ITALY

AUTHORS

Senatro Di Leo
E: senatro.dileo@imaa.cnr.it

Monica Salvia
E: monica.salvia@imaa.cnr.it
National Research Council of Italy, Institute of Methodologies for Environmental Analysis (CNR-IMAA), C.da Santa Loja, 85050
Tito Scalo (PZ), Italy.

1 OVERVIEW OF THE REGION

Characteristics of the Region

Basilicata is a small region in Southern Italy, with 577,562 inhabitants (2011), which covers an area of 9,992 square kilometres, representing only 3.3% of the Italian surface. It is one of the 20 regions of the Italian Republic (*Figure 1*). Basilicata is split into two provinces: Province of Potenza and Province of Matera. Basilicata is bounded to the west by Campania, to the north and east by Puglia and to the south by Calabria and has two small coastlines, on Tyrrhenian Sea (to the west) and on Ionian Sea (to the south-east).

Figure 1 – The Basilicata Region

The trend of the population is in decline (*Figure 2*). From 2001 to 2011 there was a reduction of about twenty thousand inhabitants mainly due to low birth rates and migration towards other regions. After Valle d'Aosta, Basilicata is the Italian region with the lowest population density, with about 60.8 inhabitants per square kilometres respect to the national average of 201 inhabitants per square kilometre. This is mainly due to the prevalent mountainous morphology of the territory and a low economic growth.

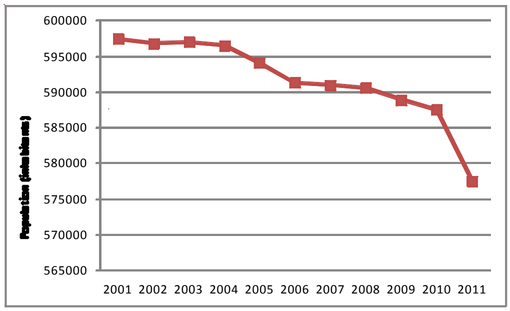

Figure 2 – Population of Basilicata 2001 – 2011 (Source: Istat, 2013)

In 2007 the Gross Domestic Product (GDP) of Basilicata was about €18,900 per capita, slightly higher than the average value in Southern Italy (€17,300 per capita) but consistently lower than the national average GDP (€26,000 per capita) (*Table 1*).

Euro per capita	2005	2006	2007
Province of Potenza	17,300	18,400	19,200
Province of Matera	16,700	17,700	18,300
Basilicata Region	17,100	18,200	18,900
Southern Italy	16,100	16,800	17,300
Italy	24,400	25,200	26,000

Table 1 – GDP values in 2005-2007 (Source: Regional Statistics Yearbook, Basilicata 2010)

The local economy is based on agriculture, in particular cereals, potatoes, vines and olives. The Basilicata industry sector is dominated by food and drink, artificial fibres, non-metallic mineral and chemical industries.

In the Val d'Agri area considerable mining of hydrocarbons is present, with preliminary treatment of extracted oil. In the North of the Region the largest Italian car maker (FIAT) has an important industrial centre. Tourism is increasing, mainly on the coastal areas, but it is still under the national average.

The total employment rate in Basilicata (37.6%) is lower than the national average (44.9%). In 2012, the labour market in Basilicata was affected by the contraction in economic activity with a decline of employees and hours worked. This has resulted in an increase in the unemployment rate (14.5% in 2012), which remains lower than the average value of Southern Italy but higher than the average Italian total.

The unemployment rate by level of education is always lower than national values. In particular, 8.4% of graduates and doctorates were unemployed in 2009 (*Table 2*).

Level of education	Basilicata	Italy
Primary school	10.9	9.9
Secondary school of first degree	12.5	9.4
Secondary school of second degree (2 – 3 years)	10.4	7.6
Secondary school of second degree (4 – 5 years)	11.6	7.2
Degree/ Doctorate	8.4	5.5
Total	11.2	7.8

Table 2 – Unemployment rate (%) by level of education. Years 2009 (Source: Regional Statistics Yearbook, Basilicata 2010)

Energy demand and supply of the Region
In 2010 the Basilicata Regional Authority approved the Regional Environmental Energy Plan (PIEAR) containing the regional energy strategy to be implemented to 2020. According to the PIEAR, in 2007 the total energy consumption was 59.23 PJ, mainly due to the Industrial sector (47%), followed by Transport (29%), Residential (13%), Commercial (8%) and Agriculture (4%) (*Figure 3*).

Natural gas and diesel are the most used fuels (23%): natural gas is mainly consumed by Industry (6.3 PJ) and Residential (5 PJ), whereas Transport is the largest consumer of diesel (10.5 PJ). Also electricity contributes substantially to the final energy consumption (18%), with 10.5 PJ of which 6.3 PJ in Industry, 2.02 PJ in Commercial and 1.84 PJ in Residential (*Figure 4*).

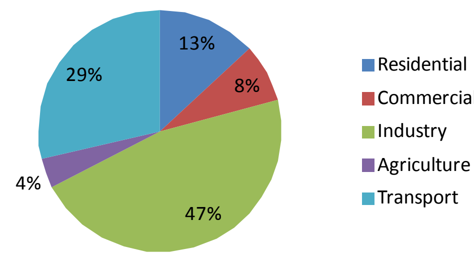

Figure 3 – Share of energy consumption by sector, 2007

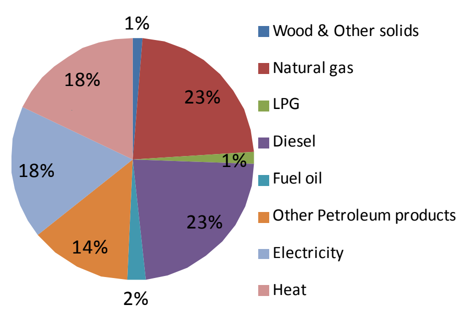

Figure 4 – Share of energy consumption by fuel, 2007

In *Table 3* a summary of energy consumption in 2007, by fuel and sector, is reported.

Energy source	RES	COM	IND	AGR	TRA	Total
Wood and Other solids	0.29	-	0.44	-	-	0.77
Natural						
Gas	5.02	2.14	6.3	0.04	0.06	13.56
LPG	0.24	0.14	0.24	-	0.25	0.87
Diesel	0.38	0.24	0.27	2.01	10.54	13.44
Fuel						
Oil	0.002	0.04	1.43	-	-	1.47
Other petroleum						
Products	-	-	1.98	-	6.07	8.05
Electricity	1.84	2.02	6.28	0.26	0.1	10.5
Heat	-	0.0003	10.6	-	-	10.6
Total	7.77	4.57	27.6	2.3	17.02	59.23

Legend: Residential RES, Commercial COM, Industry IND, Agriculture AGR and Transport TRA

Table 3 – Energy consumption (PJ) by fuel and sector, 2007 (Source: CNR-IMAA elaborations on PIEAR data and ENEA statistics)

The Region is heavily dependent on imported electricity from neighbouring regions, importing about 881.1 GWh in 2012, which is 29% of the consumed electricity (TERNA data). Thermoelectric power plants are powered by fossil fuels for a total power of 343 MW and 868 GWh of net production and are characterised by an efficiency level below the national average, as they are quite old installations. The installed capacity of cogeneration plants is about 70% of the overall thermoelectric power plants.

Regarding electricity production from renewable sources, in 2012 the main contribution was provided by wind power plants with a net production of 586 GWh and 369 MW of installed capacity. In the same year, hydroelectricity production was 304 GWh with an installed capacity of 129 MW. Most of the electricity production is provided by the Italy's largest power company (ENEL Production), which in Basilicata has three hydroelectric plants for a total capacity of 123 MW. Furthermore with the introduction of the "energy bill" there has been an increase in permits for the installation of photovoltaic (PV) systems, which has led to 330 MW of installed capacity and 586 GWh of electricity production from PV.

Basilicata holds the largest oil reservoir of continental Europe with a quantity of crude oil and natural gas extracted from its underground (actually about 90,000 barrels per day and 3 million of m^3 per day) (*Figure 5*).

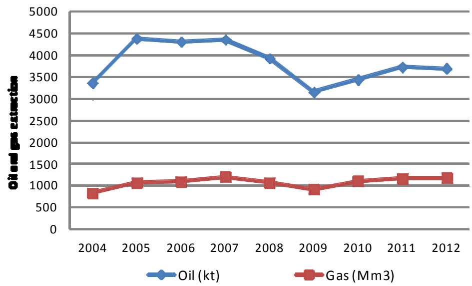

Figure 5 – Oil and gas extraction from Basilicata Region (Source: Umnig Office - Economic Development Ministry, 2013)

2. CURRENT SITUATION: TARGETS RELATED TO ENERGY POLICY

The Italian targets of the EU Climate Package by 2020 set the reduction of 13% for CO_2 emissions compared to 2005 levels and at least 17% of energy production from renewable sources compared to the gross final consumption of energy.

Italy's Budget Law 2008 (DL n. 208/2008) introduced the concept of "burden sharing", which involves the decision to split among regions the duties to achieve the EU target set for Italy for a 17% share of renewable energy by 2020. Only on 15 March 2012 this Law was acknowledged by a Ministerial Decree which set, in the particular case of Basilicata Region, an increase of the total share of thermal and electric energy produced by renewable energy sources in order to reach 33.1% of the gross final consumption within 2020, with the intermediate targets listed in *Table 4*. It should be pointed out that the reference value of the temporal trajectory of the regional targets on renewable energy is obtained by the ratio between the consumption from renewable sources and the gross final consumption. This value does not refer to a specific year, as it combines the latest information related to different years.

Also, the Italian economic and financial programming document 2008 – 2011 introduced a CO_2 emissions sharing mechanism among Regions. These provisions aimed to give more responsibility to regions and were enforced by Law 13/2009, which established a burden-sharing criterion based on the European 2020 target (IEA, 2009). In this case a ministerial decree has not been issued yet.

Year	Target
Reference value	7.9
2012	16.1
2014	19.6
2016	23.4
2018	27.8
2020	33.1

Table 4 – Trajectory of the targets (%) for renewables in the gross final consumption for the Basilicata Region (Ministerial decree of 15 March 2012)

Estimations of $ktCO^2$ emissions in 2000 – 2006 were estimated by ENEA and reported in *Figure 6*. In this period the contribution of the Basilicata Region was about 0.7% of the CO_2 total emissions for Italy. In 2006 the regional average amount of CO_2 polluted per MWh produced was 0.47, lower than the national average value of 0.59 tCO_2/MWh (Mankuso E., 2011).

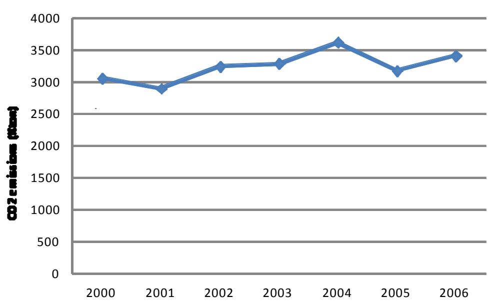

Figure 6 – CO_2 emissions of the Basilicata Region (2000 – 2006) (Source: Mankuso E., 2011)

In 2006 the highest contribution was made by the Civil sector (Commercial and Residential) which represents 1434 $ktCO^2$, that is 42% of the total regional emissions, followed by Transport (953 $ktCO^2$, 28%), Energy Production (538 $ktCO^2$, 16%), Industry (345 $ktCO^2$, 10%) and Agriculture (149 $ktCO^2$, 4%).

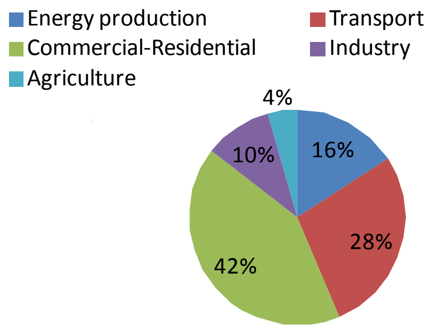

Figure 7 – CO_2 emissions by sector - 2006 (Source: Mankuso E., 2011)

The target of the PIEAR is the reduction of CO_2 emission of about 65% by 2020 compared to 1990 (2,231 $ktCO^2$).

Other Regional targets, barriers and drivers
Basilicata Region has favourable climatic conditions and topography for renewable resources development. There is a large availability of renewable energy sources including biomass, hydro, solar and wind. Delays in the installation of renewable technologies have been mainly caused by complex bureaucratic and administrative procedures. Moreover there has been legislative instability due to constant changes both in the regulations and incentive system. All these aspects could discourage private investors, already suffering from the present economic crisis and long term pay-pack periods.

The regional energy strategy is set by the Regional Energy Plan, in accordance with the instructions provided by the EU, the commitments made by the Italian Government and the uniqueness and potential of its territory. The Regional Energy Plan sets four main objectives: the reduction of fuel consumption and energy bills, the increase of electricity production from renewable sources, the increase of thermal energy from renewable sources and the creation of an energy district in Val d'Agri.

Reduction of energy consumption
In order to achieve an overall energy saving of 20%, the PIEAR proposes actions mainly focused on the efficiency of public and private buildings. In particular, it establishes the provision of grants for the implementation of measures to improve the energy performance of public and private buildings.

Measures to improve energy efficiency are also planned for public transport, encouraging the rationalisation of urban and extra-urban mobility. On the other hand, in private transport the use of more efficient engines is promoted. The plan encourages the distributed generation of electricity and, in particular, the installation of auto-production plants from renewable sources, connected to electricity distribution grids in low and medium voltage and localised in proximity of end-users.

Similarly, it promotes coupled production of electricity and heat (Combine Heat and Power). It favours the installation of auto-production plants, connected to electricity distribution grids at low and medium voltage as well as to distribution networks of steam or hot water, located in proximity to the users.

Increase of electricity production from renewable sources
Based on the potential of its territory, the Basilicata Region intends to satisfy the domestic needs of electricity almost exclusively through the use of plants powered by renewable sources. In *Figure 8*, the trend of electricity production for source in 2005 – 2012 is reported (TERNA, 2013).

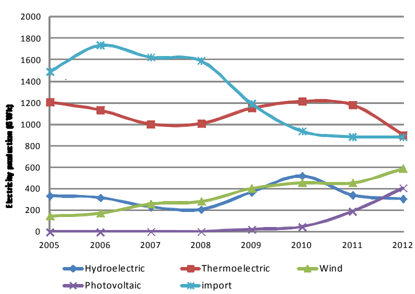

Figure 8 – Electricity production by source
Figure 8 shows an increase in the contribution of renewable energy sources in recent years.

In particular PV power generation increased from 45.7 GWh in 2010 to 407 GWh in 2012 and wind generation from 284 GWh in 2008 to 588 GWh in 2012.

Such an increase in electricity production from renewables has led to a reduction of electricity import from other regions, which halved in 2012 (881 GWh) compared to 2007 (1625 GWh). Moreover, this caused also a reduction in the share of traditional fossil fuels respect to the total electricity production, as resumed in *Table 5*.

Year	Electricity from thermoelectric respect to total production	Import of electricity respect to total consumption
2005	71	47
2006	70	52
2007	67	52
2008	67	51
2009	59	38
2010	54	29
2011	55	29
2012	41	29

Table 5 – Shares of electricity production (%) and import (%).

The Regional Energy Plan forecasts an electricity demand of 3800 GWh in 2020, with a deficit of 2300 GWh. According to the PIEAR, this deficit in electricity production will be pursued through an increased exploitation of locally available renewable energy sources (RES), as summarised in *Table 6.*

Renewable energy source	Share (%)	Electricity production (GWh/year)	Installed capacity (MWe)
Wind	60	1374	981
Solar and photovoltaic	20	458	359
Biomasses	15	343	50
Hydroelectric	5	114	48
Total	100	2289	1438

Table 6 – Renewable energy targets by 2020 (Source: Basilicata Regional Authority, 2010)

It has to be pointed out that this planned increase of electricity production from renewable sources will exacerbate problems already present in the transmission and distribution networks. In order to ensure the security of electricity regional supply and improve the quality of service for citizens and businesses, it is necessary to work on strengthening, streamlining and rationalising the primary and secondary electricity grid in Basilicata. To this end, the Basilicata Regional Authority is promoting a memorandum of understanding with TERNA, the company that manages electricity transmission in Italy, to intervene on the high-voltage transmission network. On the other hand, measures on the distribution networks at low and medium voltage will be also necessary.

The proposed interventions will be aimed to develop networks to transport and distribute electricity in an efficient and rational way, to manage the flow of energy produced by the individual production plants from renewable sources by encouraging distributed generation. To achieve this it will be important to use innovative technologies and computer control systems for transmission and distribution networks in order to improve the management of energy flows. The Regional Energy Plan indicates the importance of implementing pilot projects for the application of smart grids in local areas (micro-grids). The reduction of electrical losses in transmission and distribution networks is a more evident advantage: in fact, the use of electricity in the neighbourhoods of generation sites allows an achievement of higher efficiencies and savings in financial resources. Other valuable advantages of micro-grid installations are related to new jobs opportunities for technical graduates (engineers, informatics), technicians and specialised workers for the micro-grid operation and maintenance. The micro-grids have also a positive impact on the Medium Voltage and High Voltage macro-grids because they produce a decreasing of the electrical congestion on the Medium and High Voltage networks, thus reducing the investments addressed to solve this crucial aspect.

An important aspect concerns the simplification of authorisation procedures in order to facilitate public and private investors, for example, shortening the time for the issuance of permits and simplifying the documentation to be produced. For this reason, the Basilicata region has committed itself to harmonise the regional energy legislation with the national framework, taking into account also the provisions for environmental and landscape legislation.

Production of thermal energy from biomass and biofuels

An important objective of PIEAR is to increase the production of thermal energy using woody biomass and biofuels. In particular it aims to promote the energy valorisation of lignocellulosic biomass from forest management, agriculture and cow and pig breeding as well as local industries. A priority of the regional initiatives is the construction of district heating and mini-heating networks, especially for systems serving new public and residential buildings for which there is a less complex design and management.

Creating an energy district in Val d'Agri

As already mentioned in Basilicata, more exactly in the Val d'Agri area, there is a very large oil field currently undergoing extraction activities. In this area, the Regional Authority has planned to realise an energy district, in which developing research and technology innovation, involving universities and research centres operating in Basilicata. The main aim is to establish, in this energy district, industries that specialise in the production of innovative materials, systems and components for improving energy end-uses, both in the civil and productive sector. Other peculiarities of the district should be: the creation of innovative and experimental facilities for the production of energy from renewable sources, carrying out research and experimental activities on biofuels production and the creation of an energy park aimed at highlighting the most advanced technologies in the field of renewable energy and energy efficiency (including the construction of a demonstrative zero emissions building characterized by energy self-sufficiency).

Innovative strategies/initiatives

Also in Basilicata the EU and national challenges on climate and energy issues have been acknowledged by local authorities, committing themselves to improve the quality of life of citizens through sustainable urban development.

This is confirmed by the recent involvement of the multi-tier regional government systems in several international initiatives and networking activities, often supported by scientific institutions and universities. In particular, the Municipality of Potenza is currently involved in two South East Europe projects (EnVision2020 “ENergy VISION 2020 for South East European Cities” and RE-SEEties “Towards resource efficient urban communities in SEE”), the Province of Potenza is leading the INTERREG IVC RENERGY “Regional Strategies for Energy Conscious Communities” whereas the Basilicata Region is contributing to the LIFE08 ENV FACTOR20 “Forwarding demonstrative ACTions on a Regional and local scale to reach UE targets of the European Plan 20/20/20“ (2010 – 2012) and in the SEE ORIENTGATE “A structured network for integration of climate knowledge into policy and territorial planning” (2012 – 2014)

The increasing interest in energy policy and energy programming is also proved by the increasing number of municipalities of Basilicata, which have become members to the Covenant of Mayors (CoM). Since 2010, when the Potenza and Matera Provinces became supporting structures of the CoM, 71 cities (representing 54% of the whole number of municipalities in the region) have committed to go beyond the objectives of EU energy policy in terms of reduction in CO_2 emissions and are developing Sustainable Energy Action Plans (SEAPs).

Recently it a general increase in interest on Smart Cities initiatives has been observed aimed to help cities to start planning their future in a new way: adopting a comprehensive multi-sector approach and accelerating innovation to become more sustainable and resilient. In this framework, funded by a National Calls for bids on “Smart Cities and Communities and Social Innovation” launched in 2012 by the Ministry of Education, University and Research (MIUR), the “SMART Basilicata” project started on 30 November 2012 with a duration of 30 months.

SMART Basilicata is a coordinated project aimed to promote smartness among different local areas in Basilicata. The project constitutes a unique attempt in which, by working together, multi-layer public authorities, private enterprises, research organisations and universities have drafted the basis for a regional strategy for smart-related issues. The project is structured around five main operating objectives (Smart Environment, Smart Energy, Smart Mobility, Smart Culture & Tourism, Smart Participation) which are smartly integrated in a systematic approach towards a more sustainable configuration of the regional widespread “town” (Figure 9). All the research activities converge into four “demonstrators” located in different areas of Basilicata (SMART_ENV: Val d’Agri/Basilicata, SMART_Energy: Val d’Agri, SMART_STREET: Potenza, sMArTERA: Matera). The aim is to provide reference models for territorial development fostering the participation of multiple stakeholders from the public sector, civil society, and the private sector.

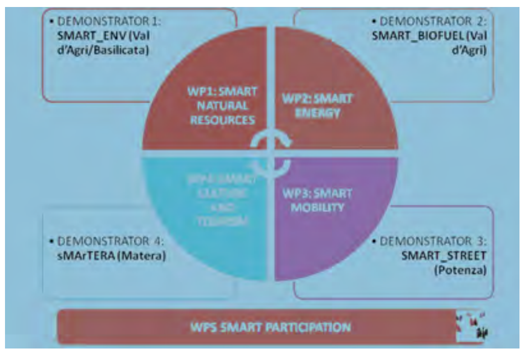

Figure 9 – Structure of the “Smart Basilicata” project

The local areas involved in this study are characterised by different dimensions, cultural identities, vocation and peculiarities whereas the replicability of the proposed solutions makes SMART Basilicata a “smart” attempt to draw a common innovation strategy on the medium/long term with a regional perspective.

3. CASE STUDY: THE TIMES-BASILICATA MODEL

The case study is focused on the Basilicata regional energy system both supply and end-use demands. It is based on the implementation of the TIMES-Basilicata model (Di Leo et al., 2013) to analyse the regional energy system and its evolution on the medium-long time horizon from 2007, the reference base year, to 2030. The main objectives, methodological aspects and results obtained are described in the following sections.

Objectives and methods

The TIMES, acronym of The Integrated MARKAL/EFOM System, is a powerful energy, economic, environment planning tool developed under the ETSAP programme of the International Energy Agency (ETSAP, 2013). It is largely utilised by numerous scientific communities to derive and study optimal development energy-environment scenarios at level of separate Communities, Province, Region, State or in a multi-regions approach, analysing in depth problems related to security of energy supply, mitigation of climate change and air pollution on a medium-long time horizon. The TIMES model allows a bottom-up technology-oriented representation of energy systems, representing energy flows from supply to end-use demands through the network of technologies, including both fossil and renewable energy vectors (Loulou et al, 2005). The energy systems evolution over the time horizon is described starting from a statistical reference year by introducing key data and constraints in the multi-period structure.
The input data concern resources availability, technical, economical and environmental features of technologies, exogenous constraints. The model individualises the minimum-cost solutions by scenario and defines the optimal levels of utilisation of resources and technologies that accomplish the system's constraints and scenario assumptions.
TIMES-Basilicata is a decision support tool for regional energy planning that has been developed at CNR-IMAA as part of the MONET Italy model, a twenty-regions energy model (Lanati F. *et al*., 2012). The data input of the TIMES-Basilicata model is structured around three sets of elaborate Excel spreadsheets, represented in the structure of *Figure 10*.

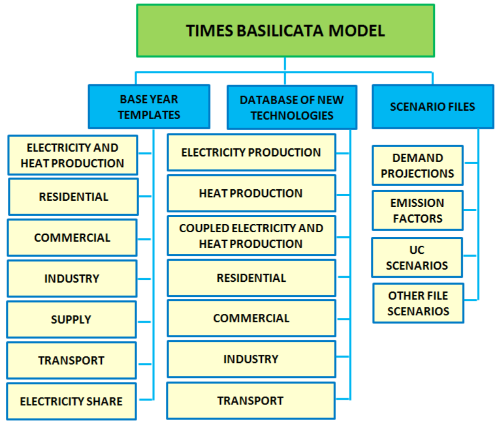

Figure 10 – Structure of the TIMES-Basilicata model

The first set deals with seven "*Base year templates*". This group involves six sector-by-sector templates which hold the data necessary to calibrate the energy flows of the base-year for the analysed end-use demands: Commercial (COM), Residential (RES), Industry and Agriculture (IND), Transport (TRA), Electricity and Heat production (ELC), and Energy Supply (SUP). In particular, these spreadsheets contain the following information: base-year energy flows, technical and economic characterisation of the existing technology stocks, transmission efficiencies. The representation of the base year is completed by the Electricity Share (SHR) template aimed to convert (through dummy technologies) the electricity at different levels of voltage into new electricity flows consumed in different industrial sectors and Agriculture.
The second set focuses on the database of new technologies ("*Subres new techs*"): new technological options are introduced and described by their technical and economic parameters distinguishing among Electricity Production (ELE), Heat Production (HET), Coupled Electricity and Heat Production (CHP), Residential (RES), Commercial (COM), Industry (IND) and Transport (TRA).

Last but not least there are the *"Scenario files"*: in order to build up alternative scenarios,

different sets of coherent assumptions about the future trajectories of demand are defined (Demand Projections) as well as exogenous constraints (User Constraints).
The characterisation of the Basilicata energy system is completed by a spreadsheet containing emission factors (both GHGs and local air pollutants) and with other files that will take into account other aspects in further studies (e.g. external costs, life cycle inventory impacts). As mentioned in previous sections, according to the Basilicata Regional Energy Plan an important role could be played by the development of distributed electricity generation, in particular micro-grids.

Assessing the possible contribution of micro-grids towards a more efficient regional energy system and reducing present distribution losses was one of the main aim of this study. The micro-grid concept was therefore introduced into the TIMES-Basilicata by reducing the transmission and distribution losses for the micro-grid generated electricity, keeping unchanged all the other parameters characterising different generating sources (capital costs, O&M costs, efficiency).

Results

In order to provide a sound basis of comparison, the first step dealt with the implementation of a Business As Usual (BAU) scenario for the Basilicata region energy system, characterised by the current energy trends and policies in use.

Two alternative scenarios were then built up to evaluate the micro-grids contribution. In particular, the MICRO-GRID1 scenario analyses the situation in which all the photovoltaic plants characterising the BAU scenario (with an increasing capacity from 36 MW in 2010 to 170 MW in 2030), operate in a micro-grids modality. Furthermore, the MICRO-GRID2 scenario investigates on the opportunity to introduce, in addition to PV plants, co-generative gas turbines (with a capacity of 26 MW constant on the time horizon), operating in micro-grids modality. In such a case, the energy credits in terms of substitution of imported electricity are also taken into account.

The amount of electricity generated over the time period 2010 – 2030 in the baseline configuration is represented in *Figure 11*.

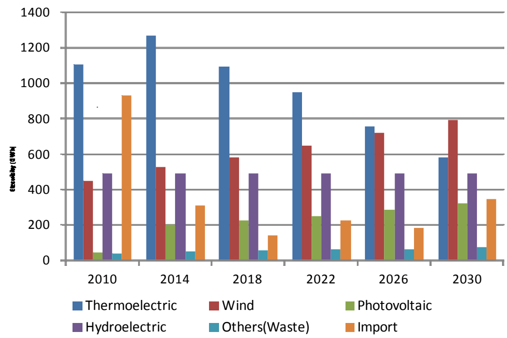

Figure 11 – Electricity production, 2010 – 2030

It can be observed that the total electricity generated in the region increases from 2149 GWh (2010) to 2277 GWh (2030) in the investigated period, while the imported electricity decreases from 935 GWh (2010) to 351 GWh (2030). The decrease of imported electricity is due mainly to two factors. The first is a reduction of the electricity consumption induced by the decrease of resident population. In fact according to ISTAT forecasts (ISTAT, 2013) the number of inhabitants could pass from 577,600 in 2007 to 531,500 in 2030.
The second is due to an increase of the renewable energy generated in the region in particular from wind plants (454 GWh in 2010 up to 796 GWh in 2030) and photovoltaic plant (from 45.2 GWh in 2010 to 323 GWh in 2030).

This sharp increase of RES sources contribution determines a significant reduction in the thermoelectric plant generation (1110 GWh in 2010 to 585 GWh in 2030 with a peak of 1269 GWh in 2014).

The energy losses of High, Medium and Low Voltage networks are shown in *Table 7*: they are on average 5.2%, 5.5% and 8.2% respectively for the High, Medium and Low Voltage networks.

	High Voltage	Medium Voltage	Low Voltage
2010	155	141	117
2014	138	127	107
2018	123	112	94
2022	124	113	99
2026	116	105	95
2030	119	110	99

Table 7 – BAU scenario: Energy losses in transmission and distribution networks (GWh)

In the MICRO-GRID1 scenario all the photovoltaic plants operate in a micro-grid framework: the corresponding generated electricity fulfils the electrical loads allowing a decrease in the network losses strongly dependent from the micro-grid topology (e.g. the distance between the plant and the loads). The following values have been assumed for the losses reduction:

- 0.5% at Medium Voltage and 0.8% at Low Voltage for the PV plants connected to the Medium Voltage network;
- 0.8% for the PV plants connected to the Low Voltage network;

The decrease of electrical losses causes a corresponding decrease of the total electricity demand (with the same consumption) as reported in *Table 8*, in which the percentages of micro-grids generation is compared with the loss reductions.

	Electricity generated in micro-grid	Loss reduction in the region networks
2010	1.5	1.4
2014	7.2	6.7
2018	8.8	8.1
2022	9.8	9.1
2026	11.6	11.0
2030	12.5	13.8

Table 8 – Decrease of losses in local networks compared to the amount of electricity generated in micro-grid (%)

The decrease of energy demand leads to a reduction of imports with relevant benefits also on the national grid.

In the MICRO-GRID2 scenario, co-generative gas turbines operate in a micro-grid framework from 2014, with a yearly energy production of 138.1 GWh. The amount of electricity produced by the gas turbines nearly replaces the imports. The corresponding electricity produced over the investigated period is reported in *Figure 12*.

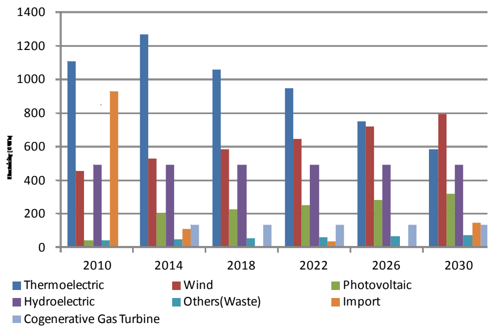

Figure 11 – Electricity production, 2010 – 2030

It can be observed that the total electricity generated in the region increases from 2,149 GWh (2010) to 2,277 GWh (2030) in the investigated period, while the imported electricity decreases from 935 GWh (2010) to 351 GWh (2030). The decrease of imported electricity is due mainly to two factors. The first is a reduction of the electricity consumption induced by the decrease of resident population. In fact according to ISTAT forecasts (ISTAT, 2013) the number of inhabitants could pass from 577,600 in 2007 to 531,500 in 2030. The second is due to an increase of the renewable energy generated in the region in particular from wind plants (454 GWh in 2010 up to 796 GWh in 2030) and photovoltaic plant (from 45.2 GWh in 2010 to 323 GWh in 2030).

This sharp increase of RES sources contribution determines a significant reduction in the thermoelectric plant generation (1110 GWh in 2010 to 585 GWh in 2030 with a peak of 1,269 GWh in 2014). The energy losses of High, Medium and Low Voltage networks are shown in *Table 7*: they are on average 5.2%, 5.5% and 8.2% respectively for the High, Medium and Low Voltage networks.

	High Voltage	Medium Voltage	Low Voltage
2010	155	141	117
2014	138	127	107
2018	123	112	94
2022	124	113	99
2026	116	105	95
2030	119	110	99

Table 7 – BAU scenario: Energy losses in transmission and distribution networks (GWh)

In the MICRO-GRID1 scenario all the photovoltaic plants operate in a micro-grid framework: the corresponding generated electricity fulfils the electrical loads allowing a decrease in the network losses strongly dependent from the micro-grid topology (e.g. the distance between the plant and the loads). The following values have been assumed for the losses reduction:

- 0.5% at Medium Voltage and 0.8% at Low Voltage for the PV plants connected to the Medium Voltage network;
- 0.8% for the PV plants connected to the Low Voltage network.

The decrease of electrical losses causes a corresponding decrease of the total electricity demand (with the same consumption) as reported in *Table 8*, in which the percentages of micro-grids generation is compared with the loss reductions.

	Electricity generated in micro-grid	Loss reduction in the region networks
2010	1.5	1.4
2014	7.2	6.7
2018	8.8	8.1
2022	9.8	9.1
2026	11.6	11.0
2030	12.5	13.8

Table 8 – Decrease of losses in local networks compared to the amount of electricity generated in micro-grid (%)

The decrease of energy demand leads to a reduction of imports with relevant benefits also on the national grid.

In the MICRO-GRID2 scenario, co-generative gas turbines operate in a micro-grid framework from 2014, with a yearly energy production of 138.1 GWh. The amount of electricity produced by the gas turbines nearly replaces the imports. The corresponding electricity produced over the investigated period is reported in *Figure 12*

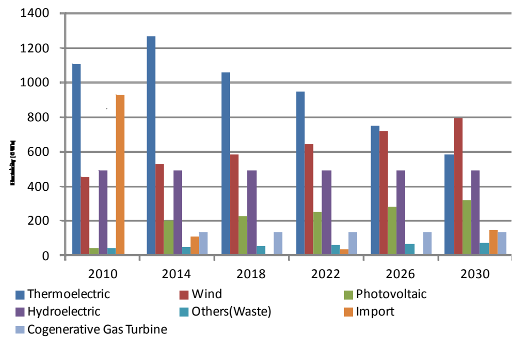

Figure 12 – MICRO-GRID2 scenario: Generation of electricity

The comparison between *Figure 11* and *Figure 12* underlines the significant changes in the mix of electricity production, fostered by an enhanced utilisation of micro-grids. As expected, network losses in the MICRO-GRID2 scenario, shown in *Figure 13*, decrease noticeably respect to the BAU scenario, ranging from 44 to 65 GWh respectively in the years 2014 and 2030. Respect to the MICRO-GRID1 scenario, energy losses reduction passes from 3 GWh in 2014 to 20 GWh in 2030.

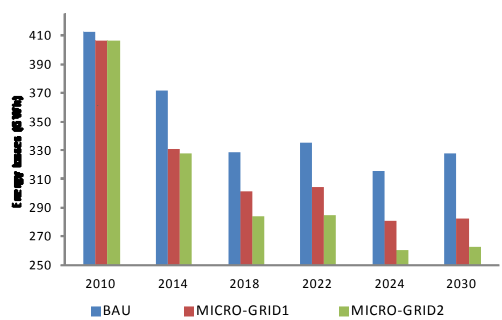

Figure 13 – Comparison of the total electricity losses between BAU and alternative scenarios

The trend of CO_2 emissions by electricity production is decreasing on the time horizon (*Figure 14*), due to an increasing contribution of renewable sources.

In the BAU and MICRO-GRID1 scenarios CO_2 emissions decreases from 517 kton in 2010 to 272 kton in 2030. In the MICRO-GRID2 scenario the co-generative gas turbines, operating in micro-grids and substituting electricity import, produce an increase of CO_2 emissions of 64 kton in 2030.

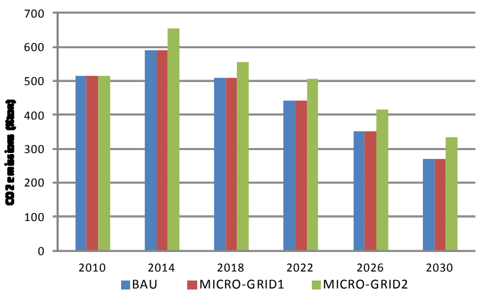

Figure 14 – CO_2 Emissions by electricity production in different scenarios

In term of costs (Table 9), for the BAU scenario the sum of electricity generation costs and transmission and distribution costs reaches 259 MEuro in 2030 with a peak of €318 million in 2014. The activation of the technologies operating in micro-grid has as a consequence a reduction in the transmission and distribution costs. In the MICRO-GRID1 scenario a reduction of costs is observed respect to the BAU scenario with the highest reduction of minus €21.4 million, -9.3% in 2018. Highest reductions are obtained in the MICRO-GRID2 scenario with values reaching minus €33.4 million (-14.5%) in 2018 respect to the BAU scenario.

	BAU	MICRO-GRID1		MICRO-GRID2	
	MEuro	MEuro	(%)	MEuro	(%)
2010	260	-2.1	-0.8%	-2.1	-0.8%
2014	318	-19.0	-6.0%	-30.5	-9.6%
2018	231	-21.4	-9.3%	-33.4	-14.5%
2022	258	-12.5	-4.8%	-27.6	-10.7%
2026	248	-16.8	-6.8%	-32.5	-13.1%
2030	259	-12.0	-4.6%	-28.9	-11.1%

Table 9 – Comparison of the electricity total cost (generation, transmission and distribution): costs reduction due to the introduction of micro-grids in the two analysed scenarios compared to the baseline situation (BAU)

4. CONCLUSIONS

The implementation of the TIMES Basilicata model allowed to analyse the evolution of the regional energy system in the medium term. The main focus was on the analysis of electricity production and the consequences derived by the micro-grids introduction. Taking into account the current incentive system, an increase of electricity production from renewable energy sources, especially wind and PV, can be implemented on the short term time horizon). This means a larger valorisation of the regional potential of renewables, with a decrease of electricity production from fossil fuels and a reduction of electricity imports from other regions.

The scenario analysis highlights the main advantages in terms of energy efficiency related to the installation of micro-grids, under the analysed scenarios, with a decrease of transmission and distribution losses ranging from 12% to 20% (MICRO-GRID2 scenario) and a higher efficiency of the overall power system ranging from 1.7% to 2.5%, respectively in the years 2014 and 2030. The results point out that the micro-grids could constitute a favourable structure for electricity generation from distributed sources, and in particular from renewables, replacing the electricity generated by fossil-fuel power stations. These considerations are generally applicable also in other local communities characterised by a large availability of RES, making micro-grids a highly replicable alternative.

This study shows how the TIMES model can be usefully applied at regional/local scale to support the definition of energy-environmental strategies on the medium-long term. In particular, it proves how the introduction of new technologies (such as micro-grids) can impact on the overall energy system. To this end the scenario analysis is particularly effective to provide decision-makers with an overall picture of the main benefits related to different choices/technologies in terms of energy, GHG emissions and money saving.

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The COST Action TU1104 Smart Energy Regions brings together over 70 researchers from European institutions to investigate the drivers and barriers that may impact on the large scale implementation of low carbon technologies in the built environment. The book "Smart Energy Regions" is the outcome of the Working Group 1 of the Action and collects analysis and case studies from 26 European countries. For more information about the Action and COST please visit www.smart-er.eu and www.cost.eu.

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