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Reference documents

No.	Title	Issued by
1	Methodology for pilots data processing	ABENGOA
2	Technical and economical evaluation of the Greek pilot micro-grid for each operating mode	CRES-Centre for renewable energy sources and saving
3	Collective self-consumption project on the pilot area of Saint-Julien-en-Quint - Cost benefit analysis	AURAEE- Auvergne-Rhône-Alpes Energie Environnement
4	Gozo Pilot- Cost Benefit Analysis	MIEMA- Malta Intelligent Management Agency
5	Technical and economical evaluation of the FOSS microgrid at the campus of University of Cyprus	UCy-University of Cyprus
6	Cost benefit analysis report for Ruše Sports Park area	ENERGAP-Energetska Agencija za Podravje
7	Pilot of the Municipality of Potenza- Technical and economical evaluation	DeMEPA-Design and Management of Electrical Power Assets
8	Reactions of the Stakeholders	CRES-Centre for renewable energy sources and saving
9	Reactions of the Stakeholders	AURAEE- Auvergne-Rhône-Alpes Energie Environnement
10	Reactions of the Stakeholders	MIEMA- Malta Intelligent Management Agency
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1. Scope

This report collects in a homogeneous form the results of the cost-benefit analysis carried out on the seven pilots developed in the frame of PEGASUS project with the aim to demonstrate the potential contribute of the microgrids in improving the share of renewable sources in electricity generation , the reliability of power supply and the energy efficiency.

The pilots was developed in terms of feasibility study and simulations in seven rural or peripheral areas and islands of the MED area:

- Mega Evydrio (Greece)
- Saint Julien-en-Quint (France)
- University of Cyprus
- Gozo island (Malta)
- Preko island (Croatia)
- Ruše (Slovenia)
- Potenza (Italy)

After a short reminder of PEGASUS project general objectives and its implementation through the seven pilots, this Report, making reference to the documentation made available by each involved Partner, summarizes for each pilot:

- the specific aims of microgrid and its consistency (internal power sources, number and type of consumers/prosumers/producers involved, etc.),
- the current legislative and regulatory frame with regard to microgrids and more generally in supporting the development of RES,
- the results of the cost-benefit analysis carried out for each pilot based on business model developed taking into account the specific situation relating to local institutional, regulatory and electricity market,
- the reactions of the social and institutional stakeholders, collected through organized meetings and questionnaires, and the Energy Regulation Authority position concerning microgrids.

Finally the concrete opportunities for the microgrids emerging from the presented review are outlined in the perspective of the development of Renewable Energy Communities in the MED countries according to the EU directives on the matter.

2. PEGASUS project : general objective and its implementation

PEGASUS project overall objective can be summarized as : contributing to an increased, efficient and effective use of RES in local territories of the MED area using microgrids, being the microgrid a group of interconnected loads and energy resources within clearly defined electrical boundaries and acting as a single controllable entity with respect to the public grid.

The project pursued these goals setting up the institutional and economic conditions enabling the application in seven peripheral areas and islands of microgrids able to improve the presence of RES, the power supply security and the efficiency of electrical consumptions.

Starting from the fact that the necessary technologies for the implementation of microgrids are available, the Project assessed for each of the seven pilots an effective and financially viable microgrid taking into account the different local conditions in terms of regulatory framework, electricity billing tariffs, social and stakeholders approval rating.

All the pilots performed the followings steps:

a) Definition of the main aims of the local microgrid (such as the improving of local electrical system resilience, consumers billing reduction, etc.);
b) Configuration of the microgrid in terms of existing and prospected RES plant, number and type of consumers/prosumers/producers involved, regulatory frame;
c) Measuring of the individual or class load profile, over a period ranging from some months up to a whole year; this monitoring campaign was necessary to base the subsequent evaluations on real and fully representative data;
d) Simulation of the microgrid operation in order to identify the most effective way according to the predefined objectives;
e) Evaluation of the achievable benefits for each class of the involved consumers under the condition of financial sustainability of the microgrid taking into account the required capital and operating costs.

Therefore each of the Cost-Benefit analysis presented in the following chapters is the result of an assessment of the number and mix of the involved consumers as well as of the power source assets in order to balance not only the load and generation profiles but also appropriate investments and operating cost of the microgrid over the time.

3. General considerations and assumptions

Microgrids must necessarily be equipped with internal energy sources and must be able to integrate those already existing on the local territory. That said, the fully energy self-sufficiency is not a goal in itself as well as the benefits deriving from a microgrid establishment cannot be limited to those related to the use of RES (such as reduction of fossil fuels, low carbon emission) that can be achieved by any initiative of a individual prosumer. Through a suitable energy management system a more efficient use of electricity has to be achieved, for instance adopting demand side management approach or even just shifting the energy consumption at times when the generation by the internal renewables sources is greater. This together with a re-negotiation of the value of the energy exchanged in input and output can reduce the billing for the consumers/prosumers clustered in the microgrid.

From the above derives the need to couple the energy management system with an economic dispatching system able to redistribute the benefits of the microgrid among its participants on the base of internal "transfer prices".

Therefore the planning of a microgrid has to take into consideration the mix of the energy internally generated, including storage capacity if appropriate, and the one externally purchased in order to achieve a better balance with the load with an investments level such as to assure both the economic and financial viability of the microgrid and measurable benefits achievable by all the involved subjects (consumers, producers, prosumers).

It has to be outlined that almost all of the PEGASUS pilots were developed in the absence of any regulation on microgrids. Some assumptions were therefore made to define the configuration of the micro-network and the related assessment of the energy, economic and financial feasibility.

In particular for the purpose of the cost-benefit analysis the existing tariffs for the electricity drawn from the network have been applied, with possible assumptions on some tariff items (for instance on the transmission and distribution costs of electricity internally generated), as well as the existing incentives for the electricity generated by renewable sources have been taken into account. Further details will be given in the description of each individual pilot .

All the developed pilots make use of the existing electricity distribution infrastructures as they have been planned to operate in connection with the public network.

In-depth assessments of the possibility to operate the microgrid in island ing conditions was taken into consideration by the pilots aimed to increase the power supply reliability in presence of weak distribution networks or frequent power outages.

A microgrid able to be operated in island mode must be controlled without the reference input of the main grid and has to detect fault signals from main grid in order to island in time. After islanding the voltage and frequency control, and appropriate power quality levels, must be provided by the microgrid. This implies additional investments and more complexity in operation, especially high when the microgrid is based only on renewable intermittent electricity sources and batteries for energy storage. Those significant additional investments and operating costs should be carefully weighed against the economic value assigned to an higher power reliability in term of the external costs related to the outages (for instance commercial or industrial activities halt).

The adoption of storage systems for the generated electricity exceeding the contemporary demand has also been considered by various pilots. The still relatively high costs of these storage systems have led to believe more economically viable to feed into the public network this exceeding electricity.

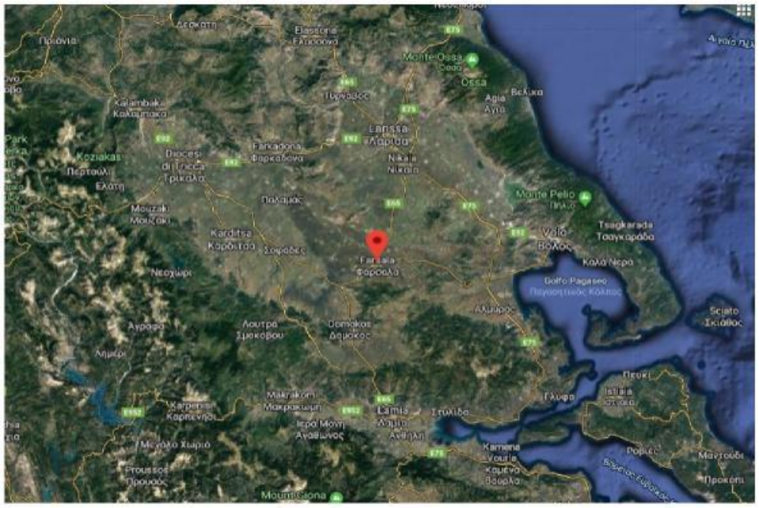
Therefore all the following cost-benefit analyses refer to microgrids that exchange electricity with the grid to integrate the one internally produced and to transfer the excess electricity generated from the not programmable renewable sources. In this context Energy storage systems was considered for the optimization of the microgrid energy balance.

All the clustered customers, producers and prosumers belonging to the microgrid are located in the same portion of the network and almost always on the same electrical substation.

The pilot developed by the Municipality of Potenza, in addition to electricity consumption the thermal consumption supplied by a dispatchable energy source was also taken into consideration.

The microgrid, adequately equipped, may be able to provide the so-called ancillary services to the network (such as those relating to the control of network voltage and frequency) and in any case reduce the network loss in connection with the local generation. The pilot of the University of Cyprus has quantified these advantages both in terms of lower losses and in investment deferral on the distribution networks, in the event of growing demand for electricity or more generally in the presence of a weak network.

4. The pilot of Mega Evydrio



The Greek pilot site is located in the Municipality of Farsala in the area of Mega Evydrio (Thessaly Region).

The consumers and producers considered by the pilot are below listed.

There also 5 producers, each one with 100 kWp PV plant.

	Category	Number	Total PV power
Public	consumer	4	-
Commercial shops	consumer	16	-
Domestic houses	consumer	295	-
	prosumer	5	45 kWp
Public Street Lighting (471 Lamps)	consumer	2	-
Public Pumping Station	consumer	1	-
Private pumping Station	consumer	147	-
Producers	producer	5	500 kWp

The electricity generated by the existing 545 kWp PV plant amounts to 700 MWh/year, being 15 MWh/y self-consumed by the prosumers and the remaining 685 MWh/year are fed into the network. The 3153 MWh/year pilot consumption is covered by withdrawals from the network for a total of 3138 MWh/year.

4.1. Regulatory framework in Greece

RES began to be incentivized in Greece starting from 2006 year . In the following some significant enacted laws until 2018:

- City/regional councils, schools, universities, farmers and farming associations are allowed to develop PV and wind power projects of up to 500 kWp, if installations are located at a considerable distance from the place of the actual power consumption (art.14A par.4 Law No.3468/2006)

- PV installed on public buildings in the context of the EU funded programmes can be incentivized up to 20% of the value of the total annual electricity production (art.14A par.4 Law No.3468/2006).
- PV plants connected to the grid are eligible for the net metering scheme (art.14A Law No.3468/2006) when:
    - PV plants <20 kWp or <50% of the agreed capacity consumption (PV Capacity ≤0.5 x Sum of the agreed power consumption (kVA);
    - PV plants operated by non-profit legal person up to 100% (art. 1 par.2 FEK B' 3583/2014 and art.1 par.2 Min. Res./F1/175067).
- In 2014 was introduced a net metering process for prosumers : in the event the difference between the electricity fed into the grid and that drawn from the grid in a certain period is positive, this surplus is credited by the electricity retailer on the next electricity bill. Otherwise, the owner of the system is required to pay based on the difference between the energy drawn and that fed into the grid (art. 2. FEK B '3583/2014);
- In 2018 in Greece was enacted a law about Energy Communities and Cooperative Energy Communities (Law No. 4513/2018), defining their scope and purpose, who can be a member of them, and their organization. No reference is made to micro-grids as a mean to operate these Energy Communities.

4.2. Cost-benefit analysis

The microgrid has been assumed to be established by the "Local Energy Community" of Mega Evydrio, participated by the Municipality of Farsala, the local residents, the local shop owners, the local electricity producers and various other interested stakeholders.

The microgrid is connected to the network through a Point of Common Coupling only and it has been assumed for the electricity exchanged with the network a net metering scheme: on the difference between the electricity withdrawn from the network and that fed into the network a tariff of at 14,56 €c/kWh is applied, deriving from the existing Business Tariff Γ21 reduced by Transmission Special duty for renewable energy sources and duty for Services of general interest.

The microgrid buys all the electricity generated by the existing producers as well as that generated by prosumers and not self-consumed, at the prices shown in the below table in close comparison with those currently applied.

	Price [€cent/kWh]	
	Currently applied to the electricity fed into the grid	**Applied to the electricity sold to the microgrid**
Public prosumer	-	10,00
Domestic prosumer	-	10,00
Producers	14,00	14,55

The microgrid supplies all the consumers and prosumers applying electricity tariffs discounted of 10% in comparison with the currently existing ones, as reported in the below table.

	Electricity Tariffs [€cent/kWh]	
	Currently	**Applied by the microgrid**
Public consumers	18,61	16,75
Commercial shops	18,61	16,75
Domestic houses	19,40	17,46
Public Street Lighting	15,52	13,97
Public Pumping Station	18,61	16,75
Private pumping Station	8,90	8,01

Moreover it has assumed to install on the roof of 75 domestic house a PV plant, 2,5 kWp in power, in order to increase the electricity generated within the microgrid.

The microgrid configuration is outlined in the below table.

	Category	**Number**	**Total PV power**
Public	consumers	3	-
	planned prosumer	1	9 kWp
Commercial shops	consumer	16	-
Domestic houses	consumers	220	-
	existing prosumers	5	45 kWp
	planned prosumer	75	169 kWp
Public Street Lighting (471 Lamps)	consumer	2	-
Public Pumping Station	consumer	1	-
Private pumping Station	consumer	147	-
Producers	existing producer	5	500 kWp

A share of 20,2 % of the 928 MWh/year generated by the 723 kWp PV plants is self-consumed while the remaining 740 MWh/year are fed into the network. The total pilot consumption of 3.153 MWh/year is covered by withdrawals from the network for a total of 2.965 MWh/year.

The annual cost of the electricity withdrawn by the microgrid from the network amounts to:

(2965 – 740) MWh x 145,6 €/ MWh = 323.814 €.

Taking into account the assumptions made on the tariffs applied by the microgrid to the consumers and the price of electricity paid by the microgrid to the producers and internal prosumers , all the members of Mega Evydrio Community are paying less or earning more when clustered in the microgrid, as shown in the following table.

	Payment [€/year]			Earning [€/year]		
	Currently	with microgrid	Saving	Currently	with microgrid	Additional
Public consumers	1.929	1.734	195	–	–	–
Public – planned prosumer	643	297	346	0	988	988
Commercial shops	27.552	24.800	2.752	–	–	–
Domestic houses – consumers	244.200	204.380	39.820	–	–	–
Domestic houses – existing prosumers	8.391	3.393	4.998	–	–	–
Domestic houses – planned prosumer	83.250	61.538	21.712	0	9.554	9.554
Public Street Lighting	97.529	87.818	9.711	–	–	–
Public Pumping Station	68.613	61.752	6.861	–	–	–
Private pumping Station	23.548	21.194	2.354	–	–	–
Producers	–	–	–	89.895	93.426	3.531
Total	**555.655**	**466.906**	**88.749**	**89.895**	**103.968**	**14.073**

From the above table the resulting yearly revenues of the microgrid for the electricity sold to its members are equal to : 466.906 – 103.968 = 362.938 €.

The operating costs of the microgrid, including those related to the electricity purchase from a provider, amount to 347.924 €/year, determining a gross margin of **15.014 €/year**.

Microgrid operating costs [€/year]	
Electricity purchasing	323.814
Fee for the use of existing networks and meters	18.000
O&M of 178 kWp PV plants	3.610
O&M of Energy Management System and Point of Common Coupling	500
Local Energy Community operation (administrative and commercial cost)	2.000
Total	**347.924**

The capital costs related to microgrid establishment concern the 178 kWp PV plants, the hardware and software of the Energy Management System and the Point of Common Coupling with the main grid, as shown in the below table.

Microgrid Capital costs [€]	
178 kWp PV plants (1368,6 €/kWp)	242.927
Energy Management System	50.000
Point of Common Coupling	10.000
Total	**302.927**

The requested investments are financed through:

- Equity by the Local Energy Community managing the micro-grid, for € 62.048 (20,5%)
- Grants for € 150.000 (49,5%)
- Loan for € 90878 (30%) , having a duration of 20 year and interest of 7%.

Under the following assumption:

√' 2% increase on yearly basis of the revenues and operating costs of the microgrid,
√' 25% of tax rate on profit,
√' 8% discount rate,

the evaluated financial indicators present the following positive values:

- Net Present Value after 20 years : € 26.976
- Internal Return Rate : 11,7%
- Simple Payback period : 9,33 years
- Discounted Payback period : 15,6 years.

4.3. Social and institutional stakeholders reactions

The meeting held with the local stakeholders (Engineers and Technicians, the head of technical department of the Municipality of Farsala, Architects, Contractors, RES investors and Planners) highlighted the interest on the business/organizational model of the microgrid of Mega Evydrio. Social and institutional constraints as well as the dominance of the incumbent utilities (production/transmission/distribution) were discussed in depth in order to verify and improve the adaptability of the presented microgrid model. From this meeting and the filled questionnaires a definitely positive opinions emerged on the proposed microgrid, considering that:

- there is a strong feeling of community in the pilot area,
- the residents of the pilot area believe that the microgrid will have a positive impact in their economics and increase the employability in the area,
- there is a great willingness to be shareholders of a local company owning the microgrid.

A seminar was organized in the premises of the Region of Thessaly with aim to provide the administrative personnel of a clearer understanding of the potential opportunities related to the microgrid and energy community concepts in the transition towards renewable energy sources. The pilot of Mega Evydrio and the opportunities on how to provide funding for the implementation of the local energy community was also discussed in depth.

4.4. Regulation Authority position

During a specially organized meeting with RAE, the Greek Energy Regulator, it was stated that the new law 4513/2018 (OJ A 9/23.01.2018) aimed to increase the use of RES and High Efficiency Cogeneration of Heat and Power, the Energy Communities are entitled to receive financial incentives. For PV projects owned by energy communities (the proposed solution for the Mega Evydrio pilot) the minimum capacity threshold that would trigger the obligation to participate in auctions are set at 1 MWp. As the Greek pilot is going to have a PV capacity of 723 kWp, the energy community projects falls under this threshold and thus can receive an operating aid in the form of a “sliding premium” according to which the price of the electricity fed into the grid is related to the price in the wholesale market.

The Regulator informed that additional supporting measures may be enacted based on the policy decision by the Ministry of Environment and Energy. RAE outlined that more than 30 production licenses for some Energy Communities in the Agrinio region (Western Greece) are going to be approved.

5. The pilot of Saint Julien en Quint

The pilot of Saint-Julien-en-Quint concerns 33 of the 45 residential consumers located in the central area of the village, all connected to the LV substation « Le Bourg ». The overhead line of the local electricity grid is vulnerable to bad weather, with consequent power outages particularly impacting on wood chip boilers, widely used for heating, and on farmers' cold stores. Thus, local representatives and inhabitants are searching for innovative solutions based on local energy sources.

31 consumers were monitored during one year so as to get their load profile while the profile of the remaining two consumers was rebuilt. The maximum and minimum engaged power was 50,3 kW and 6,5 kW, respectively, with a total electricity consumption of 178 MWh/year.

5.1. Regulatory framework in France

The law n ° 2017-227 of February 24, 2017 ratifies the "Ordonances" n ° 2016-1019 of July 27, 2016 concerning self-consumption and collective self-consumption. About the latter it was stated that :

- one or several electricity producers can provide electricity to several consumers under the conditions that they are linked inside a common legal entity and they are connected to a same power substation,
- the legal entity (gathering producers and consumers) has to declare to the DSO how the electricity produced is shifted between the various consumers.
- The excess of the generated electricity can be either sold or given for free to the grid.
- The DSOs shall develop relevant technical and legal arrangements to organize electricity metering.

About the operational implementation of collective self-consumption the following Decree n ° 2017676 dated 28 April 2017 gives more details:

- the involved producers have to be equipped with smart-meters, with 30 minutes of metering time step,
- a "distribution key" has to be defined between producers and consumers,
- DSOs shall write the procedures in their technical reference documentation.

Consequently the legal entity has to sign a contract with the DSO in which the name of consumers and producers, their point of delivery, the responsibilities of each party, the calculation details of the repartition key, the way excess electricity is used, the consumers and producers complementary contracts are clearly defined.

Through the Deliberation N ° 2018-115 dated 7 June 2018, the Energy Regulatory Commission introduced a new optional “specific” tariff formula concerning the rates of use of public electricity networks (Tarifs d’Utilisation des Réseaux Publics d’Electricité - TURPE) for the user connected to LV network and participating in a collective self-consumption scheme, specifying different tariffs for self-consumed electricity and for the electricity coming from an external provider ("alloproduits").

For consumers with a committed power up to 36 kVA, TURPE is determined by the sum of 3 components:

- the Management component (Composante annuelle de gestion - CG), a standing fee depending on the committed power;
- the Metering component (Composante annuelle de comptage - CC), a standing fee depending on the committed power;
- the Annual Withdrawal component (Composantes annuelles de soutirage - CS): a fee depending on the committed power P and the electricity consumption Ei during the i-th time period, according to the following formula:

$$CS = b * P + \Sigma ci * Ei$$

TURPE « classique »	**b (€/kVA)**	**c_i (en c€/kWh)**			
		HPH	HCH	HPB	HCB
Sans distinction temporelle (CU)	4,8	3,66			
Avec plages temporelles (CU4)	4,2	7,34	3,66	1,88	1,35
TURPE « spécifique »					
Avec plages temporelles (CU4 autoproduits)	3,12	2,89	2,18	0,75	0,71
Avec plages temporelles (CU4 alloproduits)	3,12	7,06	5,43	2,01	1,07

In the TURPE “classique” the consumer can choose for the term ci between a fixed value of or differentiated values based on the Time of Use of the electricity. For the TURPE “spécifique”, applicable for collective self-consumers only, the second of the two option is allowed.

Four time periods are considered:

- HPH : Peak hours, high season
- HCH : Off-peak hours, high season
- HPB : Peak hours, low season
- HCH : Off-peak hours, low season.

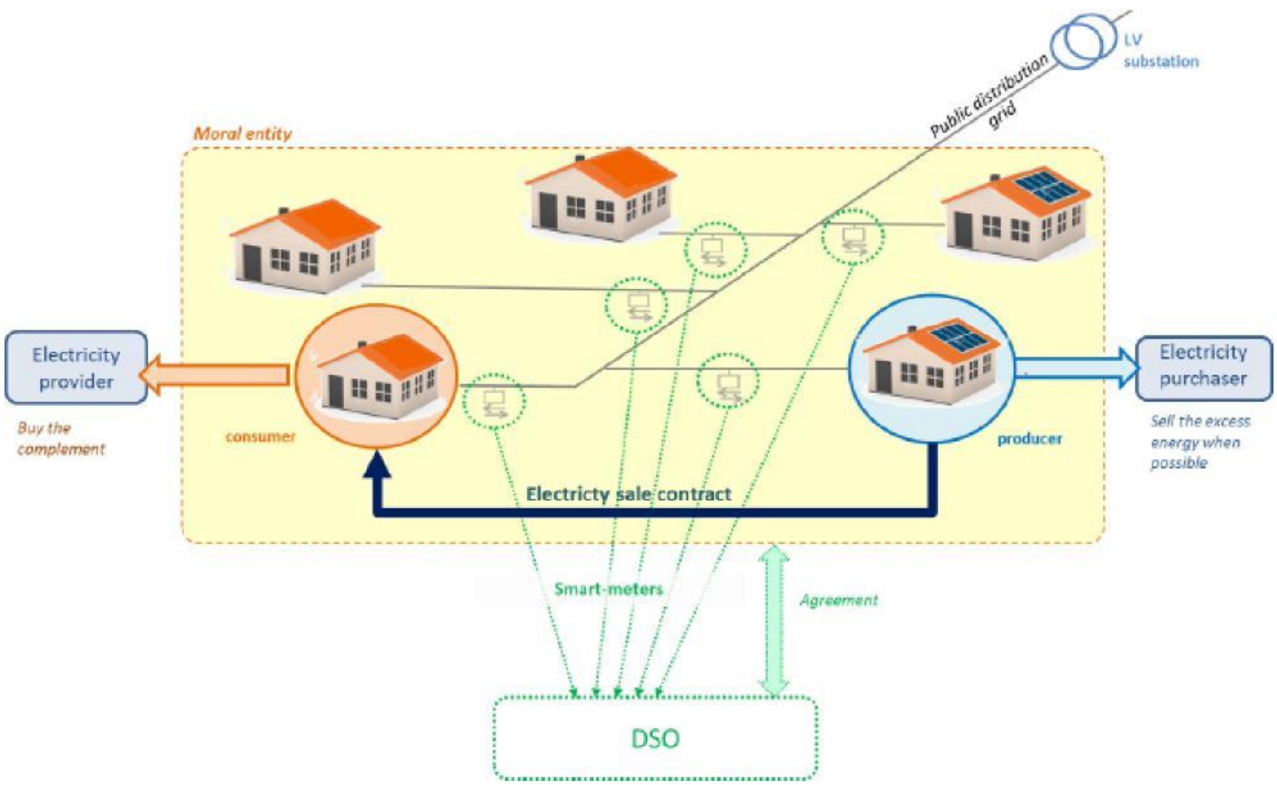
The “high season” corresponds more or less to the winter season while the” peak hours” are defined by the DSO.

5.2. Implementation of the self- collective consumption in the pilot of Saint Julien en Quint

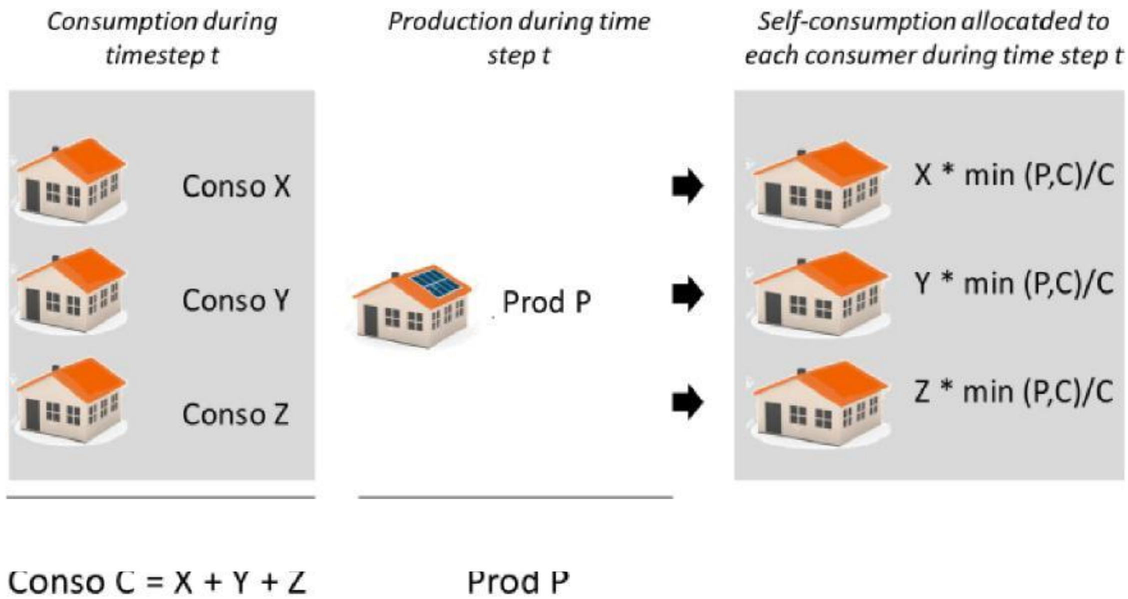
A citizen-owned local cooperative, called SAS Centrales Villageoises ACoPrEV Val de Quint, has been established in June 2018. This energy community will bear the investments in the RES plant and will also serve as the legal entity in the collective self-consumption scheme. Then, the consumers will also be shareholders.

The local energy community plans to invest in PV plants located on the roofs of various buildings through a rental agreement. It behaves as a third-party investor: investing in the equipment, paying for the operation costs and earning from the sale of electricity. This sale can be done through the collective self-consumption scheme with the local consumers or to an electricity purchaser.

Each consumer of the pilot can be supplied for a share part by the local energy community and by energy providers for the remainder. So each consumer has 2 contracts: one with the local energy community and one with an external provider and two meters.



The repartition between the electricity provided to each consumer on a collective self-consumption basis and that supplied by external providers is based on the pro-rata consumption ratio evaluate at a 10 minutes time step.



5.3. Cost-benefit analysis

The goal of the local energy community is twofold :

- the local consumers has to buy electricity by the cooperative at a lower price than the current electrical tariffs (or at least without any increase of the bill)
- the revenues of the cooperative have to cover the operating costs and the depreciation of the investment related to the installed PV plants.

To these purposes an adapted contract with the external providers supplying the complement electricity not bought by the local energy community has to be defined.

A further item impacting on the economic balance of the local energy community is the ratio between the generated electricity addressed to the collective self-consumption and that one sold according to feed-in tariff.

In order to economically balance the whole operation the citizen-owned local cooperative plans to invest on:

- a 35,28 kWp PV plant whose generated electricity of 44,1 MWh/year is devoted for 85% to the collective consumption, in so allowing a self-consumption rate of 85% of the pilot; the remainder electricity has not been economically valued;
- other three PV plants for a total of 87,86 kWp, selling the produced 115,9 MWh/year of electricity at a feed-in tariff of 12 c€/kWh.

The total request investment amounts to € 190.000.

The operational costs related to the dispatching of the electricity into the microgrid, the billing of the self-consumed electricity and the transferring of all the information to the DSO have been estimated in commercial terms of about € 50.000. Taking into account that these tasks will be probably managed in large part by the local cooperative members, without any charge, it has been adopted an annual cost of some thousands Euro.

For the financing of the investment it has been considered:

- grants up to 21% of the requested investment
- bank loan (duration 15 years, interest rate 2%) in the range from 60% up to 70% of the total investment
- equity (by cooperative members) on balance.

The following table summarizes the performed simulations in terms of the required price, taxes excluded, of the electricity supplied to the local community members to obtain a zero value of the Net Present Value.

Grant	Bank Loan	Equity	Required electricity price (before taxes) to obtain NPV=0
0%	70%	30%	**12 c€/kWh**
10%	67%	23%	**10 c€/kWh**
14%	63%	23%	**8 c€/kWh**
17%	62%	21%	**7 c€/kWh**
21%	60%	19%	**5,5 c€/kWh**

The above listed electricity prices must be considered in light of the current average local price of the electricity of about 8.5 c€/kWh: a grant not less than 15-20% of the requested investments is necessary to make competitive for the consumers the collective self –consumption in the context of financial sustainability for the local energy community.

Several simulations have been carried out to assess the sensitivity of the obtained results.

For instance the use of all the planned PV plant to supply electricity to the consumers (instead of selling 72% at a price corresponding to the feed-in tariff) does not entail any advantage to the economic balance of the citizen-owned local cooperative. Rather in the event no grant are allocated, the share of the PV plants addressed to sell their generated electricity through feed-in tariff has to be necessarily increased to assure competitive electricity price for the consumers.

Even small increases in the price of electricity over the time as well as some tax exemption on the electricity locally generated (in the simulations 20% of tax has been considered while in France the applied VAT on electricity is 5, 5%) make the collective self-consumption more interesting.

5.4. Social and institutional stakeholders reactions

The stakeholders were closely associated to the PEGASUS activities through the organization of several meetings that involved from time to time: the inhabitants of St Julien en Quint, technical and market players (design offices, installers, consulting companies), the local Municipality, the local grid operator and the DSO.

Thanks to this, the inhabitants could get up-to-date information on the project and confirmed in their answers to the distributed questionnaires that they were mostly motivated and already had all the necessary information regarding the pilot result. The reduced number of consumers and the uncertainty of an economic balance of the micro-network were perceived as the stronger threats, against which mitigation strategies were activated so that these risks must be sufficiently controlled for the operational implementation of the project. The most important stressed issue was the necessity to raise people awareness about microgrids to facilitate their acceptation and development. It has to be mentioned that the opinions of the participants were definitely positive for the French pilot micro-grid in the area of Saint-Julien-en-Quint.

5.5. Regulation Authority position

The Commission de régulation de l'énergie (CRE), the Energy Regulator in France, is strongly committed in the preparation of all the regulation linked to renewable energies and electric grids. Regarding the legislation on collective self-consumption, CRE carried out several actions:

- February 2018: deliberation and recommendations on self-consumption: launching of a public concertation on network fees, which lasted 5 weeks;
- May 2018 3rd and June 2018 7th: deliberation to modify the components of the network fees; proposition for a specific and optional grid tariff, with numerous components making a difference between self-consumed local electricity and electricity consumed from further production plants through the distribution grid. For the local electricity the taxes are decreased but for the complement, some components are increased, which makes this option not so interesting depending on the consumers' situation;
- June 2018, 19th: press release on the previous deliberation, to explain the position on network fees and also to recommend to avoid tax exoneration, contrary to individual self-consumption;
- September 2019, 26th: concerning the proposal to modify the legal perimeter allowed for the collective self-consumption projects and to increase the maximum power allowed the Regulator is contrary and prefers to keep the legislation as it is presently.

From the above it emerges a CRE cautious position on all the issues related to collective self-consumption. Despite the matter of fact that the consumers draw electricity from the nearest generation plants and thus the use of electricity locally generation should pay less taxes for the use of the grid, the Regulator is worried that the large scale application of the collective self-consumption could threaten the economic balance of the DSOs.

The fact is that it is quite difficult to meet Regulator representatives or make them give public speeches on the issue. AURA-EE made several attempts in organizing an official meeting with Regulator to present the lessons learnt from the pilot site analysis but it was always impossible.

6. The pilot of Saint Lawrenz

The pilot is located in the municipality of San Lawrenz on the island of Gozo, the second island of the Maltese archipelago. It includes 12 households, 1 commercial property and the San Lawrenz Local Council building, all connected to the same electric LV sub-station.

Consumers and producers of the pilot are below listed jointly with their annual electricity generation and consumption as they result from the monitoring campaign aimed to assess the consumption profiles of the residential users, the commercial building and the San Lawrenz municipality building. The committed power of all users is 13,8 kW (very high value indeed, especially considering that it is referred to residential buildings) with the exception of public and commercial buildings that commit 41,4 kW.

User no.	Building type	User type	Consumption [kWh/year]	PV plant power [kWp]	PV generation [kWh/year]	Self-consumption [kWh/year]	Electricity fed into grid [kWh/year]	Electricity withdrawn from grid [kWh/year]
01	Residential	Consumer	3.211	-	-	-	-	3.211
02	Residential	Consumer	3.522	-	-	-	-	3.522
03	Residential	Consumer	1.082	-	-	-	-	1.082
04	Residential	Consumer	8.051	-	-	-	-	8.051
05	Residential	Consumer	4.723	-	-	-	-	4.723
07	Residential	Consumer	3.489	-	-	-	-	3.489
08	Residential	Consumer	8.014	-	-	-	-	8.014
09	Public	Prosumer	20.179	36,50	58.407	5.468	52.939	14.711
10	Commercial	Prosumer	103.525	9,00	14.402	-	14.402	103.525
11	Residential	Prosumer	6.251	2,03	3.244	-	3.244	6.251
12	Residential	Prosumer	4.455	2,00	3.201	-	3.201	4.455
13	Residential	Prosumer	5.231	2,50	4.000	-	4.000	5.231
14	Residential	Prosumer	3.263	1,80	2.879	753	2.126	2.510
15	Residential	Consumer	5.134	-	-	-	-	5.134
		Total	**180.130**	**53,83**	**86.133**	**6.221**	**79.912**	**173.909**

In addition of RES uptake in the community, with the related reduction of the carbon footprint, there is specific interest towards microgrids for the Gozitan municipalities. In fact Gozo suffers of a "double insularity" being connected only to Malta (by ferry or private boats) and totally dependent from Malta for the energy supply. So the availability of a local efficient generation provided by microgrids can improve the reliability of the electricity supply and reduce the cost of electricity today distributed over long distances.

It has to be outlined that only two prosumers self-consume the electricity generated by the own PV plant: the San Lawrenz municipality building and one of the residential prosumer. The sale price of the electricity fed into the grid for the municipality building is equal to c€ 7,5/kWh while the average tariff for the consumed electricity amounts to c€ 13,73/kWh. For the residential buildings the electricity is billed at a tariff lower than the existing feed-in tariff for the electricity exported to the grid, as reported in the below table.

User no.	Building type	User type	Consumed electricity tariff [c€/kWh]	Feed-in tariff for exported electricity [c€/kWh]
09	Public	Prosumer	13,73	7,25
10	Commercial	Prosumer	16,73	20,00
11	Residential	Prosumer	16,07	20,00
12	Residential	Prosumer	12,98	15,50
13	Residential	Prosumer	16,07	22,00
14	Residential	Prosumer	12,98	22,00

6.1. Regulatory framework in Malta

Malta's power generation is limited to a monopoly held by Enemalta. Liberalization of the electricity market in 2007 year brought about partial completion limited to PV plant with dispatching priority on the network. Electricity generated by private producers has to either be self-consumed or sold to Enemalta at a fixed tariff.

Malta recently started buying electricity from the interconnector with Italy, however only Enemalta can buy energy directly from it.

In Malta, the distribution system operator and the electricity supplier are not legally separated from each other. Enemalta is the only owner and operator of the electricity grid, and current regulations prohibit independent third-party power suppliers or retailers to enter the energy market.

Electricity tariffs are defined by the Regulator for Energy and Water Services. They vary depending on the type of service (residential, domestic and non-residential) and on the amount of the annual consumption.

For the residential users involved in the pilot the tariffs are listed in the below table.

Band	Cumulative consumption [kWh/year]	Rate [c€/kWh]
1	up to 2000	10,47
2	2001 ÷ 6000	12,98
3	6.001 ÷ 10.000	16,07
4	10.001÷20.000	34,20
5	over 20.000	60,67

Regulations, 2010, (Legal Notice 422 of 2010) published in September 2010 established a Feed-in Tariff scheme for the electricity generated from solar photovoltaic together with the conditions for participation in such a scheme. It was established that electricity generated from PV installations was to be paid at:

- c€ 25/kWh for installations located in domestic premises over a period of 8 years, with maximum number of kWh that can be compensated per annum;the electricity that can be exported from any PV installation were allocated on 1.600kWh for any kWp with a threshold of 4800kWh/year;
- c€ 20/kWh was established for non-residential (commercial) premises for a guaranteed period of 7 years and the yearly threshold was set at 160.000 kWh.

The Regulations established an “improved” FIT of c€ 28/kWh for domestic installations located on the island of Gozo and commissioned in 2010 year.

Slightly amended FiT regulations were issued in each subsequent year with specific rates for residential and non-residential premises. Participation in the FiT scheme is accepted by the Regulating Authority on a first-come first-served basis.

Any electricity generated by PV installation and exported to the grid in excess of the yearly threshold or after the expiry of the guaranteed payment period is paid at the marginal cost incurred by Enemalta as approved by the Regulator for Energy and Water Services. The marginal cost varies from year to year and it is presently around c€ 7/kWh.

The Feed-in Tariff contract has two options as follows:

- Option 1: **full export** of the generated electricity; it usually preferred by prosumers with lower consumption and thus a price of electricity lower than the feed-in tariff;
- Option 2: **partial export** the generated electricity not consumed in real-time; it is usually preferred when high electricity consumption in order to reduce the withdrawals from the network with consequent fall in a less expensive band of consumption.

6.2. Cost-benefit analysis

In absence of any rule concerning the microgrid in the national legislation the adopted model consists in community energy system connected to the network through a single Point of Common Coupling.

Different microgrid configurations and operating ways, each one with appropriate related assumptions, have been simulated.

In the following reference is made to a collective self-consumption arrangement. The microgrid supplies its members with electricity purchased from internal prosumers and through withdrawals from the network. An Energy Management System assures the meeting of the electrical demand in real time as well as the exchanges with the network, both in input and output being the latter related to the internally generated electricity exceeding the demand.

The following assumptions have been considered:

- The electricity supplied to the microgrid members is discounted 10% in comparison with the current tariff for each consumer or prosumer,
- the electricity internally generated but not consumed in real time is sold to the network at a feed-in tariff rate of c€ 15,5/kWh,
- the electricity exceeding the self-consumption supplied by each prosumers to the microgrid is paid c€ 10/kWh; this price may appear penalizing for prosumers who currently benefit feed-in tariff rates in the range c€ 15,50/kWh ÷ c€ 22/kWh over a duration of 7 or 8 years; but after the expiry of the guaranteed payment period they would be remunerated at the marginal costs of c€ 7/ kwh; having to assess the sustainability of the microgrid over 25 years period time , a condition of greater advantage was also adopted for the prosumers.

Moreover an additional PV plant, 108 kWp in power, shall be considered for the microgrid. For the generated electricity of this plant reference was made to a plant having the same peak power installed on the building of Ministry of Gozo in Victoria. In a conservative way it has assumed that all the electricity generated by this additional plant is sold to the main grid at a price of c€ 7/ kwh for the same reason above explained.

The energy fluxes of the microgrid are below summarized:

- Total internally generated electricity: 258.933 kWh
- Electricity withdrawn from the main grid: 152.282 kWh
- Electricity fed into the main grid: 232.625 kWh.

As a result of energy exchanges with the network and the revenues related to the electricity sold to its members, the annual income for the microgrid amounts to € 15,182.

The required investments have been estimated in 150.000 € , resulting from:

- 135.000 € for the additional 108 kWp PV plant (1.250 €/kWp)
- 15.000 € for the Energy Management System and the Point of Common Coupling with the network.

These investments are supposed to be financed by:

- 75% by grant
- 25% by equity available from the energy community.

The annual operating costs of the microgrid are evaluated in 10.850 € determined by:

- 3.000 €/year as fee related to the use of the network infrastructure (annual 200 €/user)
- 1.250 €/year connected to the maintenance of the additional 108 kWp PV plant
- 6.600 €/year related to cost of the personnel involved in EMS and PCC management and in administrative/commercial duties.

The evaluated financial indicators evaluated over a period of 25 years present the following positive values:

- Net Present Value: € 30.216
- Internal Return Rate : 11,4%
- Simple Payback period : 8,75 years
- Discounted Payback period : 11,5 years.

6.3. Social and institutional stakeholders reactions

MIEMA organized several meetings with the local stakeholder groups : the building owners participating in the pilot in San Lawrenz, the representatives of the Ministry for Gozo and Gozo Regional Committee, other local councils and majors interested to replicate the pilot results. The bilateral meetings serve to keep all the involved stakeholders updated about the development of the project while at the same obtaining feedback in relation to their experience and their perception about the potential of microgrids within the local scenario. In all the meetings MIEMA presented PEGASUS project results in order to demonstrate how microgrids can help to improve the energy situation in the island Gozo in achieving a more reliable energy supply and in providing economic and environmental benefits.

MIEMA distributed questionnaires among the different stakeholders. The analysis of the received responses revealed the following:

- the majority of people are presently quite satisfied with the electricity supply in their locality and thus do not feel the necessity to move towards a more decentralized energy approach;
- a strong relationship between the community members exists as well as between the community and the local authorities; this is very positive for the establishment of energy communities;
- the level of knowledge in relation to micro-grids and energy communities is very low and thus more awareness is required;
- the perception about microgrids is overall positive where 68% of the respondents believe the microgrids will result in a better energy supply and 58% think that the implementation of a micro-grid in the community will have a positive local economic impact;
- with respect to the willingness of the stakeholders to become shareholders in an energy community, almost 50% of the respondents gave a neutral answer mainly because not enough knowledgeable to take a position while 40% of the respondents gave a positive answer.

6.4. Regulation Authority position

The meeting with the representatives of the Energy and Water Regulator was oriented to obtain the point of view of the Regulator with respect to microgrid implementation strategy and to assess the possibility of grants or other incentives for the deployment of microgrid based on renewable sources. The pilot carried out in Gozo was explained in detail to highlight advantages related to energy generation within micro-grids. The representative of the Regulator believe that the grid infrastructure in Malta is not ready to support micro-grids and certainly not autonomous systems that can be connected / disconnected from the network. The potential challenges and risks related to the use of microgrids in Malta were discussed with the Regulator to obtain more insight in relation to what mitigation strategies would be required for a successful implementation of an electric system allowing the integration of micro-grids.

It was also discussed how the use of microgrids can help to better meet the expected rising electric demand due to the increase of electric vehicles in the present energy scenario.

Feed-in tariffs for energy generated through renewables, grants and innovative financing models schemes for renewable energy system were also taken into account.

7. The pilot of the Municipality of Preko

The pilot, located on Ugljan island (Croatia), was developed by the Municipality of Preko that starting from 2015 year adopted a Strategy of Sustainable Development addressed to promote energy efficiency and renewable sources. The simulated microgrid is aimed to improve electrical supply security in connection with shutdown of network following thunderstorms.

The pilot includes a 10 kWp PV plant installed on the roof of an olive mill, one private and three public consumers located in the same building. All users are currently connected to the public network. The generation of the PV plant for the different yearly months has been evaluated through PV Sol Calculation software.

Month	Solar radiation [kWh/m2]	Average air temperature [ºC]	Generated electricity [MWh]	Electricity fed into the grid [MWh]
January	46,8	6,7	441	429
February	71,6	7,4	663	646
March	114,7	9,4	1.066	1.040
April	148,5	12,9	1.297	1.264
May	189,4	17,2	1.603	1.563
June	205,8	21	1.687	1.643
July	212	23,6	1.720	1.676
August	182, 0	23,1	1.514	1.474
September	134,7	19,8	1.182	1.153
October	96,7	15,8	885	862
November	52,8	11,5	474	460
December	36, 9	8,1	347	337
			12.879	**12.546**

The olive mill consumption is about 300 kWh /month in the season of olive oil production. The consumption of the 4 consumers is higher during the spring and summer seasons, also due to the use of air conditioning system. The measurement campaign performed in 2018 year confirmed the strong seasonal pattern of the electric consumption.

Month	Consumption [kWh]
January	153
February	415
March	589
April	802
June	1152
July	1500

The annual electricity consumption of the prosumer and the four consumers amounts to 12.145 kWh with a corresponding costs of 1671,33 € (average electricity price c€ 13,8/ kWh).

7.1. Regulatory framework in Croatia

Two laws regulate the generation from renewable sources : the Energy law (National Gazette no. 120/12, 14/14, 68/18) and the law (NG 100/15, 131/17).
Since January 2016, the electricity generation from renewable source was mainly promoted through a premium tariff allocated through public tenders. The Market Operator issues a call for tenders, at least once a year, within predefined national budget.
Producers of electricity from renewable sources, after they have been selected by the Croatian Energy Market Operator (HROTE) and have won the public tender as lower bidders, are entitled to the premium tariff, for a period of 12 years, after the connection of the generating plant to the grid. The premium tariff is defined by the formula CK = C x k1 x k2, being:

- C the basic tariff item (annually corrected on the basis of the annual consumer price index),
- k1 a corrective coefficient applicable to grid connected PV plants with installed capacity up to 300 kW and to non-connected PV plants with installed capacity up to 10 kW,
- K2 a corrective coefficient applicable to PV plant generating electricity used for water heating.

The following table lists C,k1,k2 values and the corresponding premium tariff applicable to roof-top PV plants.

Roof-top PV plant		Premium tariff				
type	Capacity	C [€c/kWh]	k1	Cxk1 [€c/kWh]	K2	Cxk2 [€c/kWh]
connected to grid	< 10kw	14,78	2,17321	32,12	1,09134	16,13
	> 10 kW and < 30 kW	14,78	1,84574	27,28	1,00000	14,78
	> 30 kW	14,78	1,36401	20,16	0,93640	13.84
Isolated	< 10kw	14,78	1,65494	24,46	-	-

Addressed to electricity producers for their own consumption (prosumers), there is a measure that does not serve as a support scheme, but rather as a protection for small prosumers who could encounter problems in finding a market operator willing to buy electricity in excess. This measure provides that the market operators are obliged to purchase excess electricity generated by paying them the following price:

- the premium tariff when the energy fed into the network is less than or equal to the energy drawn from the network,
- 80% of the premium tariff on the difference between energy consumed and energy produced when the electricity fed into the network is greater than that consumed.

7.2. Microgrid configuration solutions

Different configuration of the microgrid have been considered.

A ‘Net metering’ scheme, according to which the generated electricity exceeding the demand is fed into the public grid and then returned to consumers when the production is not enough to supply the electrical loads, could be an interesting solution. In fact, even if the energy generated by the PV PLANT (12.546 kWh/year) is almost equal, on an annual basis, to the demand of the 5 users (12.145 kWh/year), it is not at all certain that demand coincides with generation in real time. This solution would allow to almost reset the electric billing for users in the assumption that the capital and operating costs of the PV plant result in an electricity cost lower than the current one of c€ 13,8 /kW.

Considering the absence of a net metering scheme in the existing regulation, a possible alternative is to make use of an Energy storage system, with a capacity for minimum of 1-day storage,. that would be able to compensate in real time differences between electricity demand and generation.

Increasing the capacity of the PV plant installed on the roof of the olive mill, both through a net metering scheme or an energy storage system the generated electricity exceeding the users demand during daytime could be used for Preko´s public lightning.

For none of these alternatives, a cost-benefit analysis was developed.

7.3. Social and institutional stakeholders reactions

Three meetings were organised:

- with the employees of the Municipality of Preko,
- with the representatives of the local municipalities on the island of Ugljan,
- with the regional decision makers in the County of Zadar.

In all three events, the PEGASUS project results were presented to the participants. Specific focus was done about the possibilities of using renewable energy sources through microgrids and the achievable advantages.

The survey through questionnaires involved residents of the pilot area, technicians (installers and maintainers), politician and decision-makers from the Municipality of Preko and the County of Zadar,Business operators (ESCOs, engineering firms, technical consultants, power producers).

The analysis carried out on the filled questionnaires made evident that :

- more than 50% of the respondents is satisfied about the local electricity service and just as many welcome energy renewable sources,
- much less consensus is towards micro-networks and local energy communities.

8. The pilot of University of Cyprus

The pilot is located at the FOSS premises, within the campus of University of Cyprus. The pilot has also been used as a testbed in frame of a project aimed to transform the large campus of University into a self-consumption controllable microgrid fed by PV plants and Energy storage system in order to be able to operate either grid-connected or isolated in the event of a grid fault.

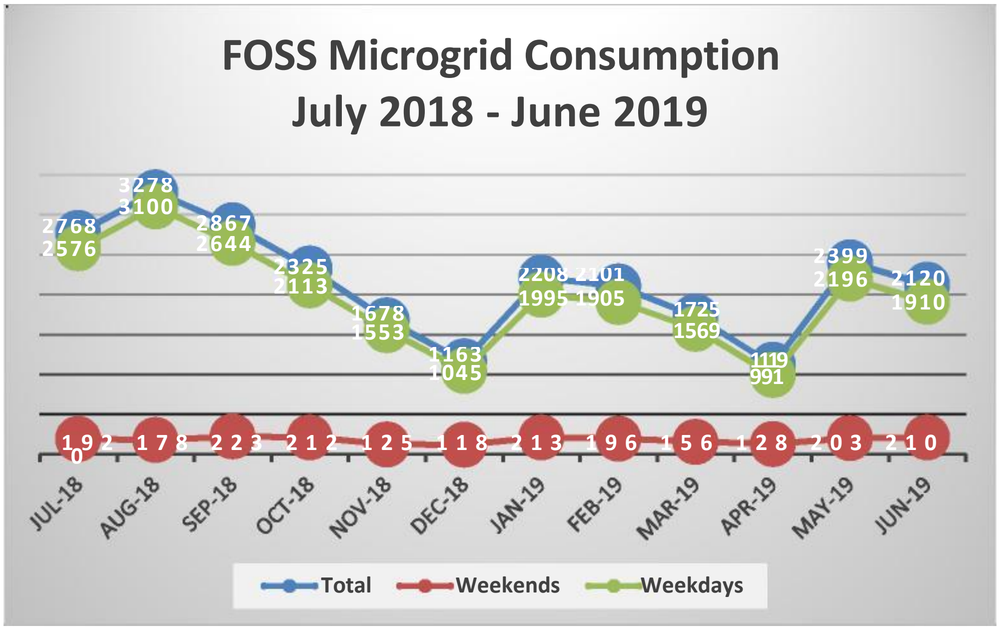
To this purpose tests have been performed on the pilot to validate the results and assists the simulated analysis.Different operating condition of the microgrid were simulated : steady-state both in grid-connected and islanding as well the dynamic operation during and the transition between the one and the other configuration.

It was also investigated the benefits that the microgrid can bring to the grid in terms of investment deferral in connection with the expected increasing load demand over the time and consequent increased grid congestion and/or voltage drop. If an operational limit (such as thermal limit of the line) is reached, new investments on network components are needed to mitigate this issue. Since maximum demand occurs only a few hours per year, the microgrid with internal generation and an appropriate energy storage system can reduce the maximum load demand and therefore reduce the losses on the transmission and distribution lines as well as to extend the life cycle of grid components. From the conceptual point of view the distributed generation and the energy storage of the microgrid substitute the “wires and poles” assets which would be required by a renewed and reinforced electric line.

The pilot considered for financial viability purposes includes in addition to a PV intermittent generators :

- 9,8 kWh battery storage system,
- electrical loads (air-conditioning units, lighting, two refrigerators, office equipment, etc.) of the FOSS Research Centre,
- programmable electrical load of 4,5 kV able to emulate alternative load capabilities and residential consumption profiles,
- a dedicated Energy Management System.

The monitoring campaign carried out over a whole year allowed to assess the electricity consumption of the FOSS Research Centre during working days and weekends, as below shown.



In order to characterize the generation capability of the PV plant to be considered in the economic analysis, reference was made to the existing 34,9 kWp in the University Campus for which was available the monthly electricity produced in the period 2014-2019.

The operation of the pilot provide that the battery storage system is generally charged during periods that PV generation exceeds the microgrid loads, in order to maximize the self-consumption and minimize grid withdrawals during peak hoursin order to minimize the electric bill.

8.1. Regulatory framework in Cyprus

Currently in Cyprus operates a scheme for subsidizing the production of electricity from renewable sources for own use which includes:

- **net metering, for PV system with capacity up to 10 kW and for all consumers,**

- net billing, for RES systems (mainly PV and biomass), with a capacity from 10 kW to 10 MW for commercial and industrial consumers and for off-grid RES, with limitation of capacity.

In the net billing scheme, customers are billed on the energy consumed from the grid at the retail electricity price and receive a credit based on a variable tariff known as the 'avoidance cost' for any excess power they feed into the grid during each billing period. The 'avoidance cost' is intended to reflect the savings for the country by avoiding the generation from fossil-fueled plants.
If the PV system owner generates more electricity than consumed during any period, the avoidance cost credit is rolled over into subsequent billing periods and is to be cancelled out over the course of each year.
In the net billing scheme the prosumers are taxed on all the consumed electricity , whether generated on site or withdrawn from the grid, and also they pay a fee for using the network.

The electric bill of the University of Cyprus are based on Time of Use (ToU) tariffs different by season, by working days or weekends and the hours of day.

Months	Days	Hours	Price Periods	Electricity price [€/ kWh]	Fixed Fee [€]
from October to May	Working days	16:00 – 23:00	P1	0.1783	0.086 per day
		23:00 – 16:00	P2	0.1644	
	Weekends	16:00 – 23:00	P3	0.1738	
		23:00 – 16:00	P4	0.1605	
from June to September	Working days	09:00 – 23:00	P5	0.2229	
		23:00 – 09:00	P6	0.1745	
	Weekends	09:00 – 23:00	P7	0.1771	
		23:00 – 09:00	P8	0.1719	

On the electricity generated by PV plant and fed into the grid is remunerated at the avoided generation cost , equal to c€ 12,11/kWh. For the electricity self-consumed and withdrawn from the network the following listed costs are paid.

Public service obligation	0,083 [c € / kWh]
Green tax	1,00 [c € / kWh]
Net billing charge for all energy self-consumed	1.63 [c € / kWh
VAT applied on all traded energy (exported or imported)	19.00%

8.2. Cost benefit analysis

The objective of the economic analysis is related to the current operation of the FOSS microgrid.
The financial viability of the microgrid making use of a PV intermittent generation and Battery Energy Storage System has been evaluated adopting the net billing scheme above described.

The BESS is generally charged during periods that PV generation exceeds the microgrid loads, in order to maximize the self-consumption and minimize grid purchases during peak hours.

In order to find the more effective investment option, different PV plant power (10 kWp , 15 kWp, 20 kWp and 30 kWp) and two BESS capacity (30 kWh and 50 kWh) have been considered, taking into account for the resulting microgrid configuration:

- the capital costs, having adopted a capital cost of 1.000 €/kWp and 400 €/kWh for the PV plant and BESS, respectively;
- the operating costs;
- the obtained bill reduction in comparison con the microgrid without any PV plant and BESS;
- the resulting payback period.

The results of the analysis carried out are below listed.

Microgrid configuration	PV plant [kWp]	BESS [kWh]	Capital costs [€]	Annual Bill [€]	Savings [€]	Payback period
0	-	-	-	5.291	-	-
1	10	-	10.000	2.983	2.308	5 years
2	10	30	22.000	2.634	2.657	12 years
3	15	-	15.000	1.709	3.582	5 years
4	15	50	35.000	1.089	4.202	13 years
5	20	-	20.000	1.592	3.699	6 years
6	20	50	40.000	980	4.310	14 years
7	30	-	30.000	1.547	3.744	10 years
8	30	50	50.000	968	4.323	19 years

In the 15 kWp PV plant without storage configuration the annual generating electricity by the PV plant (25.213 kWh) meets the annual demand of the microgrid equal to 25.751 kWh and thus resulting the optimal one in economic terms.

8.3. Social and institutional stakeholders reactions

The meeting with stakeholders took place at the Municipality of Aglantzia (Nicosia) having the opportunity to inform on the results of the FOSS microgrid pilot, whose size can be assimilated to that of a local energy community. During the meeting, participated by local inhabitants, politicians and decision-makers, business and market operators (ESCOs, engineering firms, technical consultants, power producers, TSO), recommendations were developed on how to promote the consumption energy in a responsible way and to promote renewable sources.

The most significant results by the questionnaire analysis are the following:

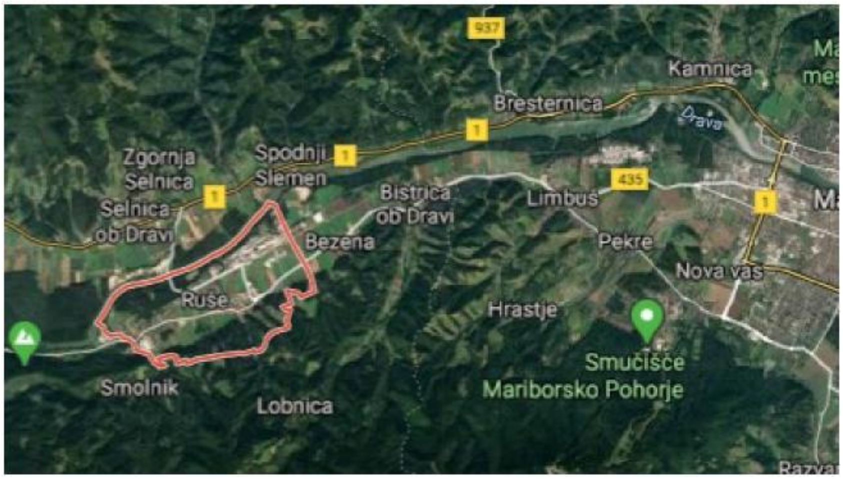
- there is a strong feeling of energy community;
- the concept of energy communities is highly appreciated by the residents who are more than ready to act as community members; they are positive as far as it concerns the way they seek and desire the energy communities;
- it is common opinion that the energy communities will lead to technological advances with related benefits in terms of employability, services and quality of provided services;
- people are ready to welcome energy communities as the technology requested exist: what is missing is the regulation and the political eagerness on the subject.

Overall, it can be summarized that the local residents are definitely positive for the proposed pilot micro-grid in the area of Aglantzia and they all appreciate and consider very crucial the involvement of the responsible sectors towards this direction.

8.4. Regulation Authority position

FOSS team had the opportunity to present PEGASUS project results to the Energy Regulators of the Mediterranean area (MEDREG) into the framework of a workshop organized by the Cyprus Energy Regulatory Authority (CERA). Starting from the FOSS microgrid pilot the potential benefits and the risks associated with the microgrids were discussed during the workshop and some recommendations were developed in considering the political objectives and the current market situation of each country of the Mediterranean area.

9. The pilot of the Municipality of Ruše



The pilot concerns the sport resort of the Municipality of Ruše (Slovenia) whose two main buildings are the Sport Parc, with an area of 2868 m^2, and the Sport Hall with an area of 2197 m2. The pilot is aimed to demonstrate the financial viability of a microgrid, grid connected, including the two buildings and with internal electric generation by a 100 KVp PV plant.

The electric consumption of the microgrid in 2017 year is below listed together with the corresponding costs.

2017 year	Annual Electric consumption [kWh]	Annual costs [€]
Sport park	421.817	48.180
Sport Hall	55.687	8.953

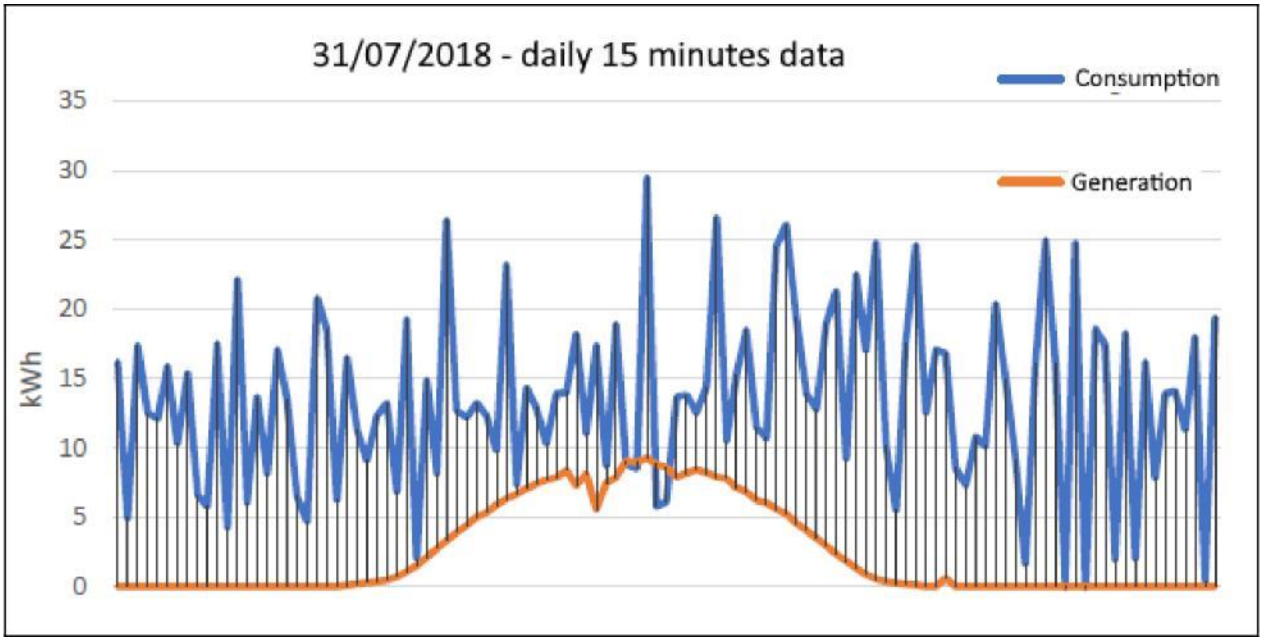
The heating of the Sport Park is carried out through natural gas fueled boiler with an annual consumption of 1.205.414 kWh$_t$ while the Sport Hall is conditioned by a wood biomas boiler.

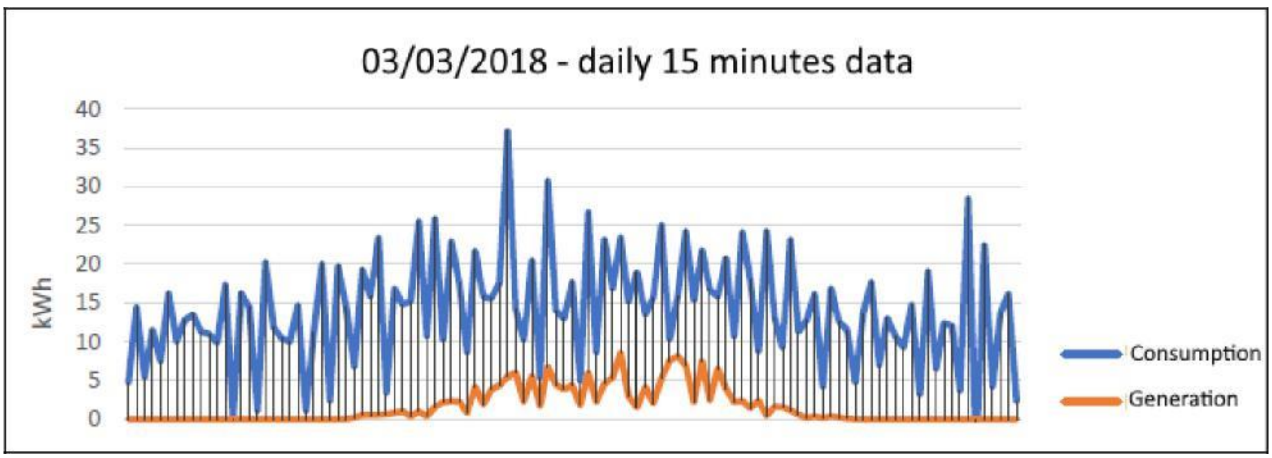
For the characterizazion of the generation capacity of the 100 KVp PV plant reference was made to the two existing PV systems installed on the roof of the two buildings and having a total power of 99,77 kWp. The annual generation of the considered PV plant has been evaluated using tools offered by the PVGIS phothovoltaic geographical information system, resulting in 114.050 kWh for a plant with nominal power of 99,77 kWp. The measurements performed on the two existing plants between March and November of 2018 years give a total generation of 97.930 kWh representing 86 % of the annual evaluated production and thus confirming the validity of the forecast data.

In order to verify the degree of local usability of the electricity generated, appropriate measurements were made on the two buildings daily load and generation daily profiles by the existing PV plants.
The reliefs on two representatives days are below shown :

- relief on 07/31/2017 with the maximum generation in the year, equal to 278 kWh,
- relief on 03/03/2018 during wich the generation was 174 kWh.

In both cases, all the energy generated can be self-consumed, as was expected given that the generation of 100 KVp PV plant represents 22% about of the microgrid consumption.





9.1. Regulatory framework in Slovenia

The regulatory framework in Slovenia does not support or oppose the implementation of microgrids.

In Slovenia, prior to 2015 year the electricity production of big PV installations was incentivized with very remunerative Feed-in-Tariffs. To limit the state's budget expenses, in 2015 year a Net-Metering regulations was introduced by the Decree on self-supply of electricity from the renewable energy (Official Gazette of the Republic of Slovenia, No. 17/14 and 81/15).

The net-metering support scheme is available for households and small businesses. The goal of the policy is to encourage electricity self-consumption rather than the production for export to the grid. Accounting period is occurring at the end of each calendar year. Owners of self-supply devices will thus receive only one electricity bill for the entire year, which will take into account the difference between consumed and produced electricity. Since the amount of the generated electricity is higher in the summer than in winter, the electricity produced in the summer and exceeding the local demand can be used free of charge in the winter time. In the event at the end of the calendar year there was more electricity fed into the grid than that withdrawn, the surplus will not be remunerated.

The owners of CHP and PV plant have to pay the network charge as well as the charge related to the committed power of the site.

There is an overall yearly connection limit of 10 MVA: 7 MVA are intended for the households and the remaining 3 MVA addressed to business. The size or nominal power of the device is limited to 11 kVA or to the power of the existing connection of the site.

Amendments are currently proposed to increase the amount of power annually permitted to self-supply devices (15 instead of 7 MVA for household consumers and 5 instead of 3 MVA for small business consumers) and to introduce a maximal current power level which may be transmitted from meter point to the public grid (11 kVA).

Furthermore, EKO Fund offers investors a grant to build solar power plants using the Net-metering scheme and addressed to self-consuming. The amount of the non-refundable financial incentive amounts to up to 20% of the recognized investment costs, but not more than €/kWh 180 per each kVAp of the installed device.

9.2. Cost-benefit analysis

Assuming an annual generation of 99.694 kWh/year, equal to that produced by the 99,77 kWp PV plant in the year 2017, the resulting billing reduction amounts to 11.814 €/year being c€ 11,85/kWh the tariff rate in 2017 year.

Estimating in 1.100 €/kWp the unit cost of PV PLAN, the requested investment amounts to 110.000 € that can financed through a 15 years loan at an interest rate of 1,8%, resulting in a total (principal plus interests) amount paid of 126.722 €.

On the above basis the following financial indicators result:

- Net Present Value, discounted at 1,95% : € 25.645
- Internal Return Rate : 4,5%
- Simple Payback period : 10,73 years.

9.3. Technical and economic assessment for the installation a CHP system

Due to the large demand for thermal energy of the swimming pool and for sanitary water at the Sports Park, it has been considered whether a cogeneration plant for the combined production of electricity and heat is a feasible option for the microgrid.

Making reference of the thermal energy consumption of the Sports Park, equal to 1.205.414 kWh_t, a CHP with 81 kW max thermal power and 50 kW electric power , a total efficiency of 90,3%, has been considered.

It has been evaluated an operation of 6500 h/year with consequent generation of 526.000 kWh_t and 325.000 kWh_e . According to existing regulation all the generated electricity is considered self-consumed (no electricity is fed into the grid). So the remaining 678.914 kWh_t of thermal energy are supplied by the existing boiler and the 152.504 kWh_e of electricity is withdrawn from the grid.

The requested investments for the purchase and installation of CHP system are below listed while the maintenance costs has been evaluated in 10.071 €/year.

	Investment (1) [€]
CHP Viessmann Vitobloc EM-50/81 purchase	91.500
Installation and commissioning	4.500
Hydraulic and mechanical accessories (Heat exchanger, pipe connections (water, gas), pumps for circulation, fittings, calorimeter, gas meter, flue gas capacitor, chimney, hot water accumulator, thermal insulation) purchase and installation	35.000
Electrical accessories (supply cables, electric lock cases), protection, gas alarm, technical documentation	12.500
Total	**143.500**

(1) VAT included

The investment is financed by a loan at an annual interest rate of 2,8% resulting in a lending cost of 11.772 €/year.

The energy balance and the relevant costs in the current situation and with CHP system is below shown.

	Current situation		**With CHP SYSTEM**	
	Quantity [kWh]	**Cost [€]**	**Quantity** [kWh]	**Cost** [€]
Thermal energy from boilers	1.205.414	61.798 (1)	678.914	34.828 (1)
Electricity withdrawn from grid	477.504	55.321 (2)	152.504	17.668 (2)
Thermal energy from CHP	-	-	526.500	53.510 (3)
Electricity from CHP	-	-	325.000	
Total		**117.119**		**106.006**

(1) At a rate of 0,1159 €/kwh
(2) At a rate of 0,0513 €/kwh
(3) At a rate of 0,0513 €/kwh x 1043080 kWh.

Taking into account the lending costs and the maintenance cost, the total costs with CHP system increases to 127.849 €/year which is 10730 € higher than the total cost in the current situation. Despite the increased energy efficiency of CHP compared to the separate generation of heat and electricity, the operation with CHP is not profitable, due to the low difference between the price of electricity and that of natural gas.

9.4. Social and institutional stakeholders reactions

The main local stakeholders have been involved from the beginning on the pilot microgrid in the Municipality of Ruše. The results of the analysis carried out on the questionnaires can be summarized as follows :

- people awareness of their own electricity generation potential capacity is not high; large share of the people are aware of recently enabled possibility to jointly set up a PV power plant but the opinion of the majority is that society is not mature enough (or they doubt if it is) for such forms of cooperation;
- nevertheless 43% of the interviewed people would joint for the implementation of a PV plant together with their neighbors, without delay;
- the general opinion is that the implementation of microgrids makes sense and may be useful and beneficial; however, they believe that there are problems in achieving a low cost of the generated electricity and on the security of supply;
- the main barriers to the faster penetration of microgrids have been identified in the high costs of purchasing a renewable source and in inadequate knowledge of how to calculate the cost of the related generated energy.

The outcomes and results on the developed pilot were presented in a dedicated meeting during which the above results of survey carried out by means of questionnaires were taken into consideration.

9.5. Regulation Authority position

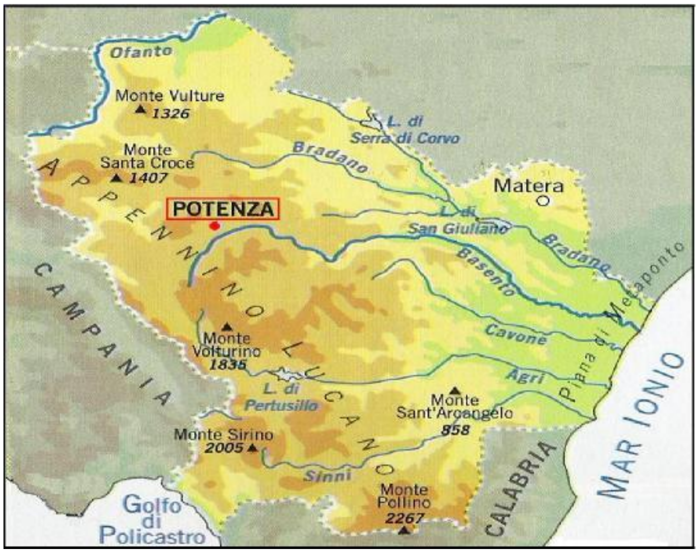
The meeting with Energy Regulator in Slovenia was addressed to get the latest guidelines concerning microgrids and how to foster the electricity market towards a large presence of prosumers. The Energy Regulator position is below summarized.

There are many regulations on EU level that that need to be transferred into Slovene legislation. This is because the existing infrastructures have to be improved to be more flexible and efficient through new technologies. Moreover an increased awareness of the stakeholders is required.

Energy Regulator will launch a public consultation about flexibility, including the identification of new market players with specific roles, responsibilities and potential benefits. The public consultation about the regulation on establishing flexibility of the market started in Slovenia at July 2019 and will be finalized in December 2019. On the national regulator side are the current objectives are the standardization of procedures, the interoperability and the adjusting of the market specification. The legislation in Slovenia already allows the self-consumption also for multi-apartment buildings and the scheme is very favorable for consumers. But there are many administrative and knowledge barriers for a wider implementation.

Many educational and informational activities have to perform at different level to be ready for smart grids, microgrids and energy communities.

10. The pilot of the Municipality of Potenza



The pilot includes two energy-intensive infrastructures owned by the Municipality: the swimming pool located in the Montereale Sport Park and the Santa Lucia escalator, 600 meters long, connecting the outskirts to the city centre. The thermal energy demand in the Swimming pool varies during the year from 3 to 5 times the electricity consumption. The 19 drive motors of the escalator are supplied with two 500 kVA power transformers.

The pilot was aimed at demonstrating the achievable advantages by the application of the Italian regulation "Scambio sul posto Altrove", according to which two or more plants can be considered as a single electric user under the condition that a renewable generation is operating at least in one of the involved sites.

Thermal and electrical consumption of the swimming pool and escalator resulting from the monitoring campaign carried out during the whole 2018 year are below listed.

2018 year	**Swimming pool**		**Escalator electrical consumption** [MWhe]
	Thermal consumption [MWht]	**Electrical consumption** [MWhe]	
January	271,4	39,2	40,7
February	244,9	35,6	36,1
March	247,0	37,2	37,9
April	146,8	37,5	31,5
May	129,2	41,5	39,4
June	79,3	39,5	33,6
July	73,0	39,5	35,1
August	36,0	13,4	29,7
September	74,7	26,0	27,2
October	145,5	38,4	31,4
November	202	37,2	30,7
December	249,2	37,9	31,5
Total	**1899,0**	**422,9**	**404,8**

A high efficiency Combined Heat Power system, able of primary energy saving more than 10% compared to the separate generation of electricity and heat, has been considered in partial replacement of the existing condensing boiler of the swimming pool. The electricity generated by CHP and exceeding the swimming pool demand is fed into the public distribution network. In a symmetrical way electricity is withdrawn from the network when local demand overcomes the electric power available from CHP.

In order to maximize the efficiency of the cogenerator it operates in heat driven mode and always at its maximum power for the only time necessary to meet the swimming pool thermal demand. When thermal demand exceeds the maximum thermal power of the cogenerator, the pre-existing boilers start operating.

Five CHP with a maximum thermal power of 60, 120, 180, 240 and 300 kW_t have been taken into consideration simulating their operation over 2 million data acquired during the whole year. The most performing CHP size in terms of return on the related investment has a maximum thermal power of 120 kW_t, a corresponding 65 kW in electric power with a natural gas consumption of 21,24 smc /h. The annual generated electricity by this CHP amounts to 457.4 MWh, of which 366.3 MWh covered large part of the swimming pool demand (thereby reducing the overall withdrawals from the network) and the remaining 91.1 MWh were fed into the grid.. The monthly data together with the increased consumption of natural gas are below listed.

2018 year	**Increased consumption of natural gas [scm]**	**Avoided electricity from the grid [MWh]**	**Electricity fed into the grid by CHP [MWh]**	**Electricity withdrawn from the grid by swimming pool and escalator [MWh]**
January	6.303	38,8	9,5	41,1
February	5.692	35,4	8,4	36,3
March	6.294	36,7	8,7	38,4
April	6.097	37,3	9,6	31,8
May	6.260	40,9	6,8	40,0
June	5.713	35,3	2,8	37,8
July	5.429	34,5	1,4	40,1
August	1.320	0,7	2,2	42,4
September	5.124	13,6	12,2	39,6
October	6.196	31,4	9,4	38,4
November	6.099	30,9	9,7	37,0
December	6.301	30,8	10,4	38,6
Total	**66.802**	**366,3**	**91,1**	**461,4**

10.1. Regulatory frame in Italy

A specific regulation concerning microgrid doen't exist currently in Italy.

Prosumers connected to the grid can applied the net billing rule, called "Scambio sul posto" (Regulation 570/2012/R/efr *by* Italian Regulatory Authority for Energy, Networks and the Environment). According to this the billing of the electricity withdrawn from the grid is computed using the common retail prices.

The electricity fed into the network entails a refund assessed taking into account also the electricity withdrawn. Every month this refund C is equal to:

$$C=min[OE\ ;CEI]+CUsf\times Es$$

being:

- $OE = Ep \times PUN$ where Ep the total monthly withdrawn electricity and PUN is the national average monthly price of electricity resulting from the Italian electricity exchange;
- $CEI = Ei \times PZ$ where Ei the total monthly electricity fed into the grid and PZ the average monthly price for the totality of electricity fed into the grid; this price is different for the 6 areas of the national territory (North, Central-North, Central-South, South and the two major islands) and it is defined on the basis of the sale contracts agreed during the month in each area;
- $Es = min[Ep\ ;\ Ei]$;
- $CUsf = CUsfnet + CUsfosg$ where $CUsfnet$ are the fees (€/kWh) for transmission, distribution, metering and dispatching services while $CUsfos$ are general charges (€/kWh); both the terms are defined and periodically updated by the Italian Regulatory Authority for Energy, Networks and Environment; in case of a high efficiency cogeneration $CUsf = CUsfnet$ only.

At the end of the year, in the event the annual electricity fed into the network is greater than the one annual withdrawn from the grid an additional reimbursement is granted, equal to:

$\sum CEI\ y - \sum OE\ y$ being y= 1, 2 ....12.

The monthly average values of PUN and PZ (referred to South-Central zone where is located the pilot) for the year 2018, used for the economic evaluations, are below listed.

2018 year	PUN (€/MWh)			PZ (€/MWh)		
	Band F1	Band F2	Band F3	Band F1	Band F2	Band F3
January	55,96	53,98	41,81	51,65	49,81	42,33
February	65,60	61,48	47,88	62,72	56,03	46,86
March	63,68	63,09	47,88	56,41	56,56	44,44
April	53,88	56,15	43,67	50,84	49,01	36,48
May	59,09	60,50	45,61	57,85	54,54	41,90
June	62,40	53,98	41,81	61,18	53,15	51,18
July	66,65	66,65	57,75	63,88	59,61	52,30
August	69,93	71,57	64,03	67,47	64,15	60,37
September	82,82	79,89	69,84	67,47	64,15	60,37
October	80,72	79,02	65,54	71,95	72,5	63,88
November	76,52	69,72	57,75	70,83	66,56	58,11
December	74,65	69,64	57,98	69,73	66,12	57,26

The average value of term *CUsfnet* referred to the CHP considered in the pilot amount to 19,57 €/MWh.

From the above explained rules it follows that the refund is null in absence of electricity fed into the grid(*Ei*=0; this is the case of a consumer) or in absence of electricity withdrawn (*Ep*=0 ; this is the case of a producer).

The monthly reimbursement is maximum when *Ei*= *Ep* and it is equal to (PZ+ *CUsfnet*) per ogni kWh exchanged in input (or in output) with the grid.

The "Scambio sul posto" applicable to any prosumers, finds a particular application in the case of two or more public sites, owned by the same Municipality. The sites are considered as an unique prosumer under the conditions that at least one of them is equipped with an electrical generation from renewable. The refund is therefore evaluated by taking into account the exchanges of electricity with the public network of all the sites. For the pilot of the Municipality of Potenza this means to consider the exchanges by the swimming pool and by the escalator as if they were made by the same user.

10.2. Cost-benefit analysis

The CHP greater energy efficiency and the net billing applied to the total energy exchanges with the network , in input and output, by the swimming pools and the escalator result in billing reduction for the Municipality, as it was in the pilot's objectives.

In the following these benefit are evaluated referring to the data of the year 2018.

The greater consumption of natural gas, equal to 66.802 scm, entails an additional cost of 52.129 €/year.

Given the high efficiency of the gas fueled cogenerating system it benefits of:

- a reduced excise tax for an annual amount of 19.225 €/year,
- the achievement of 47,3 "energy efficiency certificates" (TEE) with a corresponding value of 13.258 €/year.

The electricity generated by CHP and self-consumed in the swimming pool, equal to 366,3 MWh/year, reduces the electric billing by 86.404 €/year.

The refund due to the "Scambio sul posto" amounts to 6.300 €/year, bringing the cumulative economic benefits to 73.058 €/year.

The estimated capital costs for the installation of CHP in the swimming pool are the following:

- CHP purchase and installation : 107.500 €,
- Thermal Control Unit managing the operation of CHP and condensing boiler: 10.000 €,
- Bidirectional meter accounting the electricity fed and withdrawn from the grid and the procedural costs the eligibility to the "Scambio sul posto" rules: 5.000 €,

- Engineering services carried out for swimming pool plant adaptations, equipment procurement and installation and commissioning : 35.000 €,
- VAT(assuming the investment carried out by the Municipality that is not entitled to recover this tax): 34.650 €.

The useful life of the more critical parts of the identified CHP is around 60.000 operating hours at full power. After this operational limit the system requires a strong reconditioning consisting in the replacement of the natural gas fueled motor and an extraordinary maintenance of other components (heat exchangers, generator, electrical panels, etc.) in order to assure the CHP operation for additional 60,000 hours at full power and in reliable conditions of full functionality and reliability. Since CHP operating time at full power has been evaluated in to 7768 h/year it is mandatory to consider for the system a reconditioning intervention at the end of eighth year, with a further investment of 53.680 €, getting the total investment over a period of 16 years to 245.830 € financed by a bank loan with a duration of 16 years at 3% of interest rate.

The operating expenditures, mainly due to the CHP maintenance costs are below listed for the whole useful life of the system.

Year	**O&M Costs [€]** (VAT included)
1st and 9th	8.906
2nd and 10th	9.272
3rd and 11th	9.943
4th and 12th	10.858
5th and 13th	12.078
6th and 14th	13.603
7th and 15th	15.372
8th and 16th	17.568

Taking into account the evaluated economic benefits, CAPEX and OPEX the following financial indicators have been obtained:

- Net Present Value, discounted at 3,5%, after 16 years : 480.000 €
- Internal Return Rate: 11,4%,
- Payback period: 3,26 year.

10.3. Social and institutional stakeholders reactions

Within the ENERGYDAY event organized in Potenza a presentation of the PEGASUS project results, particularly concerning the local developed pilot, was given.

The analysis of the respondents on the questionnaires distributed to the local stakeholders made evident a lack of knowledge on the “Scambio sul posto Altrove” scheme applied in the pilot of the Municipality of Potenza. In light of the achieved results a high percentage of respondents judged positive the development or the participation in similar initiatives fostering the development of distributed energy generation from renewables.

High share of the respondents confirm the expectations from the “Scambio sul posto Altrove” application on the containment of costs and optimization of energy consumption for the involved users. Prudent optimism has emerged on the opportunities for the small communities of the Basilicata Region about the local employment in connection with local generation systems. 70% of the respondents considered the awareness of the public decision makers in order to comply with initiatives based on the regulation, thus favoring initiatives facilitating the access to credit for investments to be used to implement projects based on it.

10.4. Regulation Authority position

The meeting with the Italian Regulatory Authority for Energy, Networks and Environment (ARERA) concerned the future prospects of the regulation “Scambio sul posto Altrove” and more generally the guidelines on the microgrids.

Taking into account that most of the prosumers who benefit of the *Scambio sul posto* regulation are domestic prosumers, the Regulator is oriented to maintain this regulation, which is simplified compared to other forms of incentives for renewable sources, specifically for domestic and similar customers by limiting the maximum power value of the generating plant to 20-30 kW at the most.

For renewable plants with greater power the Regulator intends to favor the development of an "aggregator subjects" performing all the organizational and commercial functions related to put on the market the generated electricity by the prosumers. These aggregators would identify a new role in the area of electricity distributors in the context of a progressive diffusion of the distributed resources of generation and of an increasing active management of networks. The electricity produced by medium-sized renewable sources (above the threshold set for domestic customers) is made available in visible form (through an identified Point of Delivery, similarly to all producers) to the TSO and the prosumers can be asked to contribute to the overall management of the network, without prejudice to the existing incentives directly related to the renewable generation.

In this context the *Scambio sul posto Altrove*, which more correctly should not have limitations related to the number of inhabitants of the municipality but related to the same electrical node supplying the involved public utilities, will likely have an evolution similar to that of the *Scambio sul posto*, favoring for medium power size the use of aggregators. Pilot projects are underway for the purpose to collect useful elements especially in terms of evaluation of these possible new resources for electricity dispatching.

About microgrids the Regulator makes a clear distinction between microgrids operating with proper private network and microgrids connected to the grid and using the existing infrastructures. According to the Italian regulation the former ones can benefit not only of a reduction in transport costs of the electricity but also of the avoided general charges of the electric system (about 1/3 of the existing tariffs in Italy). This is not seen positively by the Regulator because new infrastructures involve additional investments and moreover the non-payment of general system charges by some users entails a greater burden for the remaining users.

Instead on the local energy communities making use of the existing infrastructures, there is the widest willingness. No specific laws are present in the national legislation on energy communities as expressed in the new European directives. ARERA is preparing indications to the Italian legislator which has to implement by 2020 the law framework on the basis of the European Directives: the "Renewable Energy Community" (hereinafter: REC) in RED II and the "'Citizen Energy Community" (hereinafter: CEC) in the Electricity Directive.

The Regulator envisaged that the Renewable Energy Communities have to be established as entity with a productive-commercial function (and therefore with its own Point of Delivery) and thus able to receive the electricity locally generated, as well as to sell electricity and to purchase electricity in order to ensure the local energy community demand. The members of the community purchasing electricity from this entity can benefit of a reduction on the common distribution and transportation charges.

A special case may be the multi-apartments residential building in the future regulation. In fact RED II provides that residents of the same building may also be granted the status of "*self-sustaining renewable energy users acting collectively"*, and Member States have to provide for differentiated treatment between "*self-sustainers of renewable energy"* and "*self-sustainers of renewable energy acting collectively"*. The Electricity Directive introduces the concept of *active customer*, understood as a final customer or a *group of customers jointly acting* that consume or accumulate or sell the generated electricity (whatever the source) on its own sites within defined boundaries, provided that these activities are not the main activity.

In this context it could be envisaged that each resident of the multi-apartments will continue to purchase the electricity from their own sales company (preserving the rights of each end customer, including that of choosing one's own seller) and that, subsequently or contextually, be assigned to a referent of the building (such as the multi-apartment administrator, or another person delegated by the residents) the greater value of the self-consumed electricity (equal to for each hour at the minimum between the electricity produced on site and fed into the grid and the electricity drawn from the the totality of apartments). This value of the self-consumed electrical energy - in order to avoid more complex analyzes - could be set equal to the transmission and distribution tariffs, without prejudice to the general system charges paid by each resident.

11. Conclusion

The analyses performed within the seven developed pilots demonstrated that, under appropriate assumptions, the improving of renewable sources to generate electricity, and in some case also heating, locally consumed is not only energy efficient but also economically profitable.

The performed simulation, based on measured profiles of local loads and internal generation systems, have shown that the implementation of microgrids within a more open and flexible electrical system is possible and convenient.

The intermittence of RES sources can be overcome either through exchanges with the network or by using storage systems which are still too expensive but in the short term can be of considerable interest since they would allow the microgrid to perform supporting services to the grid.

It has been verified through "production and consumption on site" (a more correct concept than that of self-consumption which presupposes the uniqueness between the producer and the consumer) can induce a series of positive effects on the electricity system, from the reduction of network losses to the deferral over time of investments related to the enhancement of the network when it is weak or has to face load increases, especially if they are peaks.

Even in financial terms, the microgrids were viable: in many cases, the requested capital costs have been considered to be on the responsibility of the microgrids, through equity or loans repaid over time, other times with the need for a certain grant. But in all cases the reduction of the bills of consumers aggregated in the micro-network was positively verified.

If it was necessary to demonstrate the validity of the solutions proposed by the European's Commission Package entitled 'Clean Energy for All Europeans' towards decarbonisation goals of 2050 year and a central roles of the citizens into the future energy market, the results emerging from the PEGASUS project fully confirm.

There are regulatory barriers still to be removed to promote the development of microgrids but the new European directives “Renewable energy community” and the “Citizen energy community” require the national Authorities regulating the electricity market to adjust the terms of participation in the market by local energy communities.

Through dedicated meetings and questionnaires the stakeholder feedbacks were collected as well as the public understanding and perception of micro-grids.
For all pilots a strong feeling of the residents with the local community has been verified as well as the opportunity of an effective generation based on renewable sources is widely recognized.
With some exceptions mainly due to insufficient specific knowledge, the concept of energy communities is highly appreciated by the local residents who are also interested to act as energy community members to the extent that the local energy community can improve service quality and reduce billing.

In all cases, the lack of adequate regulation in support of micro-networks to allow the benefit not only of incentives related to the use of renewable sources, but also the reduction of burdens that are not objectively justified (e.g., transport and distribution costs for locally generated and consumed energy). Also the low political eagerness is felt as a brake on the development of local energy communities.

Similar to that of politicians is the almost common position of the encountered Energy Regulators. They motivated their caution towards microgrids, and in general concerning collective consumption schemes, in the unability of the electrical system to cope with a widespread diffusion of microgrids or in possible financial risks of the current incumbent electricity system operators.

This position is partly motivated by the current situation in which Member States have to transpose at national level the European directives "Renewable Energy Community" and "'Citizen Energy Community"; on the basis of the policy choices made in each country, Regulators need to prepare the new regulatory environment that must necessarily take into account new players in the electricity system such as microgrids and local energy communities.

Overall, It can be said that the PEGASUS project has effectively demonstrate the advantages and benefits of microgrids in developing energy communities especially in rural areas and islands, providing a punctual series of indications on the technical, administrative and financial conditions for making the evolution of microgrids and energy communities a reality towards the energy transition and the meeting of 2050 target for a low carbon economy.

As further demonstration of the validity of the work carried out within the PEGASUS project, two significant events are to be noticed :

- during the development of pilot of Saint Julien en Quint, a citizen-owned local cooperative, called SAS Centrales Villageoises ACoPrEV Val de Quint, has been established in June 2018; this energy community will bear the investments in the RES plant and will operate as the legal entity allowing the local collective self-consumption scheme; the microgrid consumers will be shareholders of the local energy community;
- the solution developed in the pilot of the Municipality of Potenza was implemented in the last months of 2019 years and will be fully operational in early 2020 year.

12. Lesson learnt from the Cost-Benefit Analysis and guidelines for the toolkit

The cost-benefit analysis performed within the seven developed pilots in the framework of Pegasus project showed that, under appropriate assumptions, the improving of renewable sources to generate electricity locally consumed is not only energy efficient but also economically profitable.

The performed simulation, based on measured profiles of local loads and internal generation systems,
have shown that the implementation of microgrids within a more open and flexible electrical system is possible and convenient.

Based on the results of the seven pilot projects in seven rural or peripheral areas and islands in the MED area, the following will summarise:

- the conditions under which microgrid can be fully exploited,
- the key aspects for an effective cost-benefit analysis to be carried out for future microgrid projects,
- the expected benefits from a wide spread of microgrids.

1. Conditions for an effective exploitation of the microgrids based on renewables

Microgrids generally make use of distribution generation by renewable source. From one side this is a strong point in favor of the microgrids since the levelized cost of electricity coming from PV and wind systems continue to fall. On the other hand, it is necessary to consider the intermittence of RES that could affect a real development of the microgrid.

There are two possible solutions, both tested within Pegasus project.

The first resides in electrical system regulation allowing between the microgrid and the public network the energy exchanges, in and out, that are compensated for each other, not necessarily on an equal basis. In this way the absence of generation by photovoltaic systems during the night or with low insolation conditions is balanced by the surplus generation at sundials with high insolation. The same applies to wind sources. Regulations such as net metering or even more articulated, such as net billing, are of this type: they allow efficient management of sources without burdening either the electrical system or the other end users.

The second one is the use of storage systems, today still too expensive but in the short term they can be of considerable interest given the strong investments in the sector all over the world. IEA[1] estimates a cost reduction by 2040 around two-thirds for stationary applications (and even more for EVs). Moreover, the availability of an effective electricity storage systems allows microgrid to operate disconnected to the grid. In presence of a weak network, condition often found in remote locations or islands, a microgrid that can be islanded operated allows to mitigate the effect of grid outages or low quality of supply.

Another significant issue for a well-designed microgrids is the quantity of electricity "generated and consumed on site". In fact, among the positive effects of the microgrid it has to be accounted the avoided transmission and distribution costs and the reduction of the technical losses in transmission and distribution network. The cost of transport is of the order of 16% of the cost of electricity while the technical losses on the network are not less than 3% of the consumed electricity. The improving of the energy self-sufficiency of the microgrids implies increasing amounts of investment that can be remunerated if the benefits of lower costs for the electricity system are fully recognized.

In the current transition towards decarbonization goals of 2050 year, as planned by the European Clean Energy package, it is necessary that the regulations of the member states fully transpose what defined by the European Directives "Renewable energy community" and "Citizen energy community" regarding the keeping down of unmotivated energy costs. Among these the avoided costs of transport due to the local use of the locally generated electricity within the microgrids must be duly considered.

Energy Regulators position tends to be little inclined towards microgrids and in general on the collective consumption schemes due to a possible inability of the electrical system to cope with a widespread diffusion of microgrids or possible financial risks of the current system operators.

The opportunity must not be missed for the Member States to transpose the above-mentioned European directives into national law to give the microgrids and local energy communities the role of new players of the electric system.

[1] IEA- Innovation in Batteries and Electricity Storage, September 2020

2. The key issues for an effective cost-benefit analysis for microgrid projects

Microgrids must necessarily be equipped with internal energy sources and must be able to integrate those already existing on the local territory. That said, the fully energy self-sufficiency is not a goal in itself as well as the benefits related to the microgrid cannot be limited to those related to the use of RES (such as reduction of fossil fuels, low carbon emission) that can be achieved by any initiative of individual prosumer. The planning of a microgrid has to take into consideration the mix of the energy internally generated, including storage capacity if appropriate, and the one externally purchased in order to achieve a better balance with the load with an investments level such as to assure both the economic and financial viability of the microgrid and measurable benefits achievable by all the involved subjects (consumers, producers, prosumers).

In addition to ensuring the microgrid energy balance a suitable Energy Management System has to allow a more efficient use of electricity, for instance supporting demand side management approach or even just shifting the energy consumption at times when the generation by the internal renewables sources is greater. EMS has to be coupled with an economic dispatching system able to redistribute the benefits of the microgrid among its participants on the base of internal "transfer prices".

In the evaluation of the achievable benefits a careful assessment of the regulatory framework must be made (electricity tariffs, incentives to RES, etc.) and its foreseeable evolution over time.

A reliable assessment of the required investments is crucial for an effective cost-benefit analysis. It must cover not only all the equipment that must be installed but also their real useful life. For instance, the inverters of a PV plant have an average life usually lower than that of photovoltaic panels as well as the useful life of a battery storage system is strongly influenced by the number and characteristics of the expected charging and discharge cycles for their operation within the microgrid. A microgrid able to be operated in island mode must be controlled without the reference input of the main grid and has to detect fault signals from main grid in order to island in time. After islanding the voltage and frequency control, and appropriate power quality levels, must be provided by the microgrid. This implies additional investments and more complexity in operation, especially high when the microgrid is based only on renewable intermittent electricity sources. Those additional investments and operating costs should be carefully weighed against the economic value assigned to a higher power reliability in term of the external costs related to the outages (for instance commercial or industrial activities halt).

No less important is the evaluation of the O&M costs of the microgrid. Among these the most easily overlooked are those related to insurance expenses (to be correlated for example to possible serious damage to PV systems as a result of stormy events) and to the continuous need for updating EMS both to consider both the evolution of the microgrid (new generators or additional loads due to new members) and the reference regulatory framework over the time. Moreover, EMS provides a fair and useful continuous assessment of the efficiency of the different microgrid systems (generation sources, control systems, energy storage system) to be used for an effective maintenance operation.

3. The expected benefits from a wide spread of microgrids

In addition to the benefits already considered in the previous paragraphs, the pilots developed within Pegasus project showed that microgrids, by local use of energy locally generated, can reduce congestions in distribution networks in the event of growing demand for Electricity or an excess of electricity fed into the network by distributed generation.

In the presence of a weak network the microgrids may allow the deferral of the investments otherwise required to satisfy the loads.

Furthermore, the microgrids, adequately equipped, may be able to provide the so-called ancillary services related to the control of voltage and frequency and thus contributing to a better control of the network.

It should also be noted that local residents are generally interested in acting as members of a local energy community, being able to directly influence local energy strategies and able to directly verify the results of the choices made with the related benefits, whether they are of a better quality of service or a greater use of RES or a reduction in invoicing. This greater democratization in the matter of energy choices as well as the development of a stronger link of people with the territory is a further advantage achievable through the microgrid.