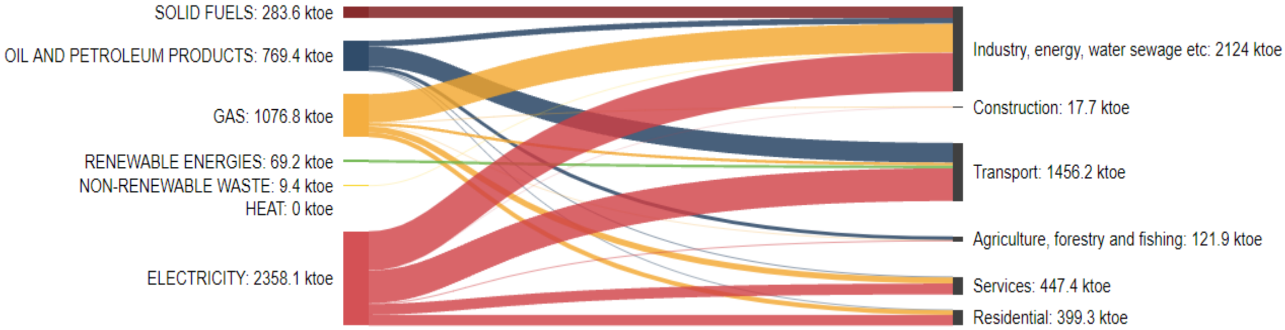



**Figure 23: long-term emissions Sankey diagram**

Besides the decrease of overall energy consumption, it is interesting how the energy mix shifts from one vector to another over the selected time frame. In figure 24 the trend seen in the previous scenario becomes more evident. In fact, in this scenario the energy vectors heat pumps and renewable energies are almost equal to the gas demand. Grid bound heat doubles and electricity is now four times the consumption in the mid-term.

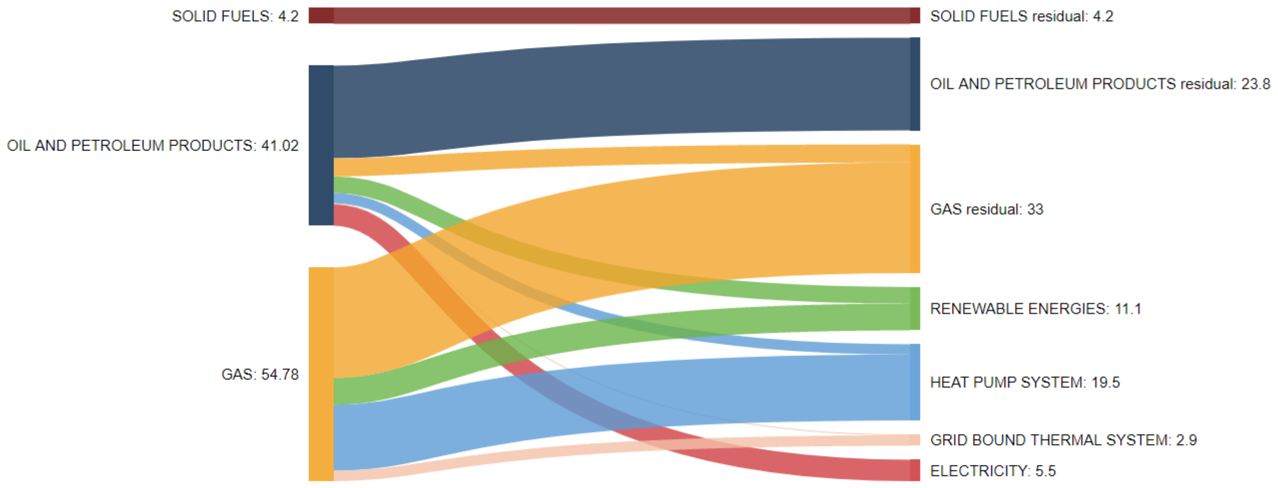



**Figure 24: long-term fuel shift Sankey diagram**

# 7. IMPLEMENTATION MONITORING AND KPIs

## 7.1 Evaluating body and evaluation periods

It is a currently active discussion to establish a regional energy observatory, built and managed jointly by APE FVG, RAFVG, the two universities of Udine and Trieste and ARPA FVG. All these agencies and institutions manage daily huge amounts of data, but currently do not cooperate in order to have a centralized database. Moreover, having the regional authority in the cooperation can unlock the access to certain data and increase the willingness of the private sector to share their data.

Regarding the periodic evaluation and monitoring of the overall system, APE FVG could cover the head role and communicate the developments of the regional energy system to the regional authority. This work could be done with a yearly report, to be built in the first place and updated year-by-year, in order to minimize the work in the future and maximize the analysis of the different trends. This will allow the regional authority to develop and adapt possible responses, whether the effect of past measures did not achieve the expected results.

## 7.2 KPIs for impact monitoring

This chapter will list and describe shortly which KPIs should be monitored regularly to analyse the development of the regional energy system and the impact of the implemented measures.

- **Renewables in primary and final consumption, by sector and by energy type** (electricity, heat and processes, fuels). These are the basic indicators to understand if the set measures are achieving the desired results. The data should be analysed both in absolute values, in order to understand the trend of the single technologies in the different sectors, and in relative shares, to understand the substitution rate with respect to the other technologies and with respect to the total consumption trend of the sector;
- **Renewables in electricity generation**, by generation type. Many EU and national goals are set on this indicator. Electricity generation is one of the most important target sectors to decarbonize, and renewables monitoring in the sector could give good insights on the effect of incentives on capacity installation, as well as on the integration of RES and development of the so-called smart grids. This becomes even more important considering that electrification of end-uses is expected to grow and become the most important final demand energy vector;
- **Electricity in final consumption by sector**. As previously mentioned, one of the main trends that is expected to accelerate in the coming years is electrification of end uses. It is important to monitor this KPI in order to understand which sector is moving faster, and if the generation is able to keep up the increasing electricity demand;
- **Investments per kWh of saved energy and per additional kWh of renewable energy.** It is important to measure the effectiveness of public funding and of overall investment. To understand how much public funds should be set in order to achieve a certain energy saving, and which interventions are more effective than the others can help focus on the

most profitable ones and exploit the current availabilities. Same logic for the investments in new RES capacity, divided by size and energy source;

- **Carbon emissions.** As the final goal is to reduce as much as possible the carbon dioxide emissions, it is fundamental to have a detailed monitoring of such data, in order to know which sectors are making progresses and which ones need stronger measures;
- **Investments per saved $CO_2$ tonne.** As for the energy efficiency and the RES generation, it can be a key aspect to know where the public and private investments achieve the most effective reduction of $CO_2$ in terms of euros per saved tonne;
- **White and green certificates.** Keep track of how many certificates are given to the companies of which sector, their market price, the volume of transactions and if they are traded/bought outside of the region;
- **Regional energy balances.** Regional generation, import and export are fundamental information to plan an appropriate development of the energy system. These data, especially regarding electricity, should have a detail time resolution, in order to allow further analysis and have a more resilient electrical grid.

# 8. ASSESSMENT OF SUITING BUSINESS MODELS AND FUNDING SCHEMES

One of the most important aspects of such a regional energy plan is surely how to practically unlock and achieve the set goals from an economic point of view. In fact, every investment, besides being efficient and effective, needs to be economically sustainable for the public administration that provides the funding. Moreover, as it is recognized that public investments will not be enough to reach the national objectives, it is important to use public funds as a leverage to unlock the private investment potential.

## 8.1 Existing business models with regional relevance for low carbon energy supply and development potentials

Currently, most incentives are given in the form of non-repayable capital contributions on the investments. This translates into a weak leverage of private equity, a limited territorial impact, complicated and bureaucratic accessibility, low competitivity of projects and higher chances of economic failure of the project.

Regarding active incentive schemes on renewable energy production, these work well to mobilise investments, but can be subject to financial speculations if not well designed. Moreover, they result in high costs for the public administration, especially if there is no territorial strategy and planning behind the way the incentive is given.

On sustainable energy investments, interest subsidies have low appeal at present due to the low cost of equity, are scarcely appreciated by investors and are not affected by state aid-compliance. On the other side they generate a good leverage of private equity and have large territorial impact.

The Public-Private Partnership model is a good instrument for energy refurbishment of public assets, the investment risk is very well managed, the fiscal compact limitations are overcome, and there are good pooling competences and operative capacities.

A simple scheme consists of small public grants up to 10.000€ for sustainable energy investments. It is simple and easy to access, and therefore appreciated by people. On the other hand, the high flexibility leads it to be used for non-critical aspects, with a scarce impact with respect to energy transition goals.

Talking about big infrastructures (HV lines, large plants, etc.), there is no regional strategy regulating these projects and how funds are given. These projects are strongly dependent on financial & lobbying capacity, and driven by national policies.

All these measures do not show a coherent planning and effective use of resources, as the regional energy plan is currently outdated and not linked to a financial plan.

## 8.2 Alternative business models and regional applicability

Before talking about alternative business models, it should be remarked how a good strategic planning is a key factor for every business model to succeed, and to address optimally energy investments.

In order to have an effective planning in the first place, and to adapt the choices and measures along the years, it is fundamental also to monitor the system and adapt the business models according to the development trends and market situation. To understand how the market and the territory are responding to the upcoming challenges as well as to assess the speed of change can help to adapt the active measures in a quick and effective way.

Pooling energy investments into pipelines could represent a possible solution to develop better structured development strategies, increase the quality of interventions, use economies of scale and therefore achieve higher efficiencies in term of benefits/investments. Moreover, approaches could become more and more standardized and as well obtain a bigger leverage of private funds. However, this solution must be coupled with an appropriate capability of local administrations to manage these pipelines, in order to act as a flywheel for the local economy and employment, and to involve consistently local stakeholders.

A good driver for research and companies to align to such technologies is to plan big green infrastructure investments: green harbours, hydrogen valleys, green corridors, green urban districts and so on. Since these projects might require investments of several million euros, it is important that the region selects few and promising ones, creates a cooperation with multiple stakeholders (universities, private companies of different size, administrations) and focuses on a quick and effective development. This will create a chain effect in the private sector of technologies and services and a positive impact on the local economy.

Last, involving private citizens with participative activities can help local decision makers in the decision process, as well as support them in making stronger commitments and make them more aware of the impact of their choices. Regarding this last aspect, energy communities could play an important role in activating private citizens and small businesses, changing their behaviour and consumption, leveraging investments and increasing distributed RES generation.

## 8.3 Usable funding schemes: applicability and possible gaps to be filled

One of the most important aspects to implement in the future funding schemes is the stability over the years of the scheme itself. In fact, until now most incentives have been set suddenly with a huge availability of money, only to last a couple years and then removed due to lack of money or too many bad practices. Lower but more stable incentives can avoid to distort the market and create speculative situations for investors, and can let market players adapt and built business plans with a longer time horizon.

Usable and effective funding schemes could be:

- A stable framework (10 years) framework to support energy refurbishment of buildings, public and private, detailed for type and investment, dimensioned on a suitable size of contribution to mobilize private investments, i.e. maximum 35% of the total cost;
- A stable framework (10 years) to support waste-heat recovery in all sectors, mainly where waste heat energy volumes are significant and available, also looking at the existing study and regional strategy for waste heat recovery;
- A stable framework (10 years) to support energy investment in DH networks supplied with local renewables, public and private, dimensioned on a suitable contribution to mobilize private investments, i.e. maximum 35% of total cost, and compliant with quality standards (e.g. QM);
- A grant programme supporting a phasing-out of obsolescent technologies, such as those with very low efficiency or based on fossil fuels, at private and public levels.

It is important that complementarity between regional and national incentives is ensured to generate a positive cumulative effect and gap filling and to avoid creating speculation opportunities in few sectors and leaving others without support. Moreover, a medium and long-term synergy will allow more investors to plan and implement initiatives with lower risk.

# 9. CONCLUSIONS

## 9.1 Summary of findings

The most important findings of this report are:

- Five major trajectories have been identified and for each one measures and actions have been evaluated. Some are more market-ready to be implemented with respect to others, depending on the maturity of the technology or the availability of sites and cooperation;
- There is a high potential for RES deployment. In particular solar PV, hydro and biomass used in DH networks seem to be the most promising ones and those which will the future system will be based on;
- There will be a major electrification of end uses, from heat pumps to electric vehicles. This will increase the efficiency of the system, improve air quality and supply cheaper energy to customers. On the other hand, this poses relevant questions on the generation status and the related infrastructures, from the control of the grid to storage technologies;
- This transition cannot be considered as a single-sector process, as it touches multiple processes and areas where different actors from very different backgrounds are involved. It is important to have a holistic view and consider the effects of each measure on the other sectors;
- There is a major need for an energy observatory, where different stakeholders cooperate in order to generate and manage a centralized database with energy data from all over the region;
- There is a major need of a good planning and selection of measures to pursue, and to track the development of the system with respect to these measures;
- There is a major need of developing a consistent and stable funding strategy to support and boost the energy transition.

## 9.2 Challenges for the regional authorities and stakeholders

Regional authorities need to drive, regulate and trigger the transition. Needless to be said, this is a very tough task, with many challenges and threats that jeopardize the whole process. Looking at the main ones:

- **Monitor** the regional energy system. Set up standard procedures and maintain them over the years in order to have usable data, select relevant KPIs and statistics. For each KPI select a time and geographical resolution. Set a unique centralized database to collect the data. This task requires to hire and train human resources for this specific job, without bringing any profit on the short-term;
- Register all energy plants of the territory in a **regional energy atlas**. Select, build and manage a centralized system with all the information about old and new, public and private plants;

- Put in place a **regional observatory** on energy flows. This tool, which could also originate from a cooperation among universities, energy and environment agencies and local authorities, would take on previous tasks and elaborate annual reports on the status of the regional energy system. Naturally, it requires a lot of resources and employees before it becomes structured and with a critical mass of data and reports to effectively contribute to the regional development;
- **Plan and design** a regional strategy. Develop a proper plan for each sector, infrastructures, set goals and deadlines for each aspect of the energy transition. This work requires competences and resources, but it is fundamental for a good use of the available funds and to achieve the results within the deadlines;
- **Finance** the plan properly. Design the most appropriate and effective funding and incentives schemes, check that there is no speculation opportunity, that the private equity leverage is effective and that the resources impact the desired sectors and technologies.

Regional authorities surely play the most important role in driving the transition, but are not the only player involved. The other stakeholders involved also face challenges, such as:

- **Awareness** of current state of issues, technologies and opportunities. In fact, for many the amount of information available on the energy transition is often not clear or chaotic. Make available a central online source of information, hold public events with specific targets for public administrations, small companies by sector, private citizens in which the current status of the local system, criticalities and opportunities are explained;
- Think “out-of-the-box” to **mobilise investments.** It is fundamental that new business models are developed in order to keep the market competitive and innovative;
- **Advocate** local decision makers for energy transition, share with them the point of view of private stakeholders and what measures are more effective and profitable for them, in order to adjust the type and magnitude of each measure;
- **Aggregate** interest to take advantage of economies of scale. Cooperation is surely a strength when it comes to such a transition process that involves the whole energy system. However, the more partners are involved, the harder it is to find a common deal.

## 9.3 Expected impact on regional economy

Surely, all measures related to energy savings and shift from fossil fuels to renewables will achieve, after the PBT, relevant monetary savings for private citizens and private administrations. This translates in higher availability of equity, higher investment opportunities and local recirculation of money. In particular, local generation and consumption, also in the form of energy community, might save a good share of the final cost of purchased electricity, which is related to the infrastructure taxes. Another option might be that local cooperatives buy and manage the local distribution grid, allowing even these taxes to stay on the territory.

One of the main trends of the whole energy transition process is to decentralize every kind of production, as RES are available also in remote areas and do not depend on the existing infrastructures. This is expected to have a very positive impact on rural and peripheral areas, such as alpine valleys. To supply and sell, install, maintain and manage a high number of small RES plants numerous job places are expected to be created, with a positive impact also on the regional

GDP. In particular for biomass supplied DH plants, which is a fundamental trajectory in FVG region, past experiences have showed what is the actual impact both on job creation and on actual money that stays in the local economy instead of going to some fossil fuel suppliers abroad.

The opportunities related to large scale projects (hydrogen valleys, green cities etc.) as well as for industrial pilot projects of new technologies and synergies can be a boost for the entrepreneurial and industrial sectors of the region, attracting investments from inside the region but also from the rest of Italy and abroad. Within these projects there is also the opportunity for Universities and research centres to pursue national and European funds, develop research teams and gain experience on the technologies and on the university-company cooperation.

## 9.4 Gaps to fill for proper implementation (technical, regulatory, financial)

Indeed, it is true that some technologies are not yet market-ready for large scale implementation, such as hydrogen, power-to-X, technologies for the decarbonization of the maritime and aviation sectors, completely smart and automated energy management systems. But as research continues on a national and international level, it can be assumed that these challenges are not the bottlenecks of the energy transition.

The main challenges for the regional authority are to design the regulatory and financing frameworks of such transition. In order to do so, the biggest gap to be filled is a proper and detailed energy action plan, based on consistent energy data collected over the years into a unique and accessible database. Since it is not possible to wait years without a proper plan while the observatory is set, the region should try to gather all the competences, information and regional stakeholders in order to develop a strategy for the next 10 years. While data are collected and the development of the system is tracked, measures can be adjusted in order to obtain better results and boost the transition. Even more important is to structure a financial strategy to support the fulfilment of the action plan. Effective funding schemes which stabilize over time, sized according to studies and previous experiences, and focussed on the most promising sectors are needed. Having a holistic and pragmatic approach regarding funding schemes and business models is key to achieve any result conceived in the action plan.