Study of energy technology options for buildings with zero CO_2 emissions due to energy use

MOLISE REGION - ITALY

European Union | European Regional Development Fund

TECHNOLOGY OPTIONS REVIEW FOR NEAR ZERO CO_2 EMISSION BUILDINGS

The following renewable energy technologies which could be used for the creation of near zero CO_2 emission buildings will be examined. These technologies could be used for covering the needs in heating, cooling and electricity in buildings.

1. Solar thermal technology with flat plate collectors (for the production of domestic hot water)
2. Solar thermal technology with parabolic collectors and Stirling engine (for space heating, domestic hot water production and electricity generation)
3. Solar-PV technology (for electricity generation)
4. Solid biomass burning (for space heating and domestic hot water production)
5. High efficiency heat pumps, including geothermal, with COPs higher than 3.5 (for generation of heat, cooling and domestic hot water production)
6. Small size wind turbines (for electricity generation mainly in isolated buildings together with solar-PVs in hybrid systems)
7. Co-generation of heat and power using biomass as fuel (for space heating, domestic hot water production and electricity generation)
8. District heating using biomass as fuel (for space heating and domestic hot water production)
9. District heating utilizing waste heat (for space heating and domestic hot water production)
10. Solar thermal cooling (for space cooling)

Table 1. technologies which could be used for the creation of Zero CO_2 buildings

	R.E. technology	Space heating	Space cooling	Electricity generation	Domestic hot water production
1	Solar thermal with flat plate collectors	+			+
2	Solar thermal with parabolic collectors and Stirling engines	+		+	+
3	Solar-PV			+	
4	Solid biomass burning	+			+
5	High efficiency Heat pumps	+	+		+
6	Wind energy			+	
7	Co-generation of heat and power	+		+	+
8	District heating with biomass	+			+
9	District heating with waste heat	+			+
10	Solar thermal cooling		+		
11	Other				

1. Availability of the renewable energy in the area

The table below shows data about the production of energy from renewable source: they are classified by type of primary source used (the data was extracted from the statistical documents provided by the GSE).

It should be noted that the data reported relate to all production systems in the regional territory and therefore also include systems used for industrial energy production and not for buildings services.

The primary source most widely used is wood biomass, mainly for the economy and the easy availability of this energy source.

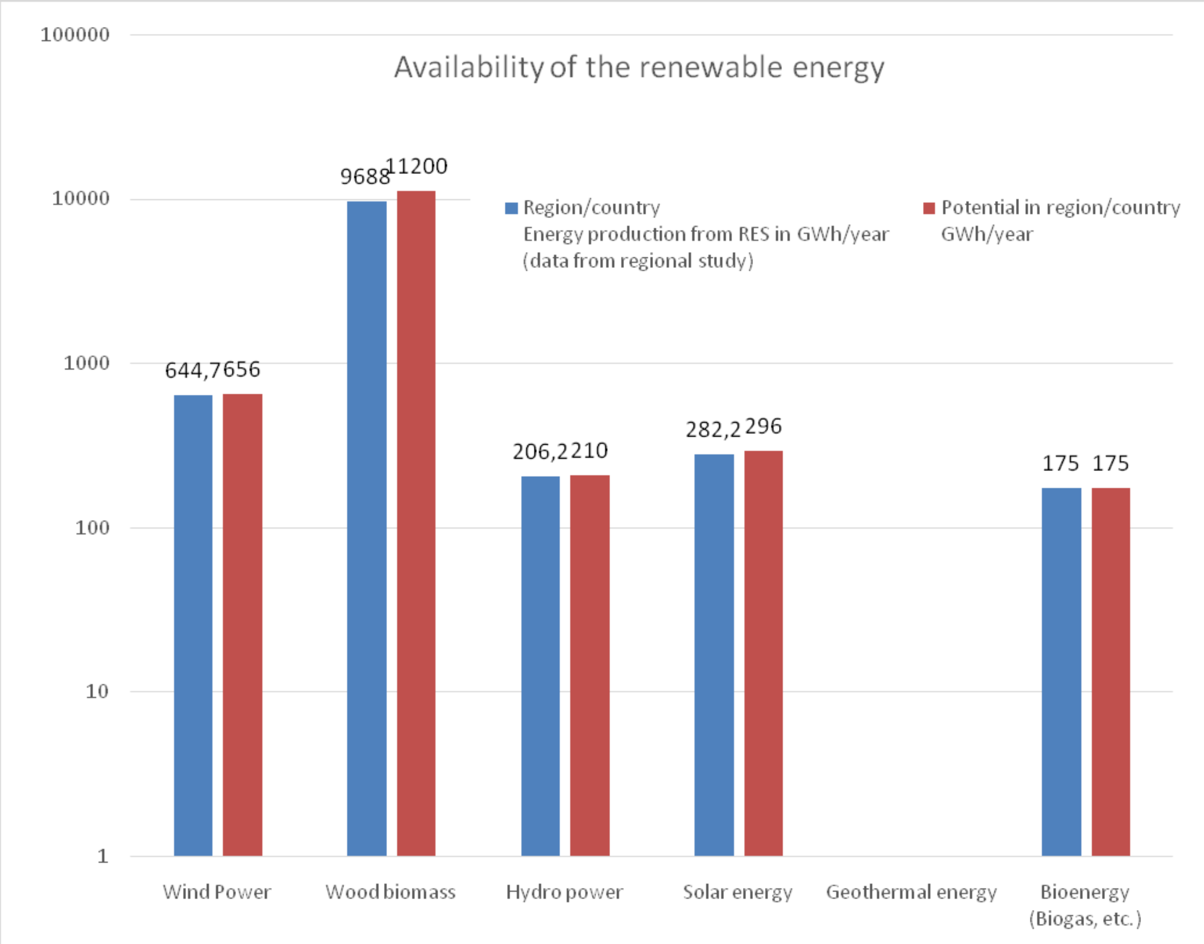
Another consideration is given to geothermal energy. In fact, in the territory of Molise, there are no installation of geothermal systems. Systems with earth/air heat pumps, commonly named low-enthalpy geothermal systems, cannot be considered as production systems and so they are considered such as high efficiency heat pumps.

Table 1.1. RES potential

RES	Region energy production from RES in GWh/y [1] [year 2015]	Potential in Region In GWh/year [2] [estimated to 2018]
Wind Power	644,7 GWh/y	656 GWh/y
Wood biomass	9688 GWh/y	11200 GWh/y
Hydro power	206,2 GWh/y	210 GWh/y
Solar energy - PV plants - Solar thermal	 223,4 GWh/y 58,8 GWh/y	 228 GWh/y 68 GWh/y
Geothermal energy	(RES not present in the region)	
Bionenergy (Biogas, etc.)	175 GWh/y	175 GWh/y [1]
Total	**10996,1 GWh/y**	**12537 GWh/y**

[1] Data given from the statistical summary for the year 2015 provided by GSE SpA.

[2] In the estimation of potencial production,it was considered the annual growth rate given in the statistical summary for the year 2015 provided by GSE SpA.



Availability of the renewable energy
100000
10000
1000
100
10
1
9688
11200
644,7656
206,2210
282,2
296
175
175
Region/country
Energy production from RES in GWh/year
(data from regional study)
Potential in region/country
GWh/year
Wind Power
Wood biomass
Hydro power
Solar energy
Geothermal energy
Bioenergy
(Biogas, etc.)

Diagram 1.1

2. Possible renewable energy technologies (RES technology) that can be used in region in order to create almost zero CO2 emission buildings due to their energy use

2.1 Technology 1 - Solar Thermal with flat plate collectors

By examining the installations of solar thermal systems for buildings service, the technologies used are both natural circulation systems (figure 2.1A) and forced circulation (figure2.1 B).

Natural circulation systems are used exclusively for sanitary water production. Forced circulation system are used for sanitary water and also for heating integration.

There are many installations of solar thermal systems (in the two technological variants) on the territory of Molise, indicating that this type of technologies is compatible with the landscape and the type of buildings present in the region.

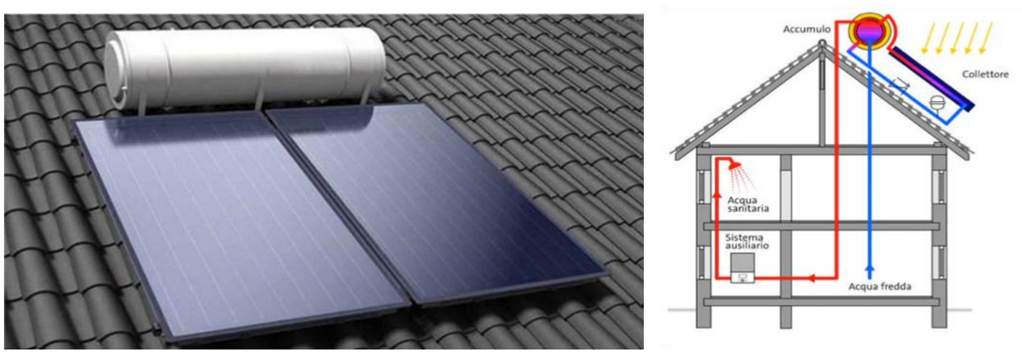


Fig. 2.1A

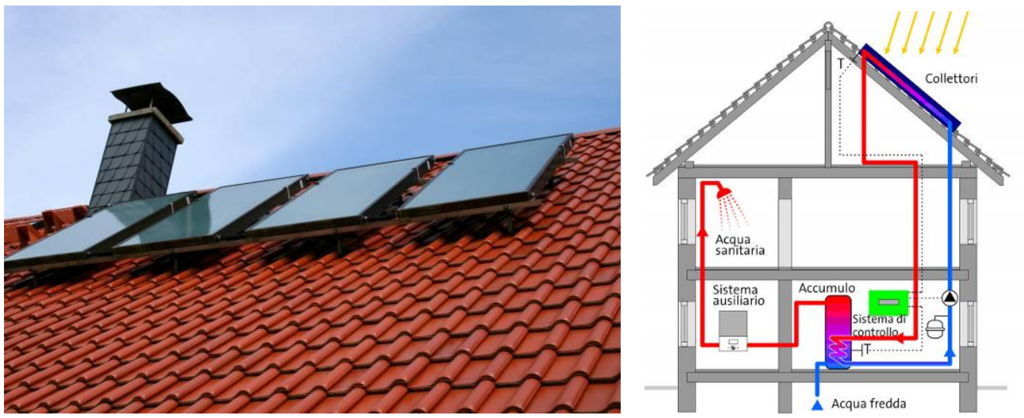


Fig. 2.1B

Table 2.1.1: Technology 1

RES Technology	Solar Thermal system with flat plate collectors.
Strengths	Limited implementation costs; Good payback; Easy and speedy installation; High thermal performance; Low maintenance costs; Avoided CO2 emissions; Easy integration into existing hydraulic system.
Weaknesses	Solar thermal panel efficiency decay; Not controllable source; Possible over- temperature.
Reliability	High reliability.
Maturity	Production technology for solar thermal panels is consolidated.
Social acceptance	Solar thermal system are socially accepted for many reasons, including: - low environmental impact; - easy installation; - reducing fossil fuels use; - decreasing of CO2 emission in the atmosphere.
Limitations – legal framework	Authorization of solar thermal systems is established by D.Lgs. 28/2011.
Limitations – type/size of the building	No limitations. Solar thermal systems are sized according to available surface and thermal power user needs.
Existing financial incentives	1. Deduction tax amounts to 65% of the expense, with a maximum refund of 96000 €; 2. "Conto termico 2.0" (Decreto interministeriale 16 febbraio 2016).

Table 2.1.2: Evaluating form for technology option 1

		Score from 1 to 5 (1 is low, 5 is high)
1	Cost effectiveness of the total investments	5
2	Simplification of installation	4
3	Accessibility	4
4	Easy to use - for end user	4
5	Easy to maintain	4
6	Reliable	4
7	Efficient	5
8	Power capacity and energy production	4
9	Social acceptable	5
10	Promotion by the government with financial or non-financial incentives	4
	TOTAL scores	**43**

2.2 Technology 2 - Solar thermal with parabolic collector and Stirling engines

The use of Solar thermal with parabolic collector and Stirling engines it's not present in Molise, and no efficient use of this technology is expected in the very next future. The small use of this technology depends on the Stirling engines characteristics (in particular the higher weight, the difficulty of regulating power delivered, the higher initial costs) which don't allow economical use for heating and energy production.

Fig. 2.2

2.3 Technology 3 - Solar - PV

In this section the type of PV solar plant listed below are considered:

1. *grid connected: the system is connected to the national electrical grid. The energy produced by the photovoltaic system supplies electricity, not taking from the power grid there's a billing savings. The energy produced and not self-consumed is measured by the counter and fed into the grid.*
2. *stand alone: The plant is not connected to the national grid and the energy produced by the photovoltaic system is stored in battery storage. The energy produced by the photovoltaic system is used for electrical utilities and the energy that is not consumed is instantly stored in storage batteries until fully charged. The batteries, then, will be used by the users during the non-production periods until fully exhausted;*
3. *storage: the plant is connected to the national grid and is equipped with accumulator batteries. In particular, the energy produced by the photovoltaic system feeds first the home demands, then, non-self-consuming energy is instantly transmitted to the accumulators until fully charged and the residual energy is measured by the counter and poured into the grid.*

There are many installations of photovoltaic solar systems present in Molise, for residential and non-residential buildings and for large-scale power generation plants. This large use depend by the last years government policies that encourage the installation of PV solar plant.

Is to underline that only few point percent of the total installation can be assigned to both stand alone and storage type. However, in the next years an increase of the percentage of storage plant installation can be expected.

Fig. 2.3

Table 2.3.1: Technology 3

RES Technology	*Solar PV plants up to 200 kW*
Strengths	*Good payback;* *Low maintenance costs;* *Easy to use;* *Avoided CO2 emissions;* *Long useful life;* *High reliability;* *Easy integration into existing electric system.*
Weaknesses	Solar PV panel efficiency decay; Not controllable source; *No production during the night.*
Reliability	*High reliability mainly thanks to the absence of organ motion.*
Maturity	*Technology for* Solar-PV plants *plants production is now consolidated.* *The hard work of research and development in the photovoltaic sector has led to a continuous improvement of the single photovoltaic cell performance, reaching very comforting values.*
Social acceptance	Solar thermal system are socially accepted for many reasons, including: - low environmental impact; - *reduction of electricity bills;* - ease of installation and use; - reducing fossil fuels use; - decreasing of CO2 emission in the atmosphere.
Limitations – legal framework	Authorization of solar PV plants is established by Legislative Decree (D.Lgs. 28/2011). Environmental and landscape constraints are set by normative references drafted in D.Lgs. 42/2004 and D.Lgs 152/2006.
Limitations – type/size of the building	No limitations. Solar PV plants are sized according to available surface and thermal power user needs.
Existing financial incentives	Deduction tax amounts to 50% of the expense, with a maximum refund of 96000 €;

Table 2.3.2 Evaluating form for technology option 3

		Score from 1 to 5 (1 is low, 5 is high)
1	Cost effectiveness of the total investments	4
2	Simplification of installation	4
3	Accessibility	5
4	Easy to use - for end user	4
5	Easy to maintain	4
6	Reliable	4
7	Efficient	3
8	Power capacity and energy production	3
9	Social acceptable	4
10	Promotion by the government with financial or non-financial incentives	4
	TOTAL scores	**39**

2.4 Technology 4 - Solid biomass burning

Solid biomasses are considered among the renewable energy sources because they have vegetal origin. In the residential sector (or, in any case, in the installations for building service and not in those for the production of electricity), the use of solid biomasses is only devoted to the heating of the rooms and the production of ACS.

There are many solid biomass heating plants in Molise. The use of this type of renewable source is facilitated by the simplicity and economics of finding wood biomass in the region.

Fig. 2.4

Table 2.4.1: Technology 4

RES Technology	*Solid biomass burning plants*
Strengths	*Good payback;* *Controlling resource usage (renewable source always available)* *Low cost resource* *Easy scalability of the system.*
Weaknesses	*However, there is production of combustion pollution (PM2.5, PM10, carbon monoxide).* *Difficulty in supplying the resource in the case of firewood.* *High maintenance costs.*
Reliability	High reliability of machine realization technologies
Maturity	*Technology is consolidated.*
Social acceptance	*Solid biomass technology is acceptable for the vast majority of the population. It is also preferred in rural housing or small urban centers where the easiest availability of the source cover the disadvantages associated with flue gases emissions in the atmosphere.*
Limitations – legal framework	*Domestic or small installations with a capacity under 35 kW don't need authorizations.* *However, they are obliged to keep the plant libraries and to report periodic maintenance to the nominated authorities.*
Limitations – type/size of the building	*There are no limitations related to the size of buildings as machinery used with significant power density.* *However, there are limitations on the intensive use of solid biomass systems in densely populated housing environments due to odors and substances emitted by exhaust fumes.*
Existing financial incentives	Deduction tax amounts to 50% of the expense, with a maximum refund of 96000 €;

Table 2.4.2 Evaluating form for technology option 4

		Score from 1 to 5 (1 is low, 5 is high)
1	Cost effectiveness of the total investments	4
2	Simplification of installation	4
3	Accessibility	4
4	Easy to use - for end user	5
5	Easy to maintain	1
6	Reliable	4
7	Efficient	4
8	Power capacity and energy production	4
9	Social acceptable	4
10	Promotion by the government with financial or non-financial incentives	4
	TOTAL scores	**38**

2.5 Technology 5 - High efficiency heat pumps

Heat pumps are increasingly used for heating buildings. In the past they were used almost exclusively for cooling of environments. Today, available technologies combined with a marked improvement of products in commerce make the heat pumps widely used for space heating.

There are many installations of high efficiency heat pumps in Molise, expecially in case of large building in which the heat pumps are used both for heating and cooling. An increase of installations is expected in the next years.

Fig. 2.5

Table 2.5.1: Technology 5

RES Technology	*High efficiency heat pumps*
Strengths	*Good payback;* *Possibility of heating and cooling with same plants;* *Ease of installation;* *Low maintenance;* *High efficiency;*
Weaknesses	*Use of refrigerants;* *Difficulty of use in critical climatic conditions;* *Noisy not always negligible;* *For economical convenience it needs to be matched with dedicated electricity tariffs or low cost electrical energy production plants.*
Reliability	High reliability of machine realization technologies now on the market.
Maturity	*Technology is consolidated.*
Social acceptance	*Heat pumps are generally accepted, thanks to advances in machine construction that have allowed a significant reduction of machine noise.*
Limitations – legal framework	*There are no significant limitations installing this technology, if there is any outside space available for machine installation.* *In the case of buildings of particular architectural interest, the installation of this machines on the facades of buildings is subject to authorization from nominated authorities.*
Limitations – type/size of the building	*There's no relation between the size of the machines used for production plants and building dimensions.*
Existing financial incentives	1. Deduction tax amounts to 65% of the expense, with a maximum refund of *46.154 €(for private citizens and companies)*; *2.* Deduction tax amounts to 75% of the expense, with a maximum refund of *40.000 €/flat (for condos);* 3. "Conto termico 2.0" (Decreto interministeriale 16 febbraio 2016).

Table 2.5.2 Evaluating form for technology option 5

		Score from 1 to 5 (1 is low, 5 is high)
1	Cost effectiveness of the total investments	4
2	Simplification of installation	3
3	Accessibility	4
4	Easy to use - for end user	5
5	Easy to maintain	4
6	Reliable	5
7	Efficient	5
8	Power capacity and energy production	5
9	Social acceptable	3
10	Promotion by the government with financial or non-financial incentives	4
	TOTAL scores	**42**

2.6 Technology 6 - Small size wind turbines

Installations of small size wind turbines are used for electricity production in buildings and managed through the on-site exchange service. Technologies here considered are horizontal axis wind (see figure A) and vertical axis turbine plants (see figure B).

There are numerous wind power plants in Molise, but there are very few small size installations for buildings. Most of the installations are large-scale wind farms for large-scale power generation.

Fig. 2.6A

Fig. 2.6B

Table 2.6.1: Technology 6

RES Technology	Small size wind turbines for buildings service, featuring a power output not exceeding 10 kW.
Strengths	*Good payback;* *Electricity production characterized by less daily variability;* *No atmospheric emissions.*
Weaknesses	*Considerable investment cost;* *Difficulty of installation;* *High variability of production depending on installation site;* *Significant noise of the generator;* *High report between geometric dimension and power;* *Source not easy to control.*
Reliability	High reliability of machine realization technologies for small size wind turbines. The maintenance burden can be considered ordinary.
Maturity	*The wind technology has certainly mature.*
Social acceptance	*Even if the wind is capable of producing low environmental impact electricity (there is no use of fuels or harmful substances in the atmosphere) it is not yet socially accepted by many people (Superintendence, environmentalist associations, animalist associations, etc.)) which underline the remarkable landscaping impact and the high noise of the machines used.*
Limitations – legal framework	Authorization of solar PV plants is established by Legislative Decree (D.Lgs. 28/2011). Environmental and landscape constraints are set by normative references drafted in D.Lgs. 42/2004 and D.Lgs 152/2006.
Limitations – type/size of the building	*The size of the machines used for the construction of wind turbines does not allow easy installation close to buildings. It is not possible the installation in residential areas and their proximity (installations that are registered are all in rural areas).*
Existing financial incentives	Deduction tax amounts to 50% of the expense, with a maximum refund of 96.000 €.

Table 2.6.2 Evaluating form for technology option 6

		Score from 1 to 5 (1 is low, 5 is high)
1	Cost effectiveness of the total investments	2
2	Simplification of installation	2
3	Accessibility	1
4	Easy to use - for end user	2
5	Easy to maintain	2
6	Reliable	4
7	Efficient	3
8	Power capacity and energy production	3
9	Social acceptable	1
10	Promotion by the government with financial or non-financial incentives	4
	TOTAL scores	**24**

2.7 Technology 7 - Cogeneration of heat and power

Cogeneration is defined as the simultaneous production of two different energy forms, both exploitable, starting from a single energy source in an integrated plant.

In the residential sector, cogenerators are mainly used for the combined production of electricity and heat. The installations examined are small cogeneration plants for building services.

In the past no relevant installations of cogenerator were located in Molise. Today, the increase of the reliability of the products in commerce and the government financial incentives are increasing the number of cogeneration units for building service installed.

Fig. 2.7

Table 2.7.1: Technology 7

RES Technology	Cogeneration of heat and power *systems for buildings service with rated power not more than 200 kW.*
Strengths	*Energy saving for lower fuel consumption;* *Long useful life;* *High reliability.*
Weaknesses	High initial investment cost; *Moderate atmospheric emissions;* *High costs of maintenance.*
Reliability	*Moderate reliability due to moving organs which require constant and programmed maintenance.*
Maturity	*Technology for cogeneration plants production is now consolidated.*
Social acceptance	*Cogeneration systems are not socially accepted, because of, even if they have a low environmental impact, they don't totally reduce CO2 release into the atmosphere.*
Limitations – legal framework	Authorization of Cogeneration of heat and power systems is established by D.Lgs. 28/2011. Environmental and landscape constraints are set by D.Lgs. 42/2004 and D.Lgs 152/2006.
Limitations – type/size of the building	Cogeneration systems must be dimensioned according to the electrical and thermal utilities inside the building. Buildings must be equipped with appropriate technical areas for installation.
Existing financial incentives	*1.* Deduction tax amounts to 50% of the expense, with a maximum refund of 96000 €; *2." Conto termico 2.0" (Decreto interministeriale 16 febbraio 2017).*

Table 2.7.2 Evaluating form for technology option 7

		Score from 1 to 5 (1 is low, 5 is high)
1	Cost effectiveness of the total investments	2
2	Simplification of installation	2
3	Accessibility	2
4	Easy to use - for end user	2
5	Easy to maintain	2
6	Reliable	4
7	Efficient	3
8	Power capacity and energy production	4
9	Social acceptable	2
10	Promotion by the government with financial or non-financial incentives	4
	TOTAL scores	**27**

2.8 Technology 8 - District heating with biomass

District heating systems powered by solid biomass is a good use of primary source for heating of final users placed on the surrounding area of the plant.

District heating permits the separation of the thermal system from the utilities thanks to properly isolated pipes and this provides advantages in terms of the possibility to use energy sources near the residential cores otherwise unused.

However, leakages along the pipes discourage the intensive application of this technology.

The implementation of underground pipelines for district heating could encounter management issues over the years because of high hydrogeological risk of Molise territory. No installation of district heating are registered in Molise.

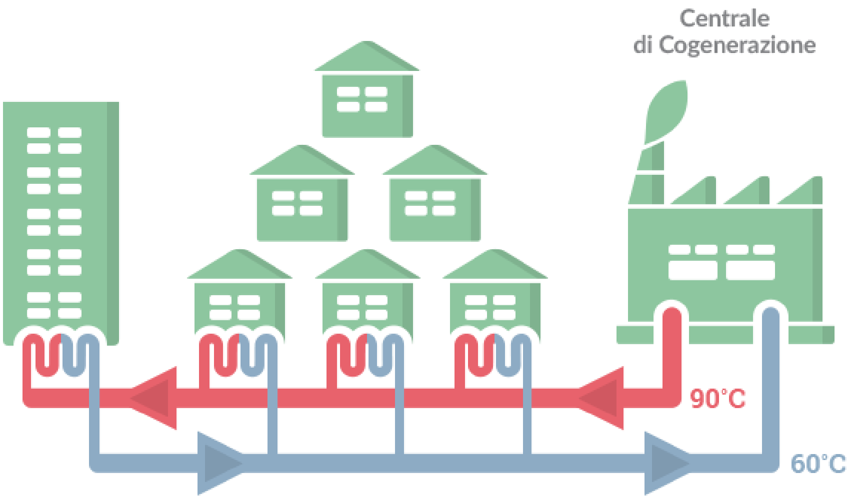


Fig. 2.8

2.9 Technology 9 - District heating with waste heat

District heating systems powered by waste is a good use of waste for heating of final users placed on the surrounding area of the plant.

District heating permits the separation of the thermal system from the utilities thanks to properly isolated pipes and this provides advantages in terms of the possibility to use energy sources near the residential cores otherwise not used.

However, leakages along the pipes discourage the intensive application of this technology.

The implementation of underground pipelines for district heating could encounter management issues over the years because of high hydrogeological risk of Molise territory. No installation of district heating are registered in Molise.

2.10 Technology 10 - Solar Thermal cooling

The solar thermal cooling is a technology that combine the cooling obtained with absorption refrigerator (systems widely used in industry for recover losses from processes) and solar thermal collector.

In this systems, the heat source (needed for the correct behaviour of the cooling cycle) is provided by solar collectors.

However, the technology not yet consolidated, high installation costs, size not compatible with the use in buildings make this kind of technology option not used as building heating system. Also in Molise no installation of solar thermal cooling are registered.

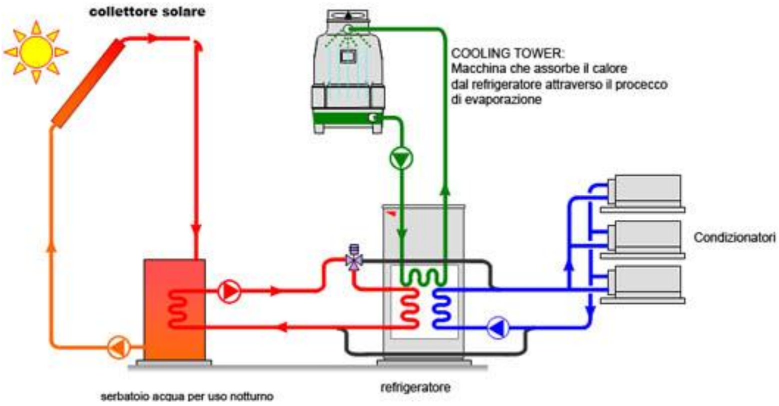


Fig. 2.10

2.11 Technology 11 - Geothermal heat pumps

The earth/water or earth/air heat pumps, well known as geothermal heat pumps, are a particular application of the heat pumps in which one of the energy source is the ground. This technology option are increasing because of, although the installation procedures are more expensive, the temperature of the ground is more stable than the one of the atmosphere. This characteristic give to this type of heat pump a better efficiency.

In Molise only in last few years are registered installations of geothermal heat pumps and no wide use of this technology can be expected because of the high cost of installation.

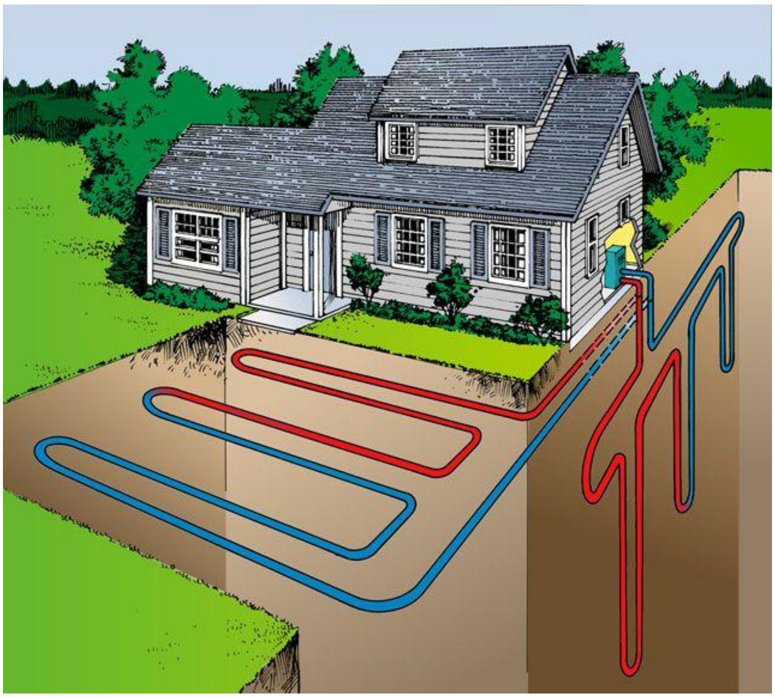


Fig. 2.11

Table 2.11.1: Technology 11

RES Technology	*Geothermal heat pumps*
Strengths	*Possibility of heating or cooling the environments;* *Absence of polluting emissions in the atmosphere;*
Weaknesses	High investment cost; *Difficulty of installation;* *For the installation there is a need for adequate means to realize the probes (in particular the vertical probes)*
Reliability	High reliability of heat pumps realization technologies .
Maturity	Technology for geothermal pumps is consolidated. There are improvements and price reductions for realization of geothermal heat exchangers.
Social acceptance	Geothermal heat pumps are largely accepted by the society.
Limitations – legal framework	it is need to permission from authorities for subsoil deep drilling (in particular in the case of vertical geothermal probes).
Limitations – type/size of the building	The high dimensions of geothermal probes restrict the use of geothermal heat pumps to buildings with sufficient space for their construction. The higher the required thermal power, the greater the size of the probes.
Existing financial incentives	Deduction tax amounts to 50% of the expense, with a maximum refund of 96000 €.

Table 2.11.2 Evaluating form for technology option 11

		Score from 1 to 5 (1 is low, 5 is high)
1	Cost effectiveness of the total investments	1
2	Simplification of installation	1
3	Accessibility	2
4	Easy to use - for end user	4
5	Easy to maintain	4
6	Reliable	4
7	Efficient	4
8	Power capacity and energy production	5
9	Social acceptable	3
10	Promotion by the government with financial or non-financial incentives	4
	TOTAL scores	**32**

2.4 List of all RES technologies based on scores:

Below a list of the RES technologies previously analyzed, with related scores. The ones with no score indicated are not present in Molise.

Table 2.4 Score list for technology options

	Technology option	Total score
1	Solar Thermal with flat plate collectors	43
2	High efficiency heat pumps	42
3	Solar – PV	39
4	Solid biomass burning	38
5	Geothermal heat pumps	32
6	Cogeneration of heat and power	27
7	Small size wind turbines	24
8	District heating with biomass	-
9	District heating with waste heat	-
10	Solar Thermal cooling	-
11	Solar thermal with parabolic collector and Stirling engines	-

3. Combination of different technologies in order to cover all of the building energy demand

The following summary table showing the possible combination of the technological options previously analyzed.

Table 3.1 Combination of different technologies

	Solar thermal –flat collector	Solar thermal and Stirling engines	Solar - PV	Solid biomass burning	High efficiency heat pumps	Small size wind turbines	Cogeneration of heat and power	District heating with biomass	District heating with waste heat	Solar Thermal cooling	Geothermal heat pumps
Solar thermal –flat collector			X	X	X	X	X				X
Solar thermal and Stirling engines				X	X	X	X				X
Solar – PV	X			X	X	X	X	X	X	X	X
Solid biomass burning	X	X	X			X				X	
High efficiency heat pumps	X	X	X			X					
Small size wind turbines	X	X	X	X	X		X	X	X	X	X
Cogeneration of heat and power	X	X	X			X				X	
District heating with biomass			X			X				X	
District heating with waste heat			X			X				X	
Solar Thermal cooling			X	X		X	X	X	X		
Geothermal heat pumps	X	X	X			X					

4. Cost effectiveness of the RES technology compared with existing conventional fossil fuel based technologies –

Here are presented three different combinations of technological options previously examined. The reference building is the city hall of Matrice, a little town located near Campobasso.

In the tables below (one for each combination of technological options) are indicated the technical-economical parameters that provide the instruments for evaluating the convenience of the solutions analyzed.

Reference Building	
Building types	City hall
Location	Matrice (CB)
Surface	250 mq
Climatic area	E
Degree Day	2.237
Energy class	G
Energy need for heating	21.380 kWh/y
Energy need for cooling	0 kWh/y
Use of electricity	4.569 kWh/y
CO2 emissions	5976,35 kg/m^2
Operating costs per year	3263 €/y

Variant 1:

As first combination, the installation of a solid biomass heating system of 50 kWt and a solar PV plant of 4,5 kW it's been considered.

In this case, the boiled powered by solid biomass (the most used type of solid biomass in Molise is "pellet") is used for heating and hot water production. The PV solar plant is used for energize the electric users installed inside the building.

As can be notice from the table below, using the solid biomass boiler instead of the boiler powered with traditional fossil fuel (such as gas) the emission of CO2 is fixed to zero kg (is to underline that fixing to zero the emission of CO2 is due to considering the full life cycle of the energy source). Moreover, the costs for heating are reduced because of the pellet unitary cost is lower than gas one.

In addition, the use of the photovoltaic plant for on-site power generation enhance the reduction of CO2 emissions and energy costs.

Table 4.1.1 Description of the RES technologies used in this example

	Building- current status	Building Variant 1
Energy need for heating kWh/a	21.380	20.413
Energy need for cooling kWh/a	0	0
Use of electricity kWh/ m^2 a	4.569	505
CO2 emissions kg/ m^2 a	2207,00(e)+3769,35(t) = 5976,35	252 (e) + 0 (t) = 252
Operating costs per year (EUR/ m^2 a) (heating and electricity)	2002 €(t) + 1261 € (e) = 3263 €	759 € (t) + 139,44 (e) = 898,44 €
Investment €/ m^2		16090 € + IVA (10%)
Investment per kg of CO2 saved annually €/ kg m^2		2,81 €/kg
Savings €/ m^2 a		2364,56 €
Public Incentives		1853 €
Net investment		14237 €
Payback period a		6,0

Variant 2:

In this case the installation of solar thermal collectors for the integration of existing heating and a photovoltaic system with a nominal power of 4.5 kW is considered.

In order to increase the efficiency of the heating system (feeded by natural gas) and reduce energy consumption, a forced convection solar thermal system is installed for heat integration. This type of plant allows thermal energy to be stored at a temperature-controlled storage tank by combining the inputs from the renewable source and the conventional fuel source.

For energize the electric users, a photovoltaic plant has been installed in order to cover most of the electricity needed.

Table 4.1.2 Description of the RES technologies used in this example

	Building- current status	Building Variant 2
Energy need for heating kWh/a	21.380	8.889
Energy need for cooling kWh/a	0	0
Use of electricity kWh/a	4.569	505
CO2 emissions kg/a	2207,00(e)+3.769,35(t) = 5976,35	252 (e) + 1.778 (t) = 2.030
Operating costs per year (EUR/a) (heating and electricity)	2002 €(t) + 1261 € (e) = 3.263 €	139,44 (e) + 832,00 (t) = 971,44
Investment €/ m^2		14.700 €
Investment per kg of CO2 saved annually €/kg m^2		3,72
Savings €/ m^2 a		2.291,56
Public Incentives		2.215,82 €
Net investment		12.484,18 €
Payback period a		5,4

Variant 3:

In this case the installation of a high efficiency heat pump with thermal power of 50 kW is considered, combined with a photovoltaic solar plan with a nominal power of 8 kW (the greater value of nominal power of the PV plant is due to the increase of the electrical energy consumptions related to the presence of the heat pump). Even if the heat pump can be used for cooling, no energy consumption are considered for building cooling for a better and easier comparison with the others technologies combinations.

Table 4.1.2 Description of the RES technologies used in this example

	Building- current status	Building Variant 3
Energy need for heating [kWh/y]	21.380	0
Energy need for cooling [kWh/y]	0	0
Use of electricity kWh/y]	4.569	1195
CO2 emissions [kg/y]	2207,00(e)+3769,35(t) = 5976,35	597 (e) + 0 (t) = 597
Operating costs per year [€/y] (heating and electricity)	2002 €(t) + 1261 € (e) = 3263 €	329,72 (e) + 0 (t) = 329,72
Investment [€]		22.700 €
Investment per kg of CO2 saved annually [€]		4,22
Savings [€/y]		2.933,28 €
Public Incentives [€]		2.983,5 €
Net investment [€]		19716,5 €
Payback period [y]		6,7

5. Conclusion

Several technology solutions can be used for realize a near zero CO2 emission. Moreover, the available products allow to implement high efficiency solution. However, only a right sizing of the system on the real energy needs and the development of the energy sources present near by the reference building allow a real and considerable energy efficiency.

In the table below the comparison between the results of the application of the three different technologies combination previously examined are indicated.

The reference building considered is the town hall of Matrice (CB).

	Building-current status	Building Variant 1	Building Variant 2	Building Variant 3
Energy need for heating kWh/a	21.380	20.413	8.889	0
Energy need for cooling kWh/a	0	0	0	0
Use of electricity kWh/y	4.569	505	505	1195
CO2 emissions kg/ m^2 a	5976,35	252	2.030	597
Operating costs €/a	3263 €	898,44 €	971,44	329,72
Investment €		16090 €	14.700 €	22.700 €
Investment per kg of CO2 saved annually €/ kg m^2		2,81 €/kg	3,72	4,22
Savings €/ m^2 a		2364,56 €	2.291,56	2.933,28 €
Public Incentives		1.853,00 €	2.215,82 €	2.983,5 €
Net investment		14.237,00 €	12.484,18 €	19.716,50
Payback period a		6,0	5,4	6,7

As can be noticed, regarding the cost per unit of carbon dioxide saved the most effective solution is to produce thermal energy with a solid biomass system (low cost energy production) combined with a PV plant for electricity production (variant 1).

However, is to underline that the use of solid biomass cannot be always applied (especially in urban places) because of solid fuels imply atmospheric emissions of particulates and other pollutants that could reach limits prescribed by law. In addition, the evaluation done in this document is focused on CO2 emissions. The combustion processes of solid fuels imply the emission in the atmosphere of a lot of pollutants and toxic substances (e.g. NOx, thin powders, volatile organic compounds, ...) here not considered.

Focusing the attention upon the variant 2 (installation of solar thermal collector as integration of the existing heating system and of a PV plant), the costs for each kg of CO2 saved is greater than one observed in variant 1 and the total amount of CO2 saved after the system installation is lower. Although this result can be indicated as negative, other positive aspect must be considered such as the economics of intervention and the lack of fine dust (natural gas is considered as fossil fuel) and other pollutants resulting from the combustion of solid fuels.

In order to reduce the pollutants emissions, in the variant 3 a solution with a high efficiency heat pump is considered. The heat pump is used to produce the thermal energy needed by building users for heating (the building cooling is not considered).

The advantages related to high energy efficiency of heat pumps mean that this technological option is, among those employing electricity, the most convenient. In the analyzed case, the increased energy consumption due to presence of the heat pump is compensate by the higher power of the PV plant than the ones of the previous cases. Infact, the PV-plant is used to energized also the heat pump and the electric users already present in the building.

Making the comparisons, the solution 3 make a relevant reduction of CO2 emission, although the cost per unit of CO2 saved is the highest. In addition, the initial cost of investment is higher than the ones of the other solutions, and higher is also the pay-back time. The advantage of this solution is the highest level of economic saving and no emission of pollutants and toxic substances in the atmosphere.

In conclusion, the technology that use solid biomass is considered economic, high effective regarding the CO2 emission saving, but with high environment impact. The solutions with thermal solar collectors or heat pumps are to be preferred.

The combination of a high efficiency heat pump and a PV plant that produce the electric energy needed by the heat pump is considered the best efficient, reliable and complete technology solution to apply in order to have a real low environment impact.