MARIE

MEDITERRANEAN BUILDING RETHINKING FOR ENERGY EFFICIENCY IMPROVEMENT

IREC

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Potential Impact Evaluation
of the MEDBEES First Draft

(Integrated Regional Benchmark Analysis)

Final Report

Barcelona, August 2012

Med
L'Europe en Méditerranée
Europe in the Mediterranean

Projet cofinancé par le Fonds Européen de Développement Régional (FEDER)

Project cofinanced by the European Regional Development Fund (ERDF)

PROJECT:	MARIE. Mediterranean Building Rethinking for Energy Efficiency Improvement
VERSION:	2
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DATE:	August 1, 2012

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1 INTRODUCTION

1.1 BACKGROUND

The strategic vision of MARIE is to achieve the professional, social and economic conditions for Energy Efficiency (EE) improvement in the MED Building Stock in the framework of EU policies, programs and standards, overcoming legal, financial and market barriers.

One of the MARIE's outputs is the so called "MED Buildings Energy Efficiency Strategy (MEDBEES)", which will propose measures to promote energy refurbishments in the existing building stock.

As a first step towards defining the MEDBEES, WP4 and WP5 developed regional benchmark analyses (RBAs) of the demand and supply of energy efficiency solutions in the MED regions. The two RBAs identified barriers for energy refurbishments (i.e., "why is not energy refurbishment common practice already?"), and proposed general policy measures to overcome them (i.e., "what can we do to make energy refurbishments mainstream?"). Some of these policy measures will be tested in the Pilot Actions.

While the tests in the implementation phase of the MARIE project will provide key inputs on the performance and the challenges of the specific policy measures being tested, they will not be enough to evaluate the potential impact of the MARIE policy measures as a whole (i.e., at regional level). Evaluating the impact of the MEDBEES in the future requires a forecast study based on a crossed analysis of the two sets of data compiled in the RBAs of WP4 and WP5.

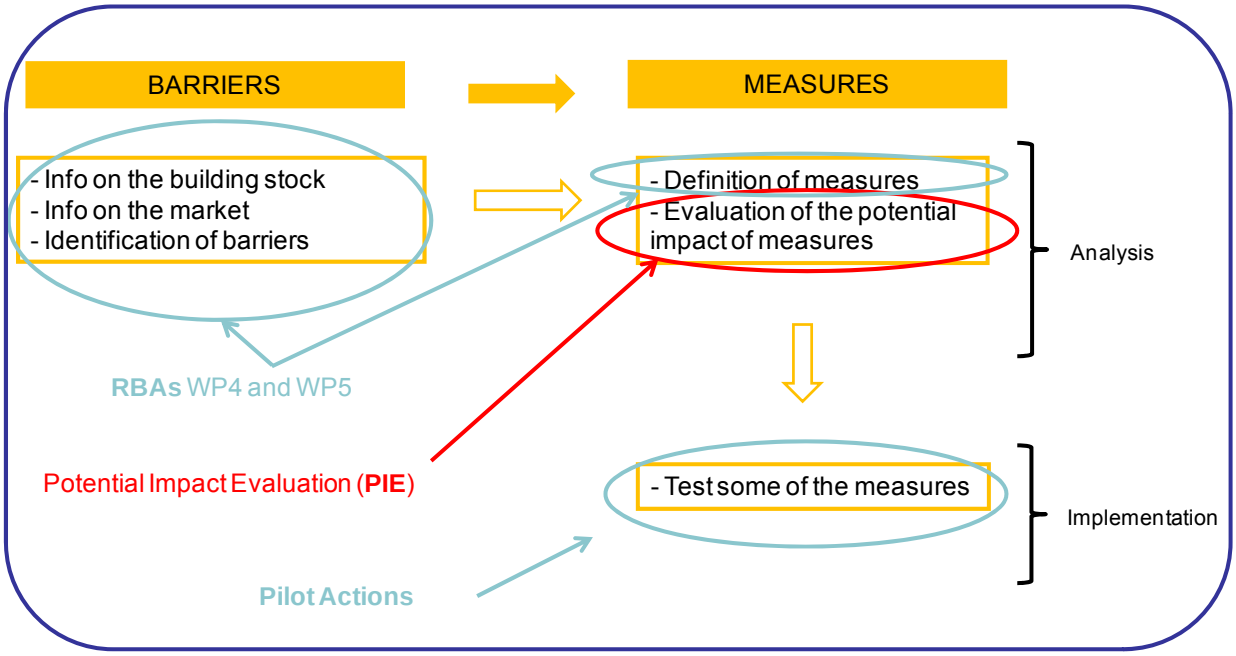


Figure 1 The Potential Impact Evaluation (PIE) within the MARIE project

1.2 OBJECTIVE

The objective of the Potential Impact Evaluation (PIE) is to assess the potential benefits of the MARIE policy measures in terms of final energy use.

The policy measures defined in the RBAs of WP4 and WP5 are indeed the first draft of the MEDBEES. The Potential Impact Evaluation aims to perform an ex-ante assessment of the potential impacts of such measures, so that its results can inform on the suitability of these policy measures in the analyzed regions.

1.3 SCOPE

The PIE provides results in terms of final energy use by end use. Primary energy calculations, CO_2 emissions, and externalities related to the policy measures (e.g., other environmental impacts, job creation...) are beyond the scope of this analysis.

The analysis includes the residential and the tertiary sectors. Transportation and industry are outside the scope.

The focus of the MARIE project is energy refurbishments in the existing building stock. Therefore, this analysis also focuses on refurbishments (both in the method and the results). Some aggregated results of final energy use in the total stock (i.e., including both new and existing buildings) are also show, however, these are meant only to provide a broader perspective (i.e., to see the relative impact of existing buildings vs. new construction). Since the project focuses on energy refurbishments, the trends in new construction were not defined in the same level as these in existing buildings.

The Potential Impact Evaluation required a great deal of data at regional level, most of which had been previously compiled in the RBA of WP4. Therefore, only the regions in WP4 could be included in the PIE. The selected regions and the corresponding partner are shown in Table 1.

Table 1 Geographic scope of the PIE

Region	Country	Partner
Liguria	Italy	ARE Liguria
Piedmont	Italy	Piedmont region
Basilicata	Italy	Basilicata region
Catalonia	Spain	LIMA Association
Andalucía	Spain	EPSA-COPV, Junta de Andalucía
Provence Alpes Cote d'Azur	France	PACA region
Slovenia	Slovenia	Goriska Local Energy Agency
Greece	Greece	ANKO Regional Development Agency of Western Macedonia
Malta	Malta	Local Council Association of Malta

2 METHOD

2.1 METHOD OVERVIEW

The Potential Impact Evaluation assesses the potential impact of the MEDBEES by comparing the outlook of final energy use of a scenario according to the MARIE measures against a "reference scenario" (i.e., scenario comparison). The objective of the PIE is not to accurately forecast the final energy use should the MEDBEES be strictly followed in the analyzed regions[1], but rather to evaluate the potential benefits of the MARIE strategy (MEDBEES) over a "reference". Therefore, the relative difference between scenarios is in this context more interesting than the results in absolute terms.

Needless to say, the way the scenarios are defined and the consistency in the method throughout the scenario setting process are absolutely key steps to achieve meaningful results in a scenario comparison study (i.e., "meaningful results require meaningful inputs"). The following sections describe the process followed to define the scenarios and their regional settings in the Potential Impact Evaluation.

2.1.1 THE PROCESS

Figure 2 shows a simplified flow chart of the complete process followed in the PIE. The initial stages define the inputs to be introduced in the simulation tools, which will in turn provide the results in terms of final energy use.

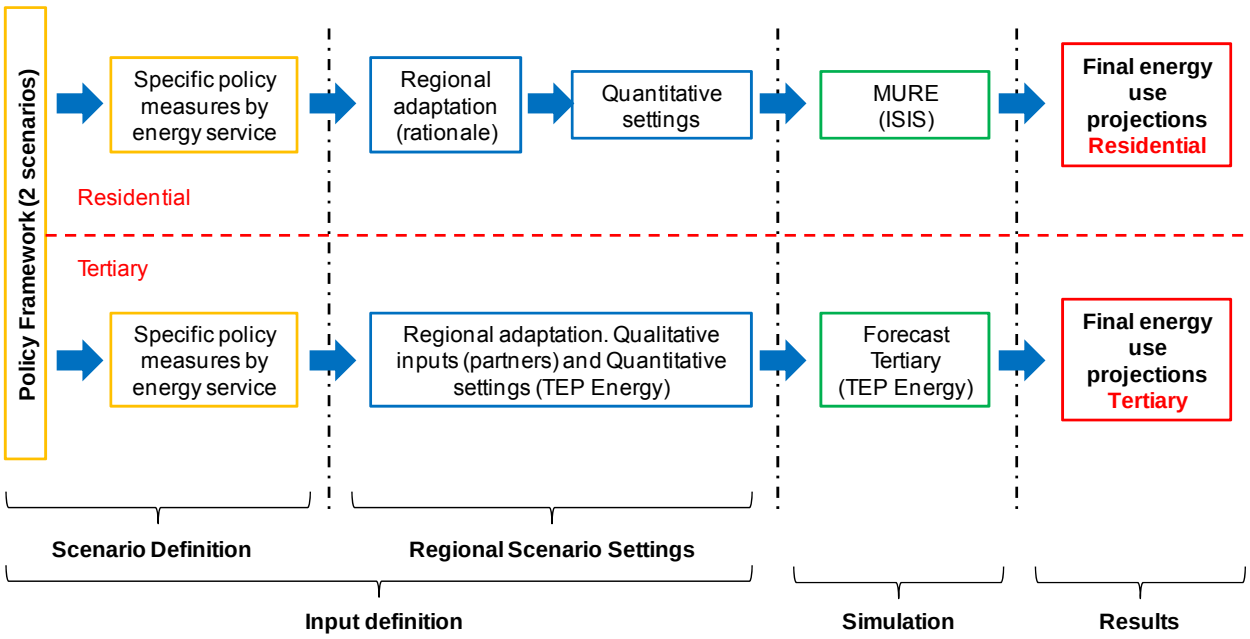


Figure 2 Process overview

[1] This would be the objective should the study be meant to (e.g.) assist energy infrastructure planning. In this case, the absolute values of final energy use outlook (as well as peak power demand) would be the main result of the analysis.

Consistency in the results largely depends on the consistency in the "input definition" phase. The quantitative inputs introduced in the simulation tools must be consistent with the overall philosophy of the scenarios and adapted to the regional characteristics. The process to bring down the general scenario philosophies to quantitative inputs for the model can be divided into two sub-processes:

- Scenario definition
- Regional scenario settings

The "Scenario Definition" process sets the general policy framework. Furthermore, it translates the general scenario philosophies into a list of specific policy measures by energy service (but still general for all the regions).

The general policy framework of the MARIE scenario is based on the barriers and measures compiled in the RBAs of WP4 and WP5, while the policy framework of the reference scenario ("Rapid Results" – see section 2.2) is based on former national energy plans, and conceived as an opposite strategy to approach energy efficiency improvements in the building sector. Figure 3 illustrates the policy framework definition process.

The first draft of the policy framework for the two scenarios was presented in the Marseille meeting (November 2011). It went through review by the MARIE partners as well as the Advisory Group (December 2011), and was eventually wrapped up when the consortium agreed on the final list of MARIE Barriers and MARIE Measures that combined the findings of WP4 and WP5 (in late January 2012, see Annex 1 and Annex 2 at the end of this document).

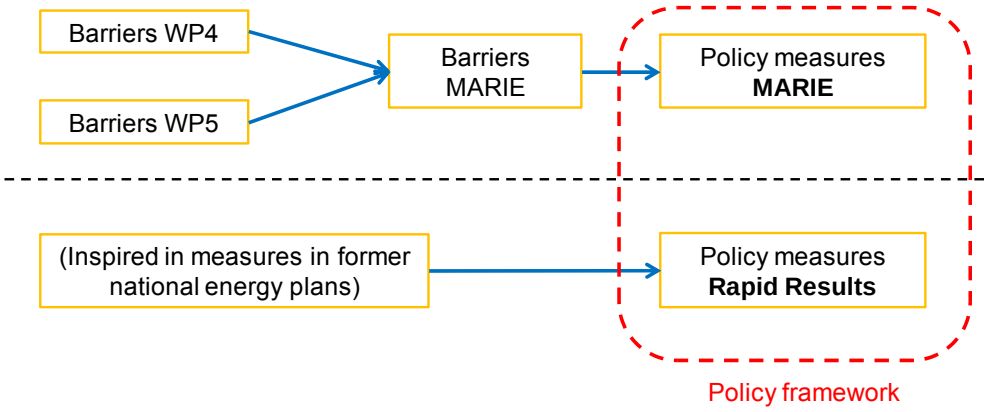


Figure 3 Policy framework definition

The "Regional Scenario Settings" process includes all the steps that were followed to translate the general policy measures (by energy service) into region-adapted quantitative inputs for the simulation tools. Figure 4 illustrates the process.

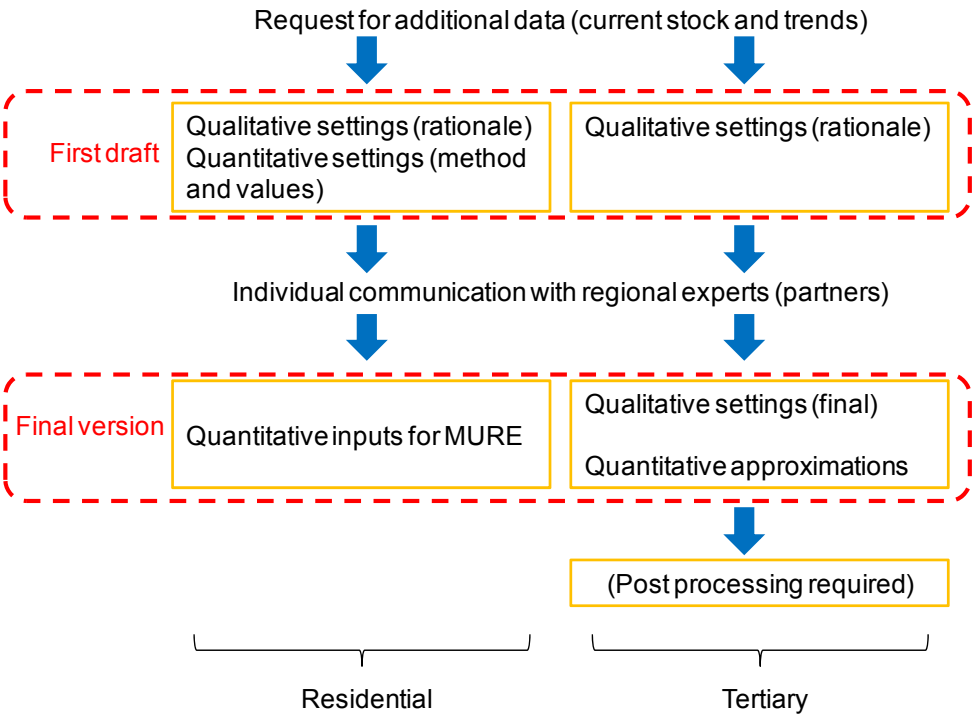


Figure 4 Regional Scenario Settings process

A first draft of the individual regional scenario settings (i.e., one per region) was prepared based on the information provided by the corresponding regional partner. The first draft included:

- Qualitative assumptions on the future trends of the energy drivers (e.g., assumptions on technology transitions), both for the residential and the tertiary sectors.
- A method to translate the qualitative assumptions into quantitative inputs (see 2.3.2) for the residential sector. For a better consistency in the quantitative inputs, it was considered crucial that all the regions used the same method.
- Quantitative settings for the residential sector.

The regional partners were provided with the first draft of their corresponding scenario settings, and were requested to provide feedback. Following individual communications with the partners, the scenario settings were adjusted according to the comments from the regional experts.

The difference in the method for residential and tertiary sectors is due to the use of different simulation tools (with different requirements) and the difference in the available data. The MARIE consortium was capable of compiling highly detailed residential data, however very little data was available at regional scale for the tertiary sector (not even for the most important energy drivers). The regional tertiary data had to undergo an intensive post processing process before using it as an input for the simulation tool (i.e., the data gaps were filled based on adaptations from national data or regions with similar characteristics).

Both ISIS and TEP Energy actively contributed in the regional scenario settings process providing expertise and filling the data gaps.

2.1.2 FINAL ENERGY USE CALCULATIONS

A sound forecast of energy use requires using comprehensive simulation tools capable of handling large amounts of data as well as the interactions among the different drivers of energy use. The tools to assist the development of the Potential Impact Evaluation (PIE) were MURE and FORECAST Tertiary. MURE and FORECAST Tertiary are bottom-up simulation models of ISIS, Rome, and TEP Energy GmbH, Zurich, respectively. Both ISIS and TEP Energy have extensive expertise in using their respective tools for evaluating National Energy Efficiency Plans of several EU member states [1-3].

MURE and FORECAST Tertiary are simulation tools for the assessment of energy policy scenarios. MURE and FORECAST Tertiary are technology oriented bottom-up models that are capable of assessing technical, operational and user dependent energy-efficiency measures, based on technology characteristics and their use in different scenarios. The output of MURE and FORECAST Tertiary is an outlook of the final energy use (by sector and end use) according to the defined scenarios.

Due to the differences in the exogenous drivers for energy use and available data, MURE and FORECAST Tertiary are independent models for the evaluation of the residential sector and the tertiary sector, respectively.

The technological measures are defined with parameters such as “saving factors”, or “efficiency”, which may depend on the technology and the location where it is implemented. In the case of FORECAST Tertiary energy-efficiency measures are selected on the basis of internal life cycle cost calculations as a function of exogenous energy prices and implicit interest rates (implicit referring to an approximation of all types of barriers).

Note that the models MURE and FORECAST Tertiary are not prediction models of the effectiveness of policy measures but simulation models that implements exogenous assumptions made by the modeling team (i.e., the effectiveness of policy measures are implicitly defined in the inputs).

2.2 SCENARIO DEFINITION

A “scenario” is a set of boundary conditions that affect a process. In this case, “energy use in the building stock” is affected by a wide range of conditions, including demographic trends (total population, population average age…), technology improvements, economic framework (availability of private and public funds, customer purchasing power, economy dynamics…), user behavior (awareness on energy systems, education, purchasing preferences,…), and the policy framework (building code characteristics, enforcement systems, incentives and subsidies, administrative procedures…). A comprehensive “scenario definition” requires making assumptions (whether they are implicit or explicit) on all the above conditions.

2.2.1 COMMON CHARACTERISTICS IN THE TWO SCENARIOS

The MARIE project is meant to provide policy recommendations to promote energy efficiency refurbishments. On the other hand, the outputs of the MARIE project will have little influence on drivers such as population trends or the economic framework. Therefore, the scenarios share the same assumptions on “non-policy drivers” (e.g., demographic trends), and vary on the policies (which, in turn, affect the penetration rates associated to the different technologies). In this study, “scenario” is equivalent to “policy framework” (i.e., a set of policy measures).

The regions were modeled independently and according to their characteristics and natural trends. Therefore, even if the "non-policy drivers" such as demographic trends are common in the two scenarios, these were adapted according to the regional characteristics.

Keeping all the non-policy drivers constant in the two scenarios substantially reduces the uncertainty in the results, and allows a more clear comparison between them (which is indeed the goal of the analysis). Remember that the interest of the PIE lays more on the relative results of the two scenarios (policy strategies) than on the absolute results of final energy use themselves.

The trends in the key parameters that remained constant in the two scenarios are summarized below:

- The economic context remains rather unstable for a few years, and gradually tends to go back to "normal". The construction sector in the Mediterranean regions saw a "boom" in the early 2000's, which was sharply interrupted by the current recession. Neither the boom nor the crisis are considered "stable situations" when defining the "normal" trends.
- Social awareness on environmental issues (including these related to energy use) tends to increase. Policy measures (e.g. awareness campaigns) in the independent scenarios build on this natural trend.
- Cost of energy tends to increase in both scenarios. However, energy "retail price" can be further increased by independent scenario policies (e.g., taxes on energy or carbon emissions).
- Demographics follow the trends shown in the regional or national outlooks.

2.2.2 MARIE vs. Rapid Results

Figure 5 summarizes the main concepts behind the MARIE and the Rapid Results (RR) scenarios.

MARIE
Includes the MEASURES defined by the MARIE consortium. Policies promote market transformation to make integral refurbishment mainstream in the long run – e.g., financial instruments for integral refurbishment

Rapid Results
Uses the opposite type of policy measures (strategy) to improve energy efficiency in the building sector. Policies are focused on measures with results in the short term - e.g., subsidies for equipment replacement

Policies in both scenarios target energy use reductions in the built environment. **The two scenarios are equally ambitious, but use different strategies**

Figure 5 Scenarios in a nutshell

The MARIE scenario is based on the measures (see Annex 2) proposed to overcome the barriers for energy refurbishment in the building sector (see Annex 1) identified by the MARIE consortium. The MARIE scenario includes policies to gradually transform the market and make large scale (high investment) integral refurbishment works mainstream in the long run. These measures include (but are not limited to) new financing formulas for large investments, changes

in legislation and administrative processes, gradual increase on energy taxes, and comprehensive communication plans to influence user behavior [4-6][2].

The Rapid Results scenario is the "reference" against which the MARIE scenario is evaluated. Rapid Results was not conceived as a "natural trends" scenario, but rather as a scenario that is as ambitious as MARIE, but uses the opposite type of policy measures (strategy) to improve energy efficiency in the building sector. The Rapid Results scenario reduces the financial barriers for "cheap" energy efficiency measures (e.g., subsidies for efficient lighting, HVAC equipment, window replacement). The results of these policies are quicker than these expected in the MARIE scenario; however the lighter market transformation may limit a sustained impact in the long run. Some of the policies in the Rapid Results scenario are inspired in former national energy efficiency action plans (NEEAPs) [7-11]. Outlook studies often compare a given scenario against a "natural trends" (less ambitious) reference [12-14]. Note that the, due to the nature of this study, the reference scenario (RR) is as ambitious as the scenario under evaluation.

The general policy frameworks briefly described above led to more specific policy measures by energy service. Table 2 to Table 5 show the measures for the residential sector. The tables compare the specific policy measures adopted in the two scenarios.

Table 2 Residential – Measures on envelope / integral refurbishment

Rapid Results	MARIE
Subsidies for window replacement[3]	N/A
Subsidies for renovated buildings that meet high energy certification levels Increasing energy performance requirements for buildings that undergo integral refurbishment (building code)	
N/A	Financial incentives/schemes to promote integral refurbishments: - Soft loans for integral refurbishments - "Green mortgages" - Tax exception/reduction for energy refurbished buildings…
N/A	Financial incentives/tools to promote energy refurbishment of rented dwellings: - Reduced taxes over rental of energy efficient buildings (high certification levels) - Split the savings in EE between landlord and tenant...
N/A	Energy refurbishment plans at neighborhood scale (to make it easier for ESCOs to step in). (This means that it is the municipality/city hall the one taking the initiative instead of waiting for the individual owners to make up their minds)
N/A	Reduction of administrative procedures required for integral refurbishments
Awareness campaigns	"Marketing-oriented", comprehensive communication strategies to promote integral refurbishment
N/A	Life Cycle Cost (LCC) as a criterion for public procurement (instead of capital cost)

[2] Conventional awareness campaigns have proved to have little impact on user behavior (both when making the decision to purchase an energy system and when using it). Recent research findings show that behavior is does not only depend on knowledge, and that a more comprehensive "marketing-oriented" approach to communication would likely provide a larger impact on the user.

[3] Except for Malta, due to climatic reasons

Table 3 Residential – Measures on heating and cooling equipment

Rapid Results	MARIE
Subsidies for heating equipment replacement - Old boilers are replaced by new ones, but there are not changes in technologies if these require large refurbishment works	N/A
Subsidies for cooling equipment replacement	N/A
Subsidies for energy management (control) systems	N/A
Awareness campaigns to promote equipment replacement	N/A
Increasing energy efficiency requirements on equipment	
N/A	Promotion of community-scale systems for heating/cooling - (measure included within the refurbishment plans at neighborhood scale. See above) - Financial incentives/schemes - Awareness campaigns - ...
N/A	Mandatory individual energy metering
N/A	High efficiency equipment is indirectly promoted by the incentives for high performing refurbished buildings - In this scenario, technology changes are linked to integral refurbishments
N/A	Consistency among codes that affect energy use for heating/cooling: requirements on envelope, ventilation (fresh air), equipment efficiency

Table 4 Residential – Measures on renewable energy systems

Rapid Results	MARIE
Subsidies for biomass systems	N/A
Few subsidies for solar thermal systems for DHW	N/A
Solar thermal systems are required for DHW Biomass is considered "renewable energy" with "zero carbon emissions" - This encourages its use in buildings with high certification levels.	
N/A	Renewable energy systems are indirectly promoted by the incentives for high performing refurbished buildings ("same as heating systems")
N/A	Some large renewable energy systems may be linked to community-scale heating and/or cooling systems (see above)

Table 5 Residential – Measures on lighting and appliances

Rapid Results	MARIE
Subsidies for replacement to high efficiency lighting	N/A
Subsidies for lighting control systems	N/A
Subsidies for replacement to high efficiency appliances tend to fade out Increasing energy efficiency requirements for both appliances and lighting	
N/A	High efficiency lighting is indirectly promoted by the incentives for high performing refurbished buildings ("same as heating systems").

The scenario definition method for the tertiary sector was different from that used in the residential sector due to the difference in data availability and the characteristics of the simulation tool. The scenario definition in the tertiary sector was based on a two tier qualitative outlook of "policy intensities", as shown in Table 6.

Table 6 Tertiary – Policy intensities by energy use

	Rapid Results		MARIE	
	< 2020	< 2035	< 2020	< 2035
Envelope				
Envelope efficiency (old)	Low	Medium	Medium	High
Envelope efficiency (new b.)	Medium	Sl. High	High	High
Retrofit rate	Medium	Medium	Sl. High	High
Utilization (e.g. controls)	Low	Low	Sl. High	High
Use and service level (e.g. temperature)	Medium	Medium	High	Sl. High
Heating system				
Replacement rate	High	Sl. High	Medium	Medium
Efficiency	High	High	Sl. High	Sl. High
Fuel market share and substitution				
Solar thermal	Low	Low	Sl. High	High
Biomass	High	High	High	High
District heating	Medium	Medium	High	Very High
Heat pumps	Low	Low	Low	Low
Ventilation and cooling				
Cooling efficiency	High	High	Sl. High	High
Ventilation efficiency	Low	Medium	Sl. High	High
Utilization (temperature and occupancy controls, free cooling etc.)	Low	Low	Sl. High	High
ICT				
Efficiency	High	High	Sl. High	High
Lighting				
Efficiency	High	High	Sl. High	Sl. High
Utilization (daylight and occupancy)	Low	Medium	Sl. High	High
Refrigerators (products)				
Efficiency	High	High	Medium	Medium

The above policies were common for all the regions included in this analysis. Their adaptation to the individual regions is addressed in the following sections.

2.3 REGIONAL SCENARIO SETTINGS IN THE RESIDENTIAL SECTOR

The quantitative scenario settings were formatted to match the inputs required by the simulation tools. Therefore, the simulation tool substantially affected the scenario setting process.

2.3.1 BUILDING STOCK CHARACTERIZATION

The first step to define the regional scenario settings is to know the characteristics of the building stock for each region. This characterization allows adapting the specific policy

measures to each region, depending on their current situation, their climate, and the social, cultural, and economic context.

The building stock (both current situation and future trends), has to be defined for all the different energy uses: heating, cooling, domestic hot water, lighting and appliances. The characterization of the building stock has followed the process showed in Figure 6. The description of each process is detailed in the chapters below.

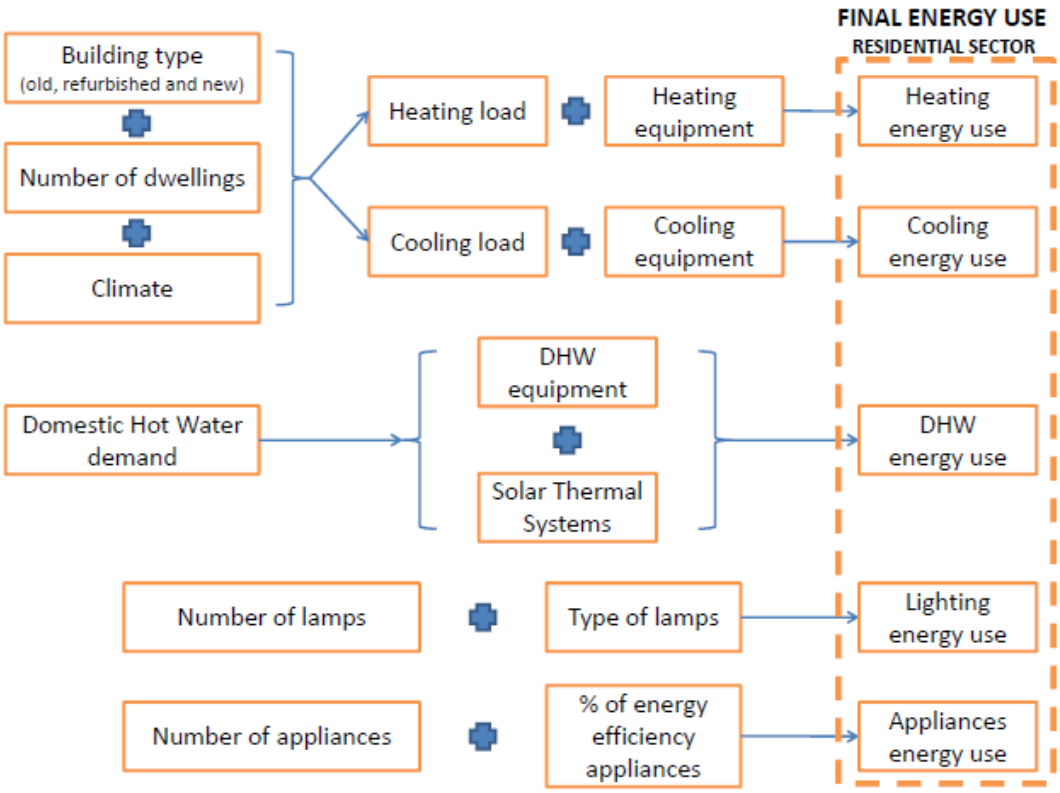


Figure 6 Process followed to characterize the building stock of each region

2.3.1.1 Heating and Cooling loads

The method that has been used to estimate energy demand for heating and cooling, for the building stock of each region is the following:

- Identification of the different building types. The objective is to define different construction periods for each region as a classification criterion. The building codes have been used to define the types in most of the regions.

- Characterization of the types. To estimate the energy demand it is necessary to characterize the construction, in terms of envelope (roof, walls and windows) thermal performance.

- Energy simulation of the building types. Building simulations have been carried out using the TRNSYS software. The heating and cooling loads have been obtained for each type of building.

- Breakdown of the dwellings stock by type (construction period). It is necessary to know the number of dwellings (single and multi family) that belong to each type. This allows determining the influence and the importance of every type on the total energy demand of the stock.

- Adaptation of the data to be inserted into MURE. Finally, the results obtained in the previous steps have been combined and adapted to the format required by MURE.

2.3.1.1.1 Identification of the different building types

Over the years, construction techniques and materials have changed, and so the unitary energy demand of dwellings. In terms of thermal envelope, the change mechanisms are basically the implementation of the building codes. One of the most important parameters to calculate the heating and cooling load is the envelope of the building. For this reason, codes on envelope requirements have been the basic criterion for type definition.

Some of this information has been obtained from the regional benchmarking analysis carried out within WP4 (RBA WP4) [15], essentially the current and the future building codes. Information on the previous building codes was requested to the WP4 partners. When the information in the codes was not available or not enough, it has been complemented with values found in literature.

In summary, the sources used to define the building typologies for each region are described in the Table 7.

Table 7 Sources that have been used to define the building types for each region

Region	Source
Piedmont Liguria Basilicata	- TABULA [16] - Decreto Legislativo 2005, n. 192 / 2006 n. 311 [17]
Catalonia Andalusia	- PhD Thesis, N. Garrido [18] - NBE-CT-79 [19] - NRE-AT-87 (only Catalonia) [20] - Código Técnico de la Edificación 2006 [21]
PACA	- Regional Benchmarking Analysis, PACA - RT 2005 [22] - RT 2012 [23]
Slovenia	- Building Codes between 1967-2010 [24-30]
Greece	- Dascalaki, 2010 [31] - Energy Performance of Buildings (5825/30-03-2010) [32]
Malta	- Minimum Requirements on the Energy Performance of Building Regulations (Legal Notice 238/2006) [33]

For all the regions, six building types have been defined, with the exception of Andalusia and Malta, which have five and three types respectively. These two regions are the warmest of the analyzed in the PIE, and the envelope requirements in their building codes started later than in the other regions.

2.3.1.1.2 Characterization of the types

The next step is to characterize the types in terms of envelope performance. The parameter needed for the building simulation is the thermal conductivity (U-values) of the roof, walls and windows. These U-values have been obtained as follows:

Three different processes have been used (depending on the initial data available) to obtain the U-values of the types corresponding to previous and current codes. These are the following:

- When a maximum value of "thermal conductivity" was required in the building code, this has been used for the simulation
- When a maximum U-value was not found in the code, but there was heating energy use data available elsewhere, the U-values were adjusted so to make the model results consistent with the data available
- When there was no information either on the envelope characteristics or on the energy performance, the Catalonia's building types have been used as reference

The thermal performance requirements in buildings have hardened in the last years, as a consequence of European directives. This trend is the reference to characterize the future typologies. However, it is important to note that the thermal requirements in buildings are not the same for all the regions. The main factor to determine this requirement is the climate.

The coldest regions (the north European countries) are typically the ones that have sought energy efficiency of building more thoroughly. In general terms, increasing insulation thickness of the building envelope is the basic measure applied. This allows reducing the energy demand for heating. However, insulation may not be an effective solution in all the Mediterranean regions because of the warmer climate.

In the warmer areas, the cooling load cannot be neglected (as it is usually the case in colder countries). On the one hand adding insulation reduces the heating load, but on the other it increases the cooling load. In the cooler regions this later effect is not so important because the cooling load remains very low. However, in the warmer areas, the additional cooling load worsens an already significant conditioning challenge. For this reason, the thermal requirements have been chosen in function of the region climate [34].

The regional climate can be observed in the Table 8. The regions are sorted from low to high solar radiation.

Table 8 Regional climate data

Region	City	Height (m)	Radiation (kWh/m^2)	HDD (15ºC)	CDD (21ºC)
Slovenia	Ljubljana	298	1110	2450	106
Liguria	Genoa	20	1260	841	281
Piedmont	Torino	240	1300	1860	210
Catalonia	Barcelona	9	1540	866	220
PACA	Marseille	12	1540	1140	294
Greece	Thessaloniki	20	1259	1260	564
Basilicata	Potenza	819	1610	1990	169
Andalusia	Seville	7	1750	630	745
Malta	Luqa	90	1900	353	552

Increasing insulation will be a more effective solution in the regions with high heating challenge (high number of HDD in Table 8), while the warmest regions (high number of CDD) would benefit the most from measures to reduce heat gains (e.g., solar protections).

To simplify the method, the future buildings for all regions are assumed to include measures to reduce both heating and cooling loads. An exception is Malta, which has such a low heating load that it does not make sense to add insulation. The thermal requirements in Malta focus on reducing the cooling load.

Two future building categories have been defined: new and the refurbished buildings. In both cases, two phases have been distinguished (up to 2020, beyond 2020), according to the EPBD [35]. The assumptions for each building type are summarized in the following table:

Table 9 Description of the thermal requirement of future building types

Future buildings	Before 2020	After 2020
New buildings	According to the current building code.	According to a future (more stringent) building code: Insulation**: 30% reduction of the heating load Solar protection: reduce cooling load by 20-40% depending on the region (according to simulation results)
Refurbished buildings	Partial refurbishment*: Window replacement (to high performance)	Partial refurbishment*: Window replacement (to high performance)
	Integral refurbishment: According to the current building code	Integral refurbishment: According to a future (more stringent) building code: Insulation**: reduce 30% of the heating load Solar protection: reduce cooling load by 20-40% depending on the region (according to simulation results)

**The partial refurbishment is not considered in Malta.*
*** In Malta, a change of window type has been considered as the solution of the integral refurbishment, in terms of reduction of the heating load.*

The requirements described in the Table 9 have been adapted to the building codes and the climates of the respective regions. All the regions follow these criteria with the exception of Malta, which follows the criterion indicated in the footnotes of Table 9.

The building types that have been defined are the same for both scenarios, RR and MARIE. The difference between the scenarios is the intensity of penetration of the more efficient building types.

2.3.1.1.3 Energy simulation of the building types

The building types have been defined in the previous steps and all the needed information is available to carry out the building simulation. The objective of these simulations is to calculate the heating and cooling loads for each building type. TRNSYS is the software that has been used to do that. It is a flexible software environment use to simulate the behaviour of the transient systems.

Two simple models have been designed, the single family building and the multi family building. Both models have the same characteristics (dwelling surface, number of windows, number of floors, etc...) for all the regions. Two parameters are changed in order to adapt the building models for each region:

- Weather data. The chosen data for each region belongs to the most populated city (or the nearest available). The cities that have been used for each region are shown in Table 2. These weather data have been obtained from the *meteonorm* database [36].

- Thermal conductivity of the envelope: walls, windows and roof. The values defined for each building type in the previous section are used in the energy simulation.

The general trends that are observed in the results of the simulations are:

- Heating load. The heating load has been decreasing over the years as a consequence of the changes in building code requirements (increase the insulation).

- Cooling load. As a side effect of increasing insulation, cooling loads increase in most of the regions

The cooling load results show the necessity to apply specific solutions for the warmest regions to try to reduce the heat gains.

Annex 3 at the end of this report summarizes the values of heating and cooling loads (kWh/m^2) resulting from the calculations and used in this study.

2.3.1.1.4 Breakdown of the stock by types (construction period)

The number of dwellings of each building type is the last piece of information required to describe the thermal energy demand of the regions. Therefore, the percentage of single and multifamily buildings for each type has to be also included in the breakdown of the building stock.

The regional benchmarking analysis carried out within WP4 [15] has the necessary information to do the breakdown for each region. This report provides the following information:

- Number of dwellings built by construction periods
- Percentage of single and multifamily buildings of the current building stock (or, in most cases, the corresponding to the latest available census)

In most of the regions, the percentage of single and multifamily buildings is considered the same for every construction period, because this specific information was not found.

2.3.1.1.5 Adaptation of the data to be inserted into MURE

MURE requires initial data to be provided in a specific format. The structure of the model is divided in three groups: old, refurbished and new buildings.“Old” buildings are existing buildings that have not been refurbished, “Refurbished” buildings are existing buildings that have undergone refurbishment work, and “New” buildings are new construction (i.e., buildings that did not exist in the past).

The characteristics (i.e., energy performance) of these groups change over time (e.g. the new buildings follow the current building code up to 2020, however the building code will change beyond 2020, so the new buildings will be adapted to it). For this reason, the MURE building

groups are divided in different MURE types, according to the time period they are active. Table 10 describes the MURE groups and their corresponding types.

Table 10 Description of the MURE building types for MARIE

MURE group	Time period	Description	MURE type
Old	Decreasing share throughout all the simulation time	Weighted average of the current building stock heating and cooling loads	Old
Refurbished	Diffusion throughout all the simulation time	Partial refurbishment	Refurbishment 1
	Diffusion up to 2020	Integral refurbishment (envelope complies with the current building code)	Refurbishment 2
	Diffusion starts beyond 2020	Integral refurbishment (envelope complies with an assumed future building code)	Refurbishment 3
New	Diffusion up to 2020	Envelope complies with the current building code	New 1
	Diffusion starts beyond 2020	Envelope complies with an assumed future building code	New 2

The MURE structure allows only one old building type. However, different old dwelling types were defined at the beginning of the method, according to the previous building codes. For this reason, a weighted average was calculated using the information of the current building stock (the heating and cooling loads and the number of dwellings of each building type).

Finally, the refurbished and the new building types coincide with the types defined in the previous chapters (as shown in Table 9 and Table 10). Therefore, the data adaptation is not necessary.

2.3.1.2 Heating equipment

The final energy use for heating depends on the heating load and the heating device installed in the dwelling. For this reason, the heating equipment stock has to be defined. The parameters needed to characterize the heating systems are the following:

- Equipment stock distribution
- Energy efficiency of the different equipment types
- Coverage factor (i.e., fraction of the dwelling heating load that is actually met by the heating equipment)

The market offers a wide range of heating devices. However, it is not possible to analyze all of them. Therefore, a selection of the most usual devices has been made. Type of final energy (electricity, NG, oil...) was one of the selection criteria. The newest heating systems (e.g. condensing boilers and centralized heat pumps) have been included in the selection, although their current market share is low. Table 11 shows the selected heating devices and their properties

The energy efficiency values in Table 11 correspond to the average energy efficiency of the equipment stock, and not the energy efficiency of the latest technology. The average energy efficiency increases over the years because the old equipment pieces are gradually replaced by new (and more efficient) ones. The energy efficiencies of the heating equipment are shown in the table below, and these are the same for all the regions.

Table 11 Definition of the heating equipment for the most of the regions

Heating equipment	Energy efficiency		Coverage factor
	Current (Reference Year)	Future (2035)	
Natural gas boiler	0.75	0.85	100%
Oil boiler	0.7	0.7	100%
Coal boiler	0.6	0.6	100%
Condensing boiler	0.9	0.95	100%
Electric device*	1	1	50%
Renewable**	0.8	0.95	100%
District heating	0.8	0.8	100%
Decentralized heat pump	2	3.5	50%
Centralized heat pump	3	4.5	100%

** Electric devices includes fixed electrical systems and mobile devices*
*** Renewable is basically biomass boilers*

Finally, the last parameter defined in the Table 11 is the coverage factor of the heating load. The coverage factor represents the percentage of the heating load that is met by the heating system. The coverage factor is linked to the equipment type (e.g. Natural gas boiler is considered a centralized system, and so its coverage factor is the 100% of the heating load). There are some variations between the coverage factors of each region. It depends on their equipment stock, their main energy used, their climate... The coverage factor values defined in Table 11 correspond to the configuration used in most of the regions.

In most of the regions, the electric devices and the decentralized heat pumps are considered not to cover all heating load (only the 50%). So, the comfort conditions required by the dwelling are not maintained in all the dwelling or over the year. The other heating equipments are centralized systems, and in consequence the whole heating demand is covered.

The sources used to define the heating equipment stock for each region are shown in the Table 12. Detailed information on heating equipment stock was often difficult to find, and in some cases the only references available were somewhat dated.

Table 12 Sources that have been used to define the heating equipment stock for each region

Region	Source
Piedmont	Piano Energetico Ambientale Regionale, 2004 [37]
Liguria	Piano Energetico Ambientale Regionale, 2001 [38]
Basilicata	Piano di Indirizzo Energetico Ambientale Regionale, 2009 [39]
Catalonia Andalusia	Encuesta de Hogares y Medio Ambiente, 2008 [40]
PACA	Résultats du recensement de la population, 2008 [41]
Slovenia	Statistical Yearbook of the Republic of Slovenia, 2011 [42]
Greece	Energy Outlook of Greece, 2009 [43]
Malta	Census of population and housing, 2005 [44]
All regions	Eurostat - national data, 2007 [45]

The parameters defined for each region were checked with their respective partner, and in some cases were corrected according to their suggestions.

2.3.1.3 Domestic Hot Water equipment

The Domestic Hot Water (DHW) demand is an independent parameter of the building type. It depends on the user behavior. This information was requested to the WP4 partners, asking a mean value of liters per day and person.

The other needed information to calculate the final energy use for DHW, is the equipment stock. The DHW equipment is strongly dependent on the heating one, as some heating equipment types can be used for both heating and DHW production.
The solar thermal system has also been included in the analysis. Usually these systems are installed together to a DHW conventional system. For this reason, the solar thermal systems are not included in the DHW equipment break down, these have been considered as an additional system.

So, the first step is to define the conventional DHW systems of the building stock. The second one is to apply the percentage of the dwellings with solar thermal systems. These steps are described in the following sections.

2.3.1.3.1 DHW equipment

The type of equipment used to DHW depends on the type of heating system of the dwelling. The following assumptions have been made:

- If the heating system is centralized, it is also used to cover the DHW demand. There are two types of DHW linked to centralized heating systems:
    - Linked to boiler. This includes the following heating equipment types: natural gas boilers, oil boilers, renewable systems, condensing boilers and district heating (it can change among the regions, depending on the characteristics of the heating equipment definition).
    - Centralized heat pump

- If the heating system is decentralized, an additional piece of equipment is necessary to cover the DHW demand. There are three types of equipment types, depending on the characteristics of each region:
    - Electric instantaneous
    - Electric storage
    - Dedicated to boiler

The mean energy efficiencies are needed to define the DHW equipment, in the same way that the heating ones. The DHW systems linked to the heating equipment have the same energy efficiencies of the corresponding heating systems. The energy efficiencies used are showed in the Table 13.

Table 13 Energy efficiency of the DHW equipment

DHW Equipment	Energy efficiency	
	Current (Reference Year)	Future (2035)
Linked to boiler	0.75	0.9*
Electric instantaneous	1	1
Electric storage	0.65	0.65
Dedicated to boilers	0.75	0.85
Centralized Heat Pump	3	4.5

** It depends on the number and type of boilers that are included in each scenario and in each region (natural gas, oil, renewable...)*

The sources to obtain the DHW information are the same that were used for heating equipment, so it can be found in the Table 6. The parameters defined for each region were checked with their respective partner, and in some cases were corrected according to their suggestions.

2.3.1.3.2 Solar Thermal systems

In the last years, the number of solar thermal system has increased. When a dwelling is equipped with a solar thermal system for DHW production, this is always supported by a conventional system. Two parameters are needed to be defined: the number of dwellings with solar thermal systems; and the fraction of the DHW demand that is provided by the solar thermal system.

The number of dwellings with solar thermal systems has been obtained from the sources defined in the Table 12, and then the data was checked with the partners of each region. For most of the regions, the percentage of dwellings with solar thermal systems is lower than 5%.

The fraction of the DHW demand that is provided by the solar thermal system is called coverage factor. The values assumed in the scenarios are: 0.5 for RR, and 0.7 for MARIE scenario.

2.3.1.4 Cooling equipment

As a difference from the heating equipment, not all the dwellings have cooling devices. However, the number of dwelling with cooling equipment has seen a substantial increase in the last years.

The percentage of dwellings with cooling devices has been obtained for the Eurostat [45], at a national level. Exceptions are Catalonia and Andalusia, for which the data have been obtained from the respective regional statistical surveys, [46] and [47].

The parameters of the cooling equipment stock were defined in the same way as the heating equipment:

- Equipment stock distribution
- Energy efficiency of the different equipment types
- Coverage factor of the cooling load (i.e., fraction of the dwelling cooling load that is actually met by the cooling equipment)

Since heat pumps in the stock are very often reversible, the cooling equipment is related to the heating one. The assumptions made are the following:

- If dwellings have centralized heat pump for heating, they use the same systems for cooling.
- If dwellings have decentralized heat pump for heating, they use the same systems for cooling.
- “Others” corresponds to the dwellings that have individual equipment for cooling. This value is the residual term, and it is obtained as a difference of dwellings with cooling devices and dwellings with centralized and decentralized heat pumps.

The dwellings that use the same system for heating and cooling, their energy efficiencies are already defined, according to the heating equipment definition.

The coverage factor for cooling differs substantially from that used in heating. Decentralized cooling systems are usually installed in only one or two rooms of the dwelling. In consequence, only a small fraction of the cooling load is covered. Also, centralized systems do not meet 100% of the cooling load, as they are often assisted by natural ventilation (i.e., occupants opening

windows). Therefore, the coverage factor for cooling usually is lower than the heating coverage factor.

All the parameters of the cooling equipment are shown in the Table 14.

Table 14 Definition of the cooling equipment for the regions

Cooling Equipment	Energy Efficiency		Coverage Factor
	Current (Reference year)	Future (2035)	
Centralized Heat Pump	3	4.5	80% / 60%*
Decentralized Heat Pump	2	3.5	20%
Others	2	3.5	20%

**Coverage factor of 80% for RR scenario, and 60% for MARIE scenario. The MARIE scenario includes awareness and information measures that would lead the occupants to use natural ventilation more effectively*

2.3.1.5 Lighting

The lighting of dwellings is another factor that affects in the energy use of the residential sector. The lighting stock is independent from the building type, and it depends on the user awareness.

Three lighting technologies have been taken into account: incandescent bulbs, compact fluorescent lamps (CFL) and LEDs. Information on the number and type of lamps used in dwellings is difficult to find, and it was not available in most cases. The sources of the information are showed in the following Table 15.

Table 15 Sources that have been used to define the lighting stock for each region

Region	Source
Piedmont Liguria Basilicata	National data provided by ISIS*
Catalonia Andalusia PACA Slovenia Greece Malta	Encuesta de Hogares y Medio Ambiente, 2008 [40]

*ISIS

2.3.1.6 Appliances

The appliances considered in the study are the following: refrigerator, washing machine, drier, dishwasher and oven. The use of energy efficiency appliances does not depend on the building type, but rather on user awareness and market transformation.

The stock of appliances is defined by two parameters. The first one is the fraction of dwellings that are equipped with each of the appliance types (e.g. all dwellings have refrigerators, but not all dwellings have driers). The second parameter is the share of energy efficient appliances (within the stock of appliances). The criterion used to classify the appliances between efficient or not was the energy labeling: appliances with a label equal to or higher than A are considered “energy efficient”.

These two parameters are based on the sources detailed in the Table 16.

Table 16 Sources that have been used to define the appliances stock for each region

Region	Source
Piedmont Liguria Basilicata	National data provided by ISIS*
Catalonia Andalusia PACA Greece	Encuesta de Hogares y Medio Ambiente, 2008 [40] Análisis del consumo energético en el sector residencial en España, 2011 [48]
Slovenia	Statistical Yearbook of the Republic of Slovenia, 2011 [42]
Malta	Census of population and housing, 2005 [44] Encuesta de Hogares y Medio Ambiente, 2008 [40] Análisis del consumo energético en el sector residencial en España, 2011 [48]

*ISIS

This information should be complemented with the energy use of each appliance. This data is provided by the MURE databases.

2.3.1.7 Other regional parameters

Some parameters not related to the building stock are necessary in order to define all the regional scenarios consistently with their socioeconomic context. Although, these parameters are not directly linked to the building stock, they will be used to define the regional scenario settings.

The economic parameter Gross Domestic Product (GDP) per capita was used to define the pace of penetration of energy efficient refurbishments. Regions with high GDP per capita are assumed to see a faster penetration of energy efficient refurbishments. The regions have been classified in three economic groups, as there are showed in the Table 17.

Table 17 Classification of the regions by GDP per capita.

	Region	GDP/Population (€/capita)	Source
C	Malta	13400	National Statistics Office [49]
B	Slovenia	17200	Eurostat [45]
	Andalusia	18300	Instituto de Estadística y Cartografía de Andalucia [50]
	Basilicata	18700	Istituto Nazionale di Statistica [51]
	Greece	19900	Eurostat [45]
A	Liguria	26800	Istituto Nazionale di Statistica [51]
	PACA	27800	Institut national de la statistique et des études économiques [52]
	Piedmont	28700	Istituto Nazionale di Statistica [51]
	Catalonia	29900	Institut d'Estadística de Catalunya [53]

Ownership of dwellings is a key factor when making the decision to refurbish. Experience from the MARIE partners shows (as mentioned in "Barriers") that energy efficient refurbishments are almost exclusive of owner-occupied dwellings, while rented dwellings see basically no energy efficiency improvements. For this reason, the breakdown of the stock by ownership type is interesting to define the regional scenario setting. The characteristics of ownership of dwellings for each region are shown in the Table 18. In most of the regions, the owner-occupied dwellings are most usual than the rented ones, except for PACA and Piedmont, where there is not much difference between the ownership types.

Table 18 Ownership of dwellings by regions

Region	Year	Dwellings		Source
		% Owner-Occupied	% rented	
Piedmont	1991	63%	37%	Piano Energetico Ambientale Regionale, 2004 [37]
Liguria	-	80%	20%	National data provided by ISIS*
Basilicata	-	80%	20%	National data provided by ISIS*
Catalonia	2007	70%	30%	Regional Benchmarking Analysis, Catalonia
Andalusia	2001	87%	13%	Census 2001 [54]
PACA	2006	55%	45%	Regional Benchmarking Analysis, PACA
Slovenia	2011	77%	23%	Statistical Yearbook of the Republic of Slovenia, 2011 [42]
Greece	2001	74%	26%	Eurostat [45]
Malta	2005	75%	25%	Census of population and housing, 2005 [44]

**ISIS*

The last parameter needed is the renovation rate of dwellings. This value represents the fraction of the total dwelling stock that is renovated in a year. These renovations include all kind of construction works, whether they are meant to improve energy efficiency or not (e.g. painting the facade, adding insulation, changing the windows, installing an elevator...). This information is difficult to find because there are no records of all the building works that have been done. The renovations rate values used in this analysis fall within 1.3% and 2% depending on the region ([55], [56] and national data provided by ISIS). The suggestions of the partners have been used for the regions without information.

2.3.2 TECHNOLOGY TRANSITIONS

The second step to define the regional scenario settings is to establish a method to estimate the diffusion of the different measures. Definition of a common method is important in order to follow the same criteria to consistently adapt the specific policy measures for all the regions.

The effects of measures can be translated like technology transitions (e.g. a measure that aim to promote energy efficiency equipment for heating can be seen as a substitution of the oil boilers for condensing boilers). Thus, the method selected is based on the theory of diffusion of innovations [57]. This theory explains the processes that follow new technologies when they are introduced in the market. According to recent studies the market penetration of sustainable and energy efficient building follows the patterns described in Roger's diffusion theory [58]. Therefore, this was considered a valid method to define technology transitions in the present study.

The theory proposes the main elements that influence the spread of a new idea: innovation, communication channels, time, and social system. If we focus on the social adoption of the innovation, it is possible to distinguish 5 social groups: innovators, early adopters, early majority, late majority and laggards (Figure 7). The "early adopters" would adopt the new technology right away, while the "laggards" would need a much longer time to change to the new technology. The cumulative frequency distribution of these social groups follows an "S-curve", which can be translated into mathematical language like a logistic function (Eqn 1).

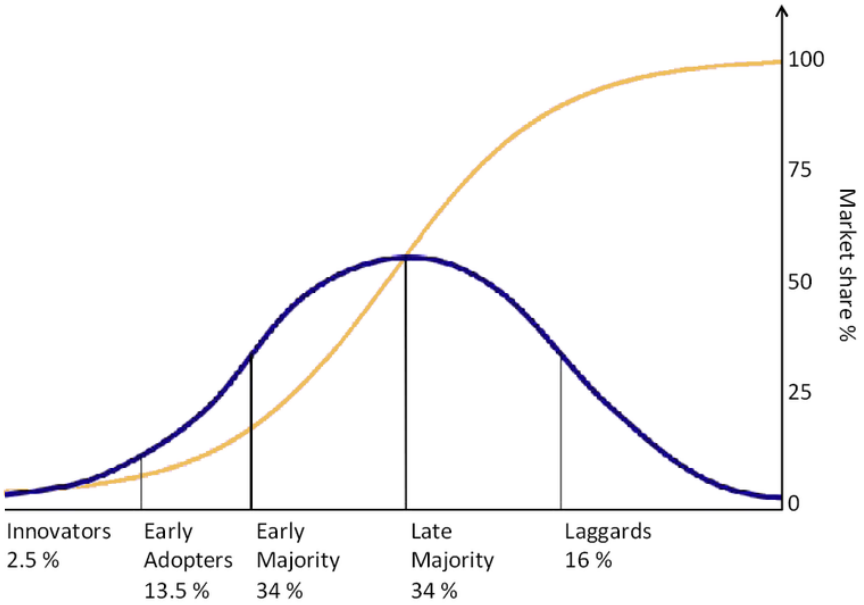


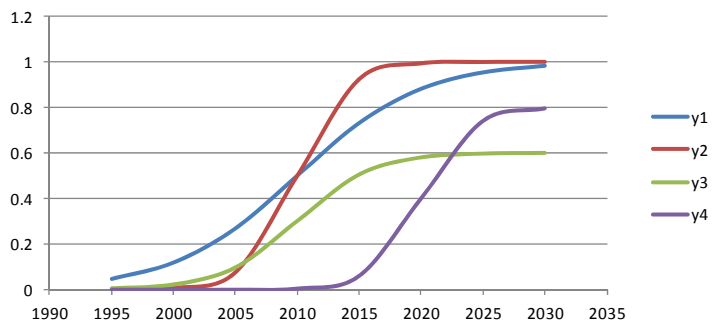
Figure 7 Diffusion of innovations according to Rogers, 1962 [57]. In mathematics the S-curve is known as the logistic function. In blue, probability density function. In yellow, cumulative distribution function (S-curve).

——— (Eqn 1)

The S-curves are defined by three parameters:

- *Saturation limit*: it is the value of the variable at time equal to "infinity". The (ideal) share of a given technology in the very long future, when the transition is complete.
- *t:* sets current point in the technology transition. The S-curve is half-way completed when t=0 (this is the centre of the S-curve).
- *τ:* it is the time constant of the technology transition (i.e., sets the pace of the transition). The larger the τ, the slower the transition.

Some examples of S-curves with different settings are shown in the following figure:



	Saturation	t=0	Tau
y1	1	2010	5
y2	1	2010	2
y3	0.6	2010	3
y4	0.8	2020	2

Figure 8 Example of S-curves with different settings

This method has been used to estimate the implementation of the different measures in both scenarios. The parameters of the S-curves have been adjusted in each case, depending on the measure, the scenario and the region. Diffusion curves were used to define the trends on the

building stock (i.e., the relative fraction of buildings by building type) as well as the changes in market shares for the different lighting technologies and types of heating, cooling and DHW equipment. Assumptions on technology transitions (equipment) for the individual regions are described in Section 2.3.4. The "building model" (i.e., the way assumptions are interconnected to define the building stock in every simulation step) is more complex than the other technology transitions (i.e., equipment and lighting), and is explained in Section 2.3.3.

2.3.3 BUILDING REFURBISHMENT DYNAMICS

Figure 9 illustrates the method used to define the building refurbishment dynamics.

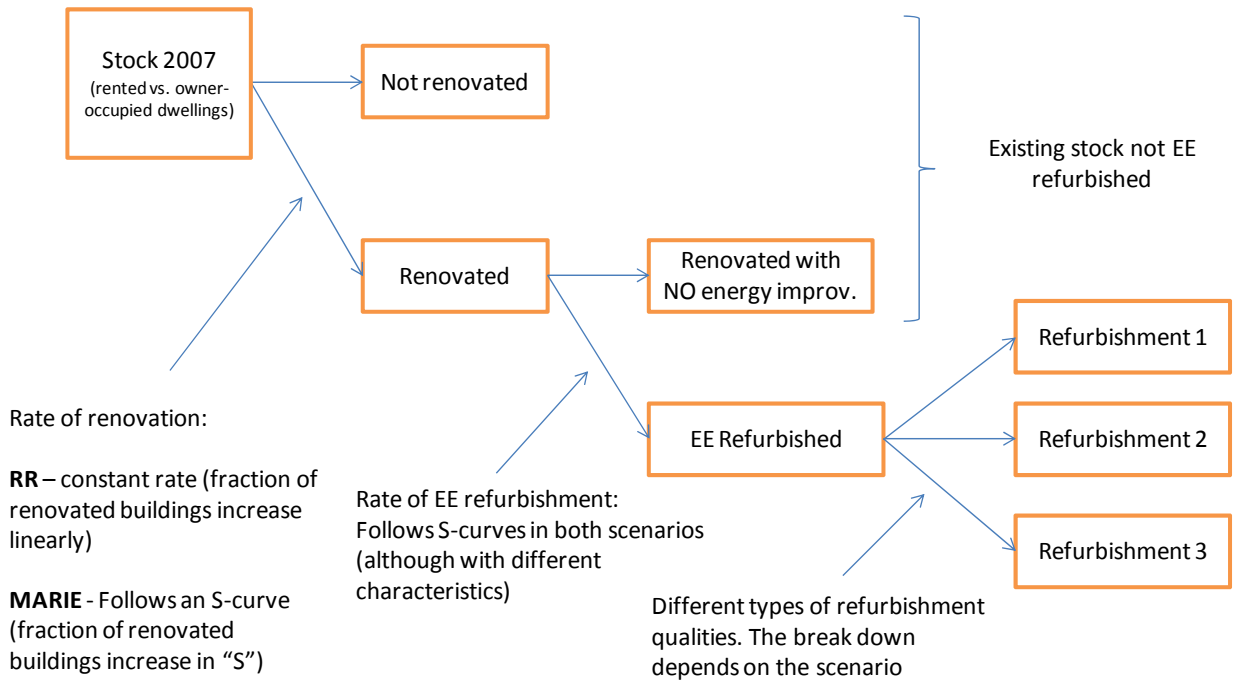


Figure 9 Building refurbishment dynamics

The key parameters in the regional definition are:

- Rate of renovation
- Rate of energy refurbishments
- Break down of energy refurbishments by refurbishment type

The values of the three parameters above were adapted to the individual regions. However, the general trends depend more on the scenarios than on the regions themselves. It should be noted that the energy performance of the building types (e.g., "Refurbishment 1", etc.) was already differentiated by region (see Section 2.3.1.1 for details).

Table 19 explains the "rationale" behind the dynamics of the aforementioned parameters in both the MARIE and the Rapid Results scenarios.

Table 19 Building refurbishment dynamics

Rapid results	MARIE
Renovation Rate	
This is: # renovated buildings per yr/ building stock (2007). Renovations may or may NOT include energy efficiency measures	
We assume this rate is constant throughout the years	Since the measures proposed in MARIE help reduce the barriers (mostly financial) for EE refurbishments, the quantity of renovations in general also tend to increase. Therefore the Renovation Rate increases following an S-curve, meaning that it takes a while before increasing, and eventually flattens at a "final renovation rate" equal to 3% (which is similar to the assumptions in recent EU policy targets - time between renovations = 33 yrs). This transition is only half-way completed by 2030
Rate of energy refurbishments	
This is: # EE refurbished buildings / # of renovated buildings	
Dynamics of EE renovations are different depending on whether dwellings are rented or occupied by their owners. Therefore, the fraction of renovated buildings is broken down by ownership type (rented vs. occupant-owned), which are calculated with independent assumptions of fraction of EE refurbishment. The EE refurbishments of the two ownership types are added up to calculate the total.	
The fractions of EE refurbishment follow an S-curve. The S-curve represents the transition from conventional renovations to EE renovations, and depends on whether policies are more or less successful at overcoming the barriers for EE renovations	
There are few policies to tackle barriers on EE refurbishments, and no measures promote EE refurbishments in rented dwellings. Therefore: - Diffusion of EE refurbishments in owner-occupied dwellings increases slowly. This increase in EE refurbishments is the result of a more stringent building code and the effect of energy certification. - There are no EE refurbishments in rented dwellings	There are policies to overcome these barriers, some of which directly address the issue of EE refurbishments in rented buildings. Therefore: - Diffusion of EE refurbishments in owner-occupied dwellings is faster and with a higher saturation limit than in the RR scenario. - Rented dwellings also see a diffusion of EE refurbishments, although this comes with some delay and a lower saturation than the owner-occupied dwellings
Break down of energy refurbishments by refurbishment type	
The EPBD requires a minimum performance for buildings that undergo INTEGRAL REFURBISHMENTS. Since the barriers for EE refurbishments are basically still there, there are VERY FEW integral refurbishments, and most of the refurbishments only imply window replacement (through subsidies). The "partial refurbishments" don't need to comply with the EPBD, and become Type 3. The "integral refurbishments" comply with the building code, which is type 5 until 2020 and type 6 afterwards	The regulatory framework (EPBD) is basically the same as in the RR scenario, however there are less barriers (or the barriers are easier to overcome) for integral refurbishments and less incentives (subsidies) for window replacements. Therefore the fraction of EE refurbishments that comply with the building code is larger than in the RR scenario. The same refurbishment type break down is assumed for both rented and owner-occupied dwellings.

Figure 10 shows an example (Catalonia) of the building stock dynamics for the two scenarios. Values in the charts correspond to the share of a given building type in a given year. The share of not refurbished buildings is calculated as the residual. Slopes correspond to the penetration rates of the different building types.

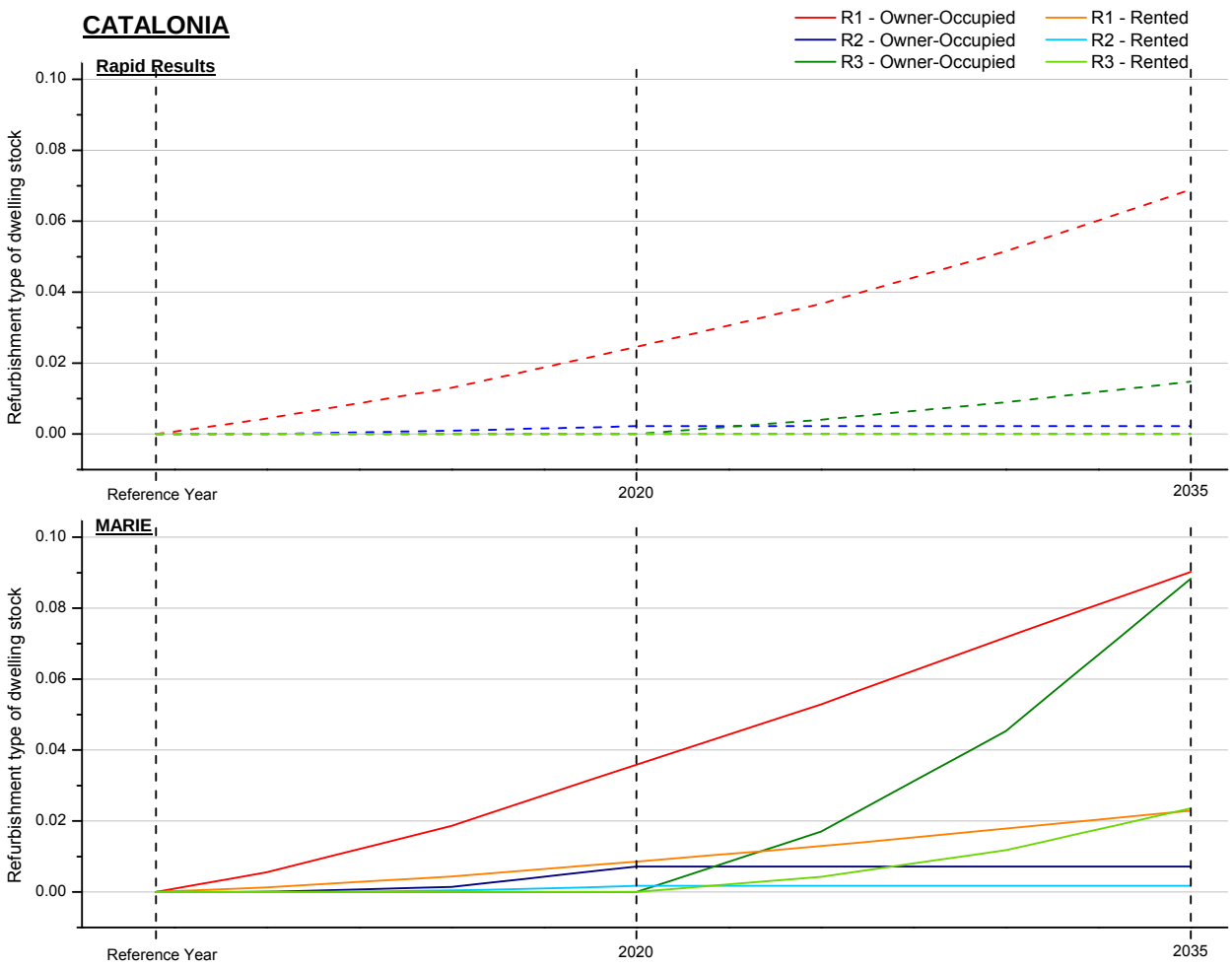


Figure 10 Building refurbishment dynamics in Catalonia. Rapid Results (top) vs. MARIE (bottom)

2.3.4 DYNAMICS OF THE EQUIPMENT STOCK

The heating system is the most important energy system in the residential sector. It is the largest energy user, and the most common in a residential setting. Furthermore, it is often used for domestic hot water production and sometimes even for cooling (reversible heat pumps).

The breakdown of the current heating equipment stock shows large variations among regions, probably due to differences in climate severity and availability of natural resources. Both the current stock breakdown and the local constraints were taken into account to assign different dynamics of technology changes by region and scenario. Table 20 shows the summary.

Table 20 Dynamics of the heating equipment stock

	Rapid Results	MARIE
Liguria	- Data shows that heating systems in Liguria are mostly centralized already (natural gas and oil boilers). We consider that in the RR scenario the subsidies for equipment replacement help introduce condensing boilers into the market, while oil tends to decrease rapidly. The share of "conventional" increases as oil decreases, but then decreases as condensing boilers gain share. - Renewable systems are initially decentralized. We assume that these systems are gradually replaced by centralized systems. The share of biomass increases slowly, but the average coverage factor also increases (because the new systems are centralized) - Neither Electric systems nor decentralized HPs are introduced in the market (since the centralized systems perform better) - Centralized HPs are introduced in some integral refurbishments, but these are rare in the RR scenario	- Since the systems are already centralized, the dynamics don't change much compared to the RR scenario. - There are no subsidies for boiler replacement, therefore, condensing boilers are not as popular as in the RR scenario - Oil systems tend to decrease, but at a slower pace than in RR - Biomass tends to increase more here, because of the effects of energy certification of buildings - Centralized heat pumps are more common in the MARIE scenario because there are more integral refurbishments - Centralized HPs can provide cooling in the summer (when combined with radiant floors-panels), and this may be appealing for users
Piedmont	- Data shows that heating systems in Piedmont are mostly centralized already (natural gas and oil boilers). Furthermore, the regional law in Piedmont (legge regionale 13/2007 – DGR 46-11968) does not allow installing any non-condensing boilers in new or refurbished buildings. We consider that in the RR scenario the subsidies for equipment replacement help speed up the diffusion of condensing boilers into the market, while oil tends to decrease rapidly. The share of "conventional" increases as oil decreases, but then decreases as condensing boilers gain share. - Renewables tend to increase, but not much - Neither Electric systems nor decentralized HPs are introduced in the market (since the centralized systems perform better) - Centralized HPs are introduced in some integral refurbishments, but these are rare in the RR scenario	- Since the systems are already centralized and the regional law requires condensing boilers, the dynamics don't change much compared to the RR scenario. - There are no subsidies for boiler replacement. Condensing boilers are introduced into the market at a slower pace than in the RR scenario. - Oil systems tend to decrease, but at a slower pace than in RR. - Biomass tends to increase more in this scenario due to its benefits in terms of energy certification of buildings - Centralized heat pumps are more common in the MARIE scenario because there are more integral refurbishments - Centralized HPs can provide cooling in the summer (when combined with radiant floors-panels), and this may be appealing for users

Table 20 Cont. Dynamics of the heating equipment stock

	Rapid Results	MARIE
Basilicata	- Around 60% of the dwellings have centralized NG systems, which are gradually replaced either by new conventional NG boilers or Condensing boilers. The later are more common in the RR scenario because of the subsidies. - Almost all the remaining heating systems are biomass (renewable) systems, however, according to the data available, these seem to be decentralized systems (i.e., they provide heating only to one or two rooms). We assume that these are either replaced by new biomass systems or (less often) by individual HP units, which are also decentralized systems, and have a coverage factor of 50%. - Decentralized HPs are the natural replacement for decentralized electric heating systems	- The main difference in the MARIE scenario is that the share of centralized systems increases (due to the larger fraction of integral refurbishments). This means: - Centralized HP systems are gradually introduced - Decentralized HPs are not introduced - Some of the decentralized biomass systems turn into centralized biomass systems - Condensing boilers see a smaller increase in share because there are not direct subsidies to boiler replacement
Catalonia	- There are subsidies for boiler replacement, which makes the transition to condensing boilers start sooner than in the MARIE scenario - The share of centralized HPs increases gradually but slowly - Biomass systems gain share due to the subsidies - Oil systems and electric heating devices tend to disappear	- Condensing boilers increase at a slower pace because there are no incentives - Centralized HPs are more common in the MARIE scenario, because the fraction of integral refurbishments is larger - Biomass systems gain share due to the higher number of buildings that undergo energy certification - Oil and electricity follow similar dynamics to these in RR
Andalucía	- Decentralized HPs are the "natural substitute" for decentralized electric systems (the most common in Andalucía), so these tend to gain share rapidly - Centralized systems tend to gain share, however at a very slow pace (since this involves larger renovation works). - Within centralized systems, biomass is the dominant because of the benefits in terms of energy certification. The new NG boilers are assumed to be condensing boilers. NG systems are limited to a small number because NG network is not usually available in Andalucía. Oil tends to disappear.	- The main difference compared to the RR scenario is that centralized systems are more common, due to a higher rate of integral refurbishments. This means that centralized HPs and biomass systems have a larger share than in the RR scenario. - Decentralized HPs still gain share as a substitute for electric systems, however they are less popular than in the RR scenario because of the trend to centralized systems - NG systems are still limited by the availability of a NG network. The new NG boilers are assumed to be condensing boilers.
PACA	- Decentralized HPs are the "natural substitute" for decentralized electric systems, so these tend to gain share rapidly, while electric systems tend to disappear - Oil boilers tend to disappear in favor of NG boilers. - A large fraction of the new NG boilers are condensing boilers (whether they replace oil boilers or old NG boilers). - District heating doesn't change much, since this requires urban planning...	- Decentralized HPs are still a substitute for electric systems, however, in the MARIE scenario centralized HPs have a larger share (due to a larger rate of integral refurbishments) - Renewables also increase - District heating systems are also more common, since there are policies to promote community-scale systems - The lack of subsidies for boiler replacement result in lower penetration of these in the MARIE scenario. - Oil tends to disappear in the same way as in RR

Table 20 Cont. Dynamics of the heating equipment stock

	Rapid Results	MARIE
Slovenia	In the RR scenario there are subsidies for efficient and/or low emitting systems. Therefore, we assume that: - Natural gas and oil boilers are replaced by: condensing boilers, biomass, or new (yet not condensing) NG boilers. - Little is done in terms of urban planning - There are no changes in district heating - Electric systems are gradually replaced by more efficient centralized HP systems The most important characteristic in Slovenia is the large fraction of renewables (biomass) - We believe that the availability of this resource makes it very convenient for the region, and therefore, its share would either slightly increase or stay as it is	The systems in Slovenia are already centralized; therefore, the MARIE scenario does NOT increase the fraction of centralized systems. The main differences in the MARIE scenario are: - An increase in DH systems - due to urban planning - A sharper increase of centralized HP units - This is due to a larger rate of building refurbishment. This technology change is not (or at least not only) meant to increase efficiency, but rather a consequence of user preferences (centralized HPs also provide cooling in the summer) - There are no subsidies on boiler replacement, therefore, the share of condensing boilers does not increase as sharply as in RR
Greece	- Decentralized HPs are the "natural substitute" for decentralized electric systems, so these tend to gain share rapidly, while electric systems tend to disappear - Oil boilers tend to disappear in favor of NG boilers, condensing boilers, and biomass boilers. There are subsidies for efficient boiler replacement, therefore the share of condensing boilers increase more rapidly - There are few new centralized HPs.	- Decentralized HPs are still a substitute for electric systems, however, in the MARIE scenario centralized HPs have a larger share (linked to a larger rata of integral refurbishments) - It takes longer for centralized HPs to gain market share, therefore the share of electric systems does not decrease as much as in RR - Renewables increase more because they have more favorable market conditions - The lack of subsidies for boiler replacement result in lower penetration of condensing boilers in the MARIE scenario. - Oil tends to disappear in the same way as in RR
Malta	- We assume that the "natural" substitute for electric systems are decentralized HPs (which are more efficient). - Decentralized HPs are the most common in Malta, and we assume that in the future will increase the fraction of these systems due to the subsidies for equipment replacement.	The trends in the MARIE scenario are similar to these in RR. The main differences are: - Centralized HP systems are more common in MARIE (due to the larger rate of integral refurbishments), although the increase is not very significant, because in Malta don't have sense the centralized systems (Malta is very hot country). - The introduction of new decentralized HP systems is slower here, because there are no direct subsidies for equipment replacement

As explained in Section 2.3.1.3 and 2.3.1.4, the systems used for DHW production and for cooling are closely linked to the heating system. Therefore, the dynamics of the heating system drive the dynamics of these other systems as well.

2.3.5 DYNAMICS OF LIGHTING TECHNOLOGIES AND APPLIANCES

The residential stock is currently dominated by incandescent lamps. The efficient alternatives considered in this study are compact fluorescent lamps (CFLs) and light emitting diodes (LEDs).

CFLs usually have the same fixture than incandescent lamps, and do not require any construction works. Therefore, CFLs are considered the main replacement for incandescent bulbs in the Rapid Results scenario (which includes subsidies for efficient lighting, but has little integral refurbishment). On the other hand, LEDs are more common in the MARIE scenario due to the higher integral refurbishment rates.

Neither Rapid Results nor MARIE have subsidies for efficient appliances, as it is considered that the market is already transformed (i.e., there are basically no inefficient appliances available). Therefore, both scenarios show the same trends.

2.4 SCENARIO SETTINGS IN THE TERTIARY SECTOR

The quantitative scenario settings were defined according to the format used by the Forecast Tertiary simulation tool.

2.4.1 THE FORECAST TERTIARY CALCULATION APPROACH

As further detailed in the publications by Jakob et al. and Fleiter et al. [59-61], the Forecast Tertiary (FT) model calculates final energy use as the product of specific energy demand per unit of "energy driver" and the quantity of the corresponding "driver". The "energy drivers" are further broken down into "Global drivers" (such as number of employees or m^2 floor area) and "Energy service drivers" (such as number of computers per employee). In turn, the "specific energy demand" is calculated as the product of the installed power (such as W per computer) and the annual utilization (hours). Forecast Tertiary performs the above calculation for the different energy services (e.g., space heating), sub-sectors of the economy, and regions, so that the total final energy use in a given year "t" is ultimately calculated according to the following equation (adapted from Jakob et al. [61]):

$$T_t = \sum_{C=1}^{n}\sum_{S=1}^{l}\sum_{E=1}^{k} G_{C,S,t} \cdot D_{C,S,E,t} \cdot P_{C,S,E} \cdot U_{C,S,E} \cdot \prod_{SO=1}^{x}(1 - DR_{C,S,E,SO,t} \cdot \Delta_{C,S,E,SO}) \qquad \text{(Eqn 2)}$$

With

T	=	total bottom-up energy demand of the tertiary sector [kWh]
$G_{C,S}$	=	global driver [# of employee, m2]
$D_{C,S,E}$	=	energy service driver [unit depends on energy service]
$U_{C,S,E}$	=	utilization rate (annual full load hours) [h/a]
$P_{C,S,E}$	=	installed power per unit of driver [W/unit of driver]
$\Delta_{C,S,E,SO}$	=	relative saving of energy-efficiency option EEO [%]
$DR_{c,S,E,SO,t}$	=	Diffusion rate of energy saving option [% of energy service driver]

Indices:

C	=	region/country
S	=	sub-sector
E	=	energy service
SO	=	number of saving options

The MARIE consortium was not capable of gathering regional data on the tertiary sector with sub-sector details. When regional data was not available, national rates, specific drivers or data were used as a proxy (various sources, see [59-61]. In some cases, within-country break-downs

were made based on meteorological data (estimates on cooling degree days based on the geographical location of the regions) and based on labor force statistics.

The total final energy use in the tertiary sector in the reference year (2010) was calculated based on the most recent data available. However, energy outlooks required making assumptions on the future trends of the drivers and the diffusion rates of the energy saving options (last terms in the equation above). The following sections describe the criteria used to define these trends according to both the RR and MARIE scenarios.

2.4.2 DYNAMICS OF GLOBAL ENERGY DRIVERS

Global energy drivers include number of employees by sub-sector and floor area per employee. Dynamics of these two drivers basically depend on the general economic framework in a given region. Since the two scenarios in this study (Rapid Results and MARIE) share the same assumptions on overall economic environment, dynamics of the global energy drivers are also the same in both scenarios.

Based on data found in the ODYSSEE database [62] and analogies and assumptions by TEP Energy on typical figures of floor area per employee, total floor area was calculated based on projections of the number of employees (Figure 11). The assumed trends on the number of employees (Figure 12) were derived from extrapolations of past trends and internal data of the FORECAST Tertiary model. Note that both figures show large differences across regions.

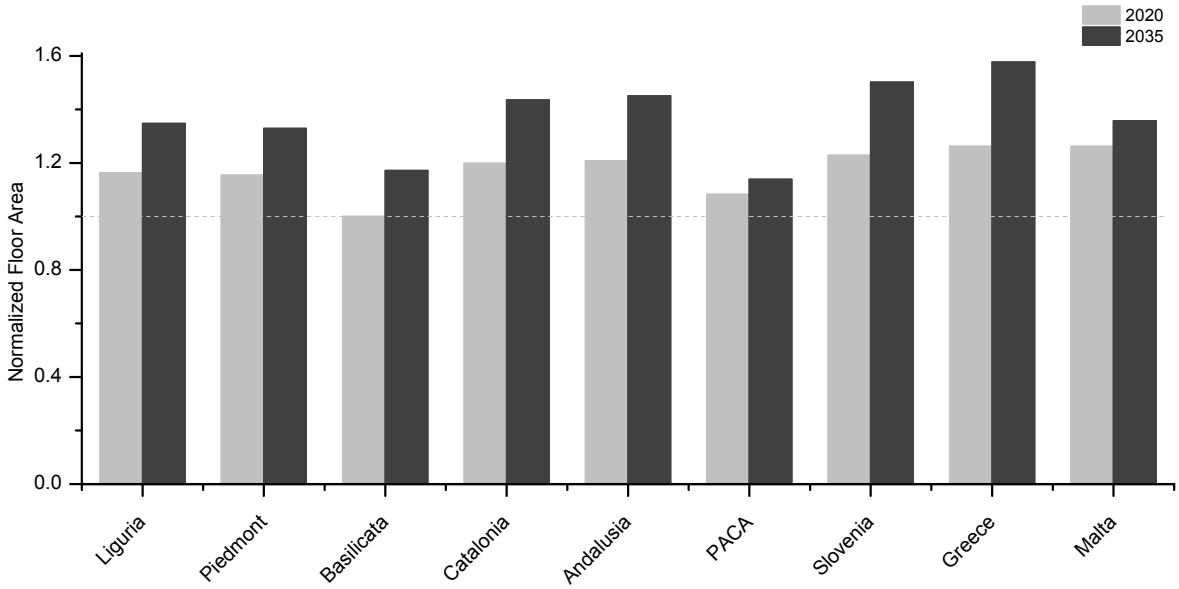


Figure 11 Normalized floor area (reference year value = 1)

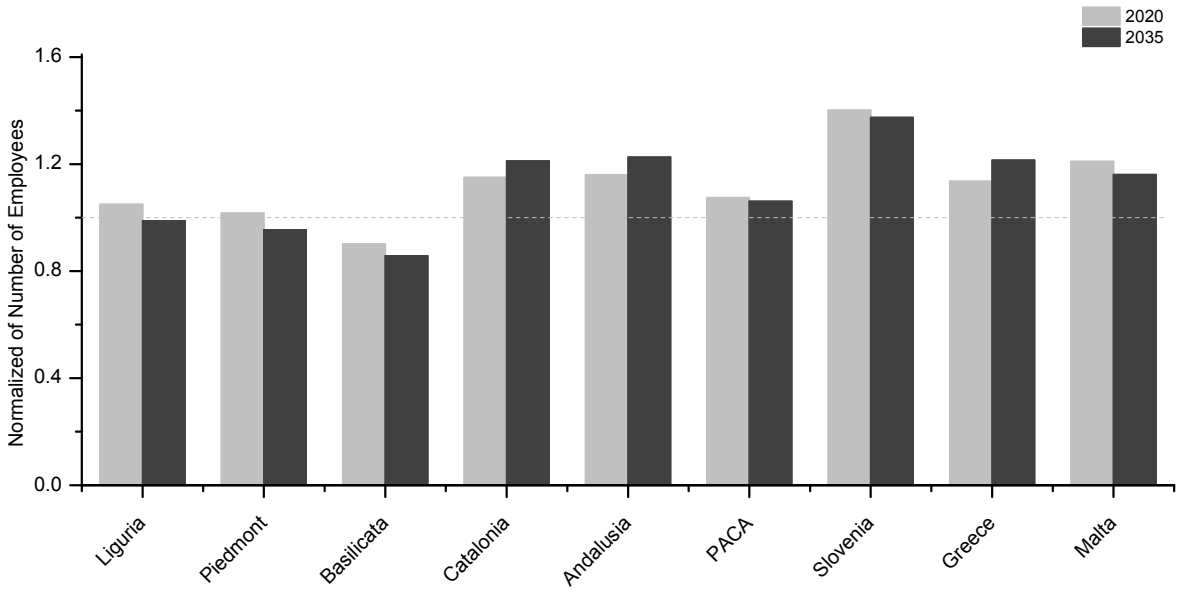


Figure 12 Normalized number of employees (reference year value = 1)

2.4.3 DYNAMICS OF ENERGY SERVICE DRIVERS

Energy service drivers describe the amount of "energy service" required by a unit of "global driver", and include (e.g.,) the share of ventilated/cooled floor area, the number and type of ICT devices per employee, and the use of service hot water per employee (see [60] for details).

Energy service drivers vary over time and across regions, depending on the past development, the sub-sector, and the energy service considered. As an example, Figure 13 shows the assumed trends on share of ventilated/cooled floor area, which is one of the energy service drivers with the highest impact on final energy use. Note that the differences across regions are substantial (both in terms of the starting value in the reference year and the assumed future trend).

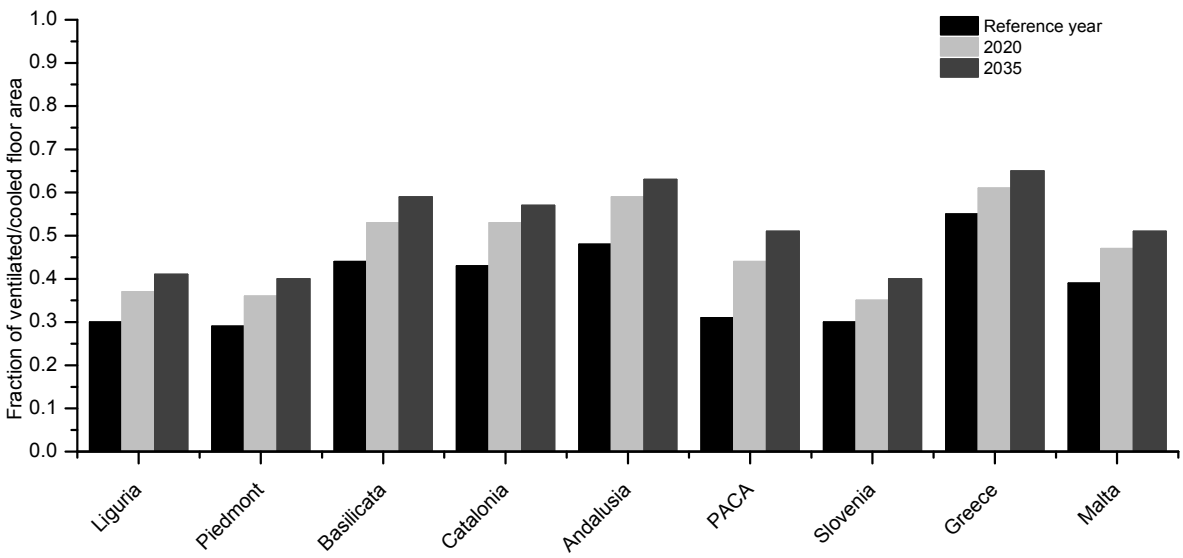


Figure 13 Diffusion of air conditioning and ventilation

The trends used in this study are based on the rationale in [59, 61], which differentiates regional trends according to economics and climate.

Similar to the global energy drivers, trends on energy service drivers are independent on the energy policies adopted. Therefore, this study used the same trends for both RR and MARIE.

2.4.4 DIFFUSION OF ENERGY SAVING OPTIONS

The Forecast Tertiary model "decides" on the diffusion of a given energy saving option (ESO) based on cost calculations: when an ESO is cost effective the model follows the "maximum diffusion path", otherwise, the model follows the "autonomous diffusion path". Dynamics and saturation levels of these two diffusion paths depend on the typical life span of the technologies and ESOs considered.

The "cost effectiveness" criterion is based on "annualized life cycle cost", which depends on the discount rates assigned to the ESOs as well as on energy price. These two factors strongly depend on the energy policies implemented. Therefore, the regional scenario settings process in the tertiary sector basically consists in translating the policy frameworks of the respective scenarios (see Section 2.2.2) into "discount rates" associated to ESOs and "energy prices". Energy saving options targeted by policy measures would see their corresponding discount rate reduced, increasing the present value of their corresponding future energy savings, and therefore making them more cost effective.

Implicit discount rates used in this study vary by scenario, region, and ESO. The concept of implicit discount rates reflects the fact that observed investment and retrofit behavior usually is not explained by classic cost-benefit calculus using observed (market) interested rates. Given these interest rates energy-efficiency measures should be adopted more than observed. In the literature the discrepancy between expected and observed behavior is referred to as "energy-efficiency gap" [63]. Observed behavior can be approximated by using a higher discount rate, called the implicit discount rate. It includes "implicit" costs such as information and other transactions costs, barriers and preferences.

Table 21 shows the ranges of implicit discount rates that were used in this study for energy saving options (ESO). The values in the table are modeling assumptions of TEP Energy based on past modeling experience and on the qualitative inputs of the regional partners in the MARIE consortium.

Table 21 Implicit discount rates

ESO type	Rapid Results		MARIE	
	2010-2020	2020-2035	2010-2020	2020-2035
Building Retrofit	13-16%	25-30%	18-22%	15-18%
HVAC Equipment	12-13%	18-25%	12-13%	15-17%

The measures proposed in the two scenarios could reduce direct costs of loans (capital costs) by subsidies, but also "implicit" costs, for instance transaction costs, through information and education programmes. On the other hand, a bad economic development could reduce willingness to make long term energy-related investments.

The energy price trends were obtained from the Energy System Analysis Agency (ESA[2]) [64].

2.5 LIMITATIONS

The main limitations in this study are summarized in the following list:

- Due to data availability, the scope of this study is limited to the 9 regions involved in WP4, namely: Liguria, Piedmont, Basilicata, Catalonia, Andalucía, PACA, Slovenia, Greece and Malta. The individual results shall therefore be used to evaluate the relative impact of the MARIE measures in the individual regions. The results can also be useful to provide general qualitative inputs/conclusions for regions with similar characteristics. However, the quantitative results should NOT be used as an accurate representation of the impact of the MARIE strategies in the MED space.

- Lack of up to date data on the building stock at regional level. Very limited data was available at regional level, particularly for the tertiary sector (there was nearly no data on the tertiary stock for some regions). When data was available, it was often dated, which means that it did not include the impacts of the most recent national and regional energy plans. The current data available was used to define the starting point of the simulation; therefore, the accuracy of the current data drives the accuracy of the projections.

- Accuracy of the results is limited by the uncertainties typically associated to the input assumptions in long-term forecasting studies. Particularly important sources of uncertainty in this include:

    - The extremely unstable economic framework in the MED space. Europe, and particularly the Mediterranean countries, are currently facing the strongest recession in the EU history.

    - The unreliable trends in the building sector in the last years. The construction market saw a major increase in the early 2000's and sharply decreased from around 2006 onwards. Therefore, the market trends from the first decade of the 2000's could not be used as "stable/representative".

    - Most of the measures proposed in the MARIE scenario are new (i.e., have never been tested before), and most of them are yet to be defined in detail (e.g., "Reduced taxes over rental of energy efficient buildings", "Marketing-oriented, comprehensive communication strategies to promote integral refurbishment", …). Furthermore, the effectiveness of these measures largely depends on the implementation details. Therefore, at this point there is no actual experience that can be used to forecast their impact on market transformation and energy use.

- The scope of the present study is limited to final energy use, and does not include impacts in terms of primary energy use or carbon emissions. Results of this study distinguish between electricity and fuel use, but the strategies in both scenarios target total final energy use reduction (including both electricity and fuel). Some measures were introduced accounting for carbon concerns, however, their benefits in terms of carbon emissions were not analyzed in this study. Namely, biomass was largely

introduced in the MARIE scenario because it was considered consistent with its overall policy framework, yet, its benefits were not accounted for.

- Since the MARIE project targets only energy refurbishment of existing buildings, new construction was not included in this analysis. While this is consistent with the objective of the study (i.e., evaluation of refurbishment policies through comparison), it precludes using the results to evaluate the likelihood of meeting the 2020 energy efficiency targets (which include both new and existing buildings).

3 RESULTS

The results obtained from the MURE and TERTIARY simulations are showed in the sections below. Section 3.1 shows the results of final energy use for the reference year according to the bottom up simulations, and compares them against the top-down regional values found in by the partners in the WP4 RBA. Section 3.2 shows the detailed results by region, while Section 3.3 compares results across regions.

Results are often normalized based on the reference year to allow for a clearer perspective of the relative impact of the scenarios (both for the individual regions and across regions). Note that the objective of the Potential Impact Evaluation results is to assess the relative impact of the MARIE scenario (i.e., a first draft of the MEDBEES).

3.1 REFERENCE YEAR RESULTS

The objective of the present analysis is to evaluate the potential benefits of one strategy (MEDBEES) over its opposite, and results in the next sections are often shown in normalized values to allow for a clear comparison between strategies (i.e., results in absolute terms of final energy use are not the main output of this analysis). However, results of the bottom-up model for the reference year were compared against final energy values collected in the WP4 RBA as a “quality check” before running the outlook simulations.

Table 22 and Table 23 compare results of the MURE and Forecast Tertiary bottom-up models with findings in the Regional Benchmark Analysis of the Demand Side (RBA-WP4) for the residential and the tertiary sectors, respectively. Note that in both sectors the RBA and the analysis results correspond to different years.

Table 22 Final energy use in the residential sector. MURE results vs. RBA findings

	2005 RBA (ktoe)	2007 MURE (ktoe)	% Error
Liguria	881	897	-2%
Piedmont	2700	3039	-13%
Basilicata	n/a	319	n/a
Catalonia	2316	2578	-11%
Andalusia	1776	1519	14%
PACA	2900	2567	11%
Slovenia	1186	1280	-8%
Greece	5497	4613	16%
Malta	73	72	2%

Table 23 Final energy use in the tertiary sector. Forecast Tertiary results vs. RBA findings

	2005 RBA (ktoe)	2010 Forecast Tertiary (ktoe)	% Error
Liguria	515	541	-5%
Piedmont	1317	1440	-9%
Basilicata	n/a	114	n/a
Catalonia	1716	1679	2%
Andalusia	1127	1458	-29%
PACA	1613	1091	32%
Slovenia	474	453	4%
Greece	1939	2218	-14%
Malta	155	70	55%

Relative error in the residential sector results ranges from -2% (Liguria) up to 16% (Greece). In turn, errors in tertiary sector range from -29% (Andalusia) up to +55% (Malta). It should be noted, however, that Malta shows the lowest (by far) energy use of all the analyzed regions, and a relative error of 55% corresponds to a 85 ktoe absolute error.

Considering that:

- The two sources date different years, and should not be directly compared.
- Information to base the bottom-up analyses was very limited at regional level, which led to making extensive approximations of the inputs (particularly for tertiary) often based on national data.
- Reliability of some of the data collected in the RBA is also fairly limited
- The objective of this analysis is not to accurately forecast absolute values of final energy use, but rather to compare strategies
- Unavailability of detailed data at regional level did not allow fine-tuning the model

The results from the bottom-up models were accepted as good-enough approximations for the analysis.

3.2 OUTLOOK RESULTS BY REGION

The results are presented according to the following structure.

- Residential sector

  - Total energy use for residential sector provides a general view of the impacts of the two scenarios in the residential sector. Total energy use results for both, the total building stock and the existing building stock, are shown in order to contextualize the effect of the measures (note that the MARIE project focuses on energy efficient building refurbishment, i.e., existing buildings). The figures also include pie charts with the breakdown of total final energy use by energy service for the reference year and the 2035 outlooks corresponding to the two scenarios.

  - Energy use in existing dwellings. The MARIE project, and in consequence the measures defined in the scenarios, are focused building refurbishment. Therefore, the detailed results belong to the existing building stock (old and refurbished dwellings).

- Heating and Cooling. Heating and cooling loads and the associated final energy use are represented in the same graphics to allow comparing the individual impacts of the passive (envelope) and active measures (equipment). The energy use variation is a consequence of trends in three parameters: building envelope performance (heating and cooling load), the type and efficiency of the heating and cooling equipment, and the fraction of load that is met by the heating/cooling system (coverage factor, which in turn depends on the system type).

- Breakdown of the energy use by heating equipment type. In this figure there are represented the current and the future breakdowns of the heating energy use by equipment, for both scenarios. This information allows understanding some of the results of the heating energy use. Most of the regions show an increase of the centralized systems (biomass, condensing boiler, heat pumps and district heating).

- Domestic Hot Water. The total energy use for DHW is broken down by energy source (electricity and fuel). The fraction of load covered by solar thermal systems is included in the same graphic. The reduction of DHW energy use is a consequence of two measures: the improvement in equipment energy efficiency and the increasing diffusion of the solar thermal systems (the fraction of dwellings and the coverage factor of the solar thermal systems)

- Tertiary sector

  - Total energy use for tertiary sector provides a general view of the impacts of the two scenarios. Results focus on energy use of the existing building stock. The figures also include pie charts with the breakdown of total final energy use by energy service for the reference year and the 2035 outlooks corresponding to the two scenarios. The break down splits final energy use in heating, cooling and ventilation, and “others” (which includes: lighting, ICT, cooking, refrigerators, laundry and miscellaneous building mechanical equipment).

  - Projections of final energy use for heating and cooling and ventilation according to the two scenarios. While there are other important end uses in the tertiary sector, these two are the most relevant in terms of refurbishment policy (i.e., neither MARIE nor RR included extensive measures targeting the “other” category).

3.2.1 LIGURIA

The following sections show the results of the residential and tertiary sectors for Liguria. The obtained results are based on the assumptions and the input data that are defined in sections 2.3 and 2.4.

3.2.1.1 Residential

The results obtained for Liguria are shown in the following figures. Figure 14 shows the normalized total energy use. Up to 2020, both scenarios follow almost identical trends, however beyond this year, the energy savings achieved with the MARIE scenario gradually increase over those obtained with the RR scenario.

Figure 14 also includes pie charts with the breakdown of total final energy use in the residential sector by end use (heating, domestic hot water, cooling, lighting and appliances). The pie charts in the figure correspond to the reference year and the outlooks for 2035 according to the two scenarios. Heating is the largest energy use, and represents around 2/3 of the energy use of the sector. In 2035, the fraction of energy use for appliances doubles, while the fractions of energy use for heating, DHW and lighting decrease.

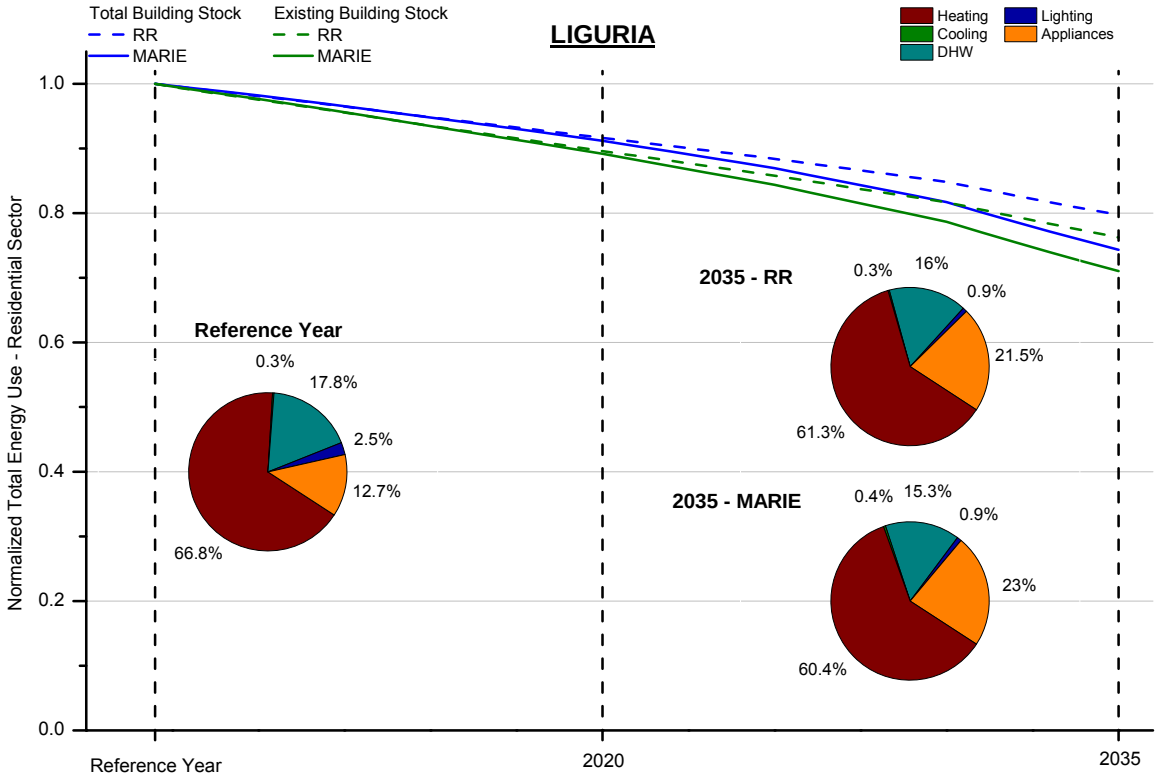


Figure 14 Normalized total energy use for the residential sector. Inner pie charts: left, breakdown by energy use in reference year; top right, breakdown by energy use in 2035 for the Rapid Results scenario; bottom right, breakdown by energy use in 2035 for the MARIE scenario.

Figure 15 shows normalized values of final energy use for heating and heating load. Similarly to the results of total energy use, both scenarios show similar behaviors up to 2020. However, beyond 2020 the energy savings in the MARIE scenario see a larger increase than in the RR scenario. As noted in the method section, the two scenarios assume that a new building code (which defines more energy efficiency building performance (Table 9)) is applied in 2020. The main differences between scenarios are the rate of equipment replacement (higher in RR) and the rate of integral refurbishment (higher in MARIE). The higher penetration of integral refurbishment combined with the increased energy performance requirements in the new building code result in larger energy savings in the long term with MARIE.

In terms of energy use by heating equipment type (Figure 16), the differences between scenarios are relatively small. In both scenarios natural gas remains the dominant heating source and oil decreases substantially. RR see a larger increase of condensing boilers (due to subsidies) while MARIE sees a larger increase of biomass and heat pump systems.

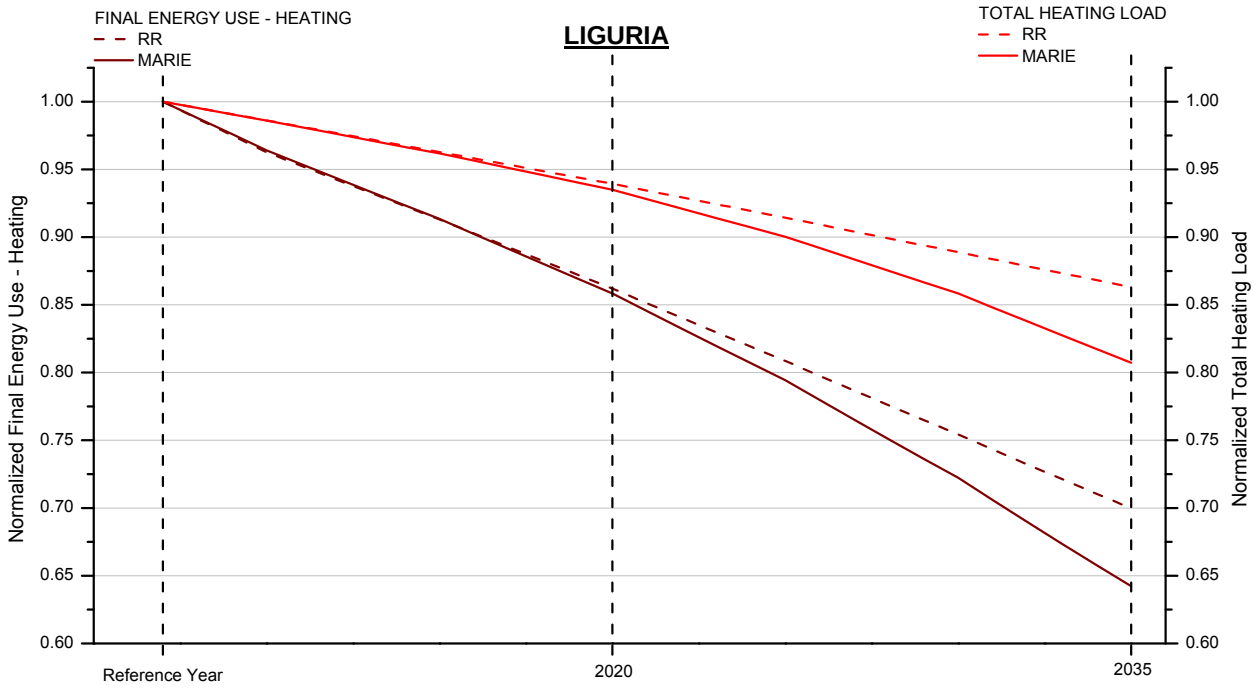


Figure 15 Heating results for the existing stock. Normalized final energy use for heating on left axis. Normalized total heating load on right axis

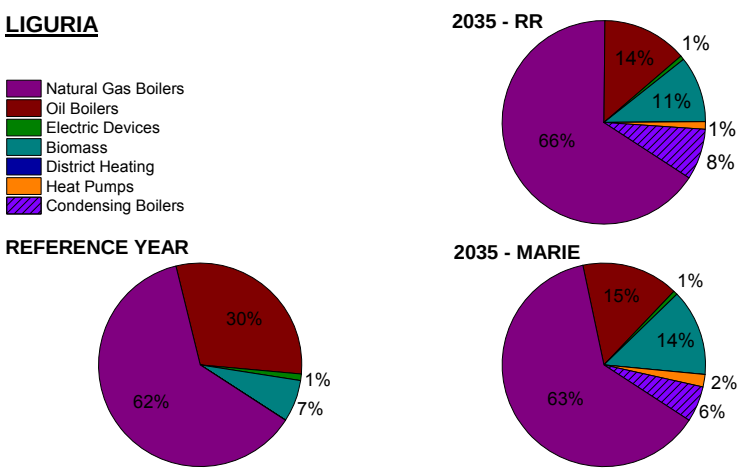


Figure 16 Breakdown of energy use by heating equipment in Reference Year and 2035, for Rapid Results and MARIE scenarios.

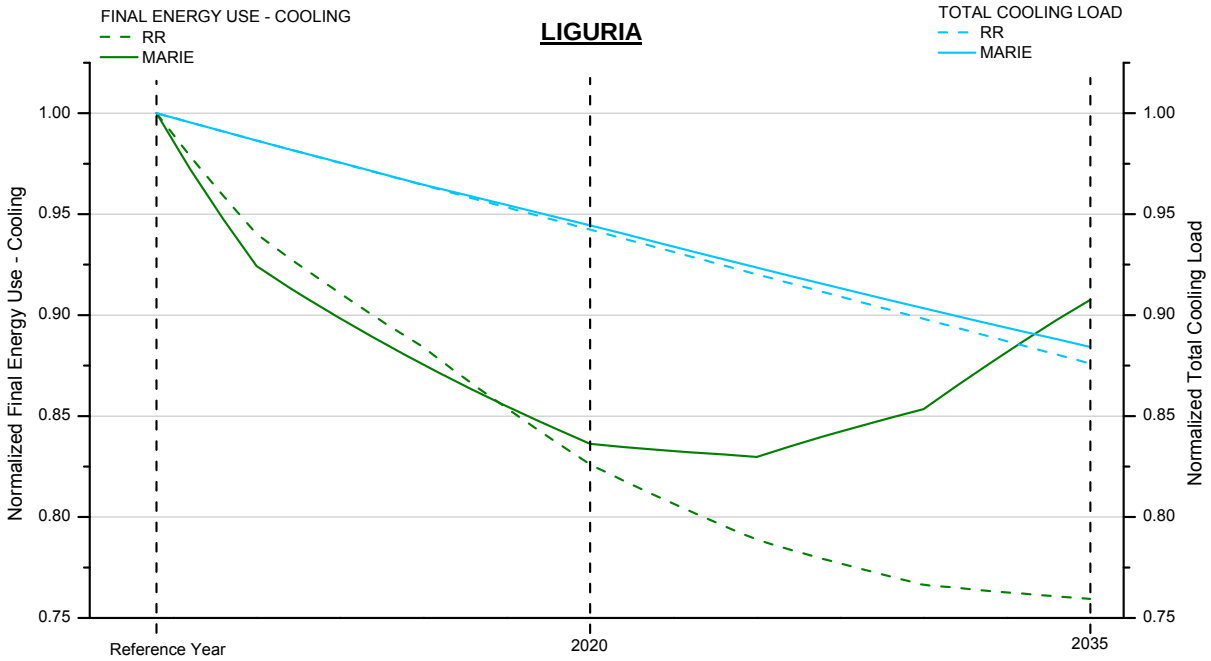


Figure 17 Cooling results for the existing stock. Normalized final energy use for heating on left axis. Normalized total cooling load on right axis.

Figure 17 shows normalized values of final energy use for cooling and cooling load. It should be noted that cooling is a negligible energy use in the residential sector (it is less than 1% of the final energy use). Therefore, while results in Figure 17 may be useful to evaluate the consequences of the two strategies on this specific energy use, they have virtually no impact on the overall building energy use.

Results show that the RR scenario achieves larger energy savings than the MARIE scenario. The factors related in these results are the following:

- Cooling loads of refurbished buildings are higher than the cooling loads of the existing building in the stock (insulation reduces heating loads but slightly increases cooling loads. See Annex 3 for details). Since in the MARIE scenario the refurbishment rate is higher than in RR, cooling load of the total building stock with MARIE is also higher (the general downtrends in Figure 17 are due to the demolition of buildings that were in the stock in the reference year).

- The number of dwellings equipped with cooling system increases over the years. This study assumed that heat pumps (both centralized and decentralized) introduced for heating purposes are also used for cooling. The larger share of centralized heat pumps in MARIE results also in a larger share of covered cooling loads (Table 14) (i.e., higher comfort). The MARIE scenario includes education and awareness measures for users. However, these are not enough to balance the increasing energy use linked to the higher comfort.

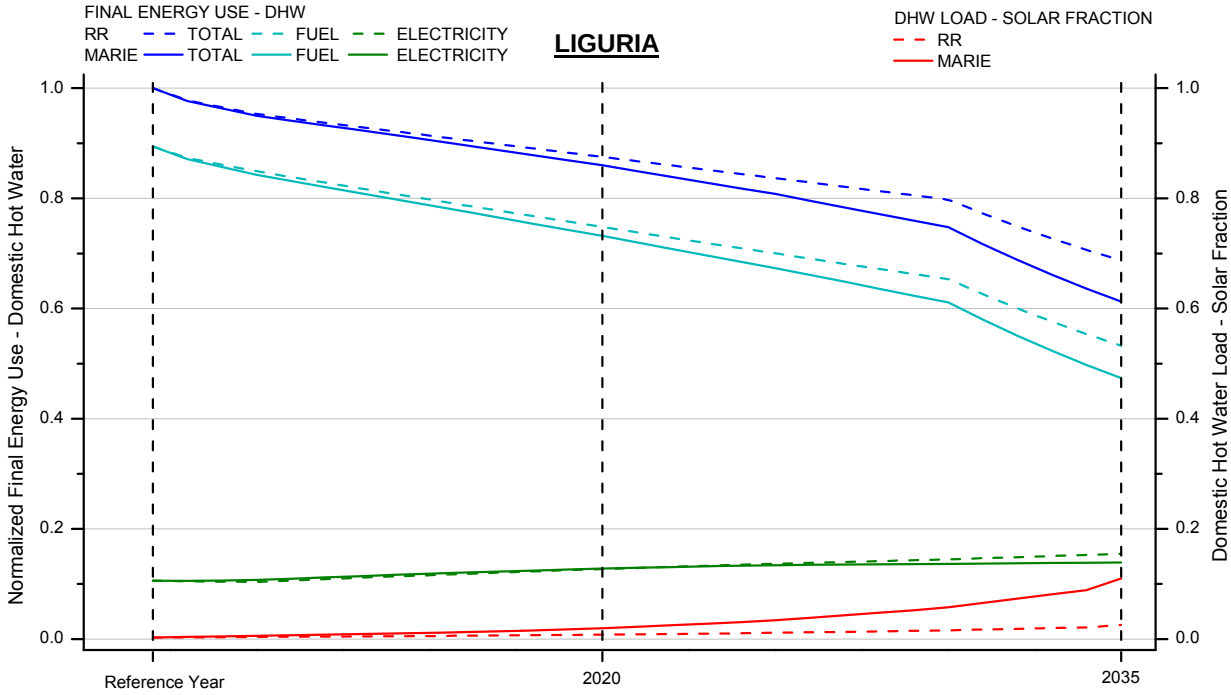


Figure 18 Domestic hot water results for the existing stock. Breakdown of normalized final energy use for DHW by energy source on left axis. Fraction of domestic hot water load covered by solar thermal on right axis

Figure 18 shows the breakdown of domestic hot water (DHW) energy use by energy source (fuel vs. electricity). Note that the final energy use breakdown does not include the energy provided by solar thermal systems, since this is considered a reduction of DHW load. Figure 18 also shows the fraction of DHW load that is covered with solar thermal systems. The assumptions on domestic hot water systems can be found in Section 2.3.1.3.

3.2.1.2 Tertiary

Figure 19 shows normalized values of total final energy use in the tertiary sector for the existing buildings in the stock in the reference year. The figure also includes pie charts with the breakdown of total final energy use in the tertiary sector by end use (heating, cooling and ventilation, and “others”). The pie charts in the figure correspond to the reference year and the outlooks for 2035 according to the two scenarios.

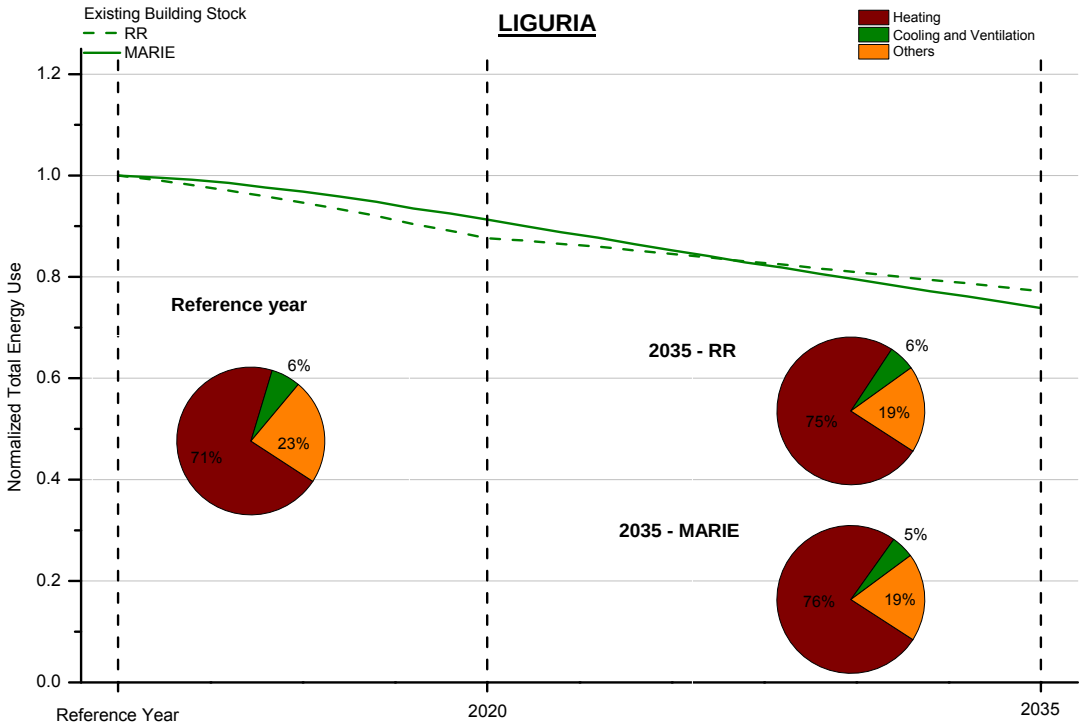


Figure 19 Normalized total energy use for the tertiary sector (existing building stock). Inner pie charts: left, breakdown by energy use in reference year; top right, breakdown by energy use in 2035 for the Rapid Results scenario; bottom right, breakdown by energy use in 2035 for the MARIE scenario

RR provides larger energy savings than MARIE in the first years of simulation. However, in the long run, the MARIE measures are more effective at reducing final energy use. Similarly to the residential sector, heating is the dominant energy use in tertiary. However, cooling and ventilation show a much larger share.

Figure 20 shows projections of normalized final energy use for heating and cooling and ventilation according to the two scenarios.

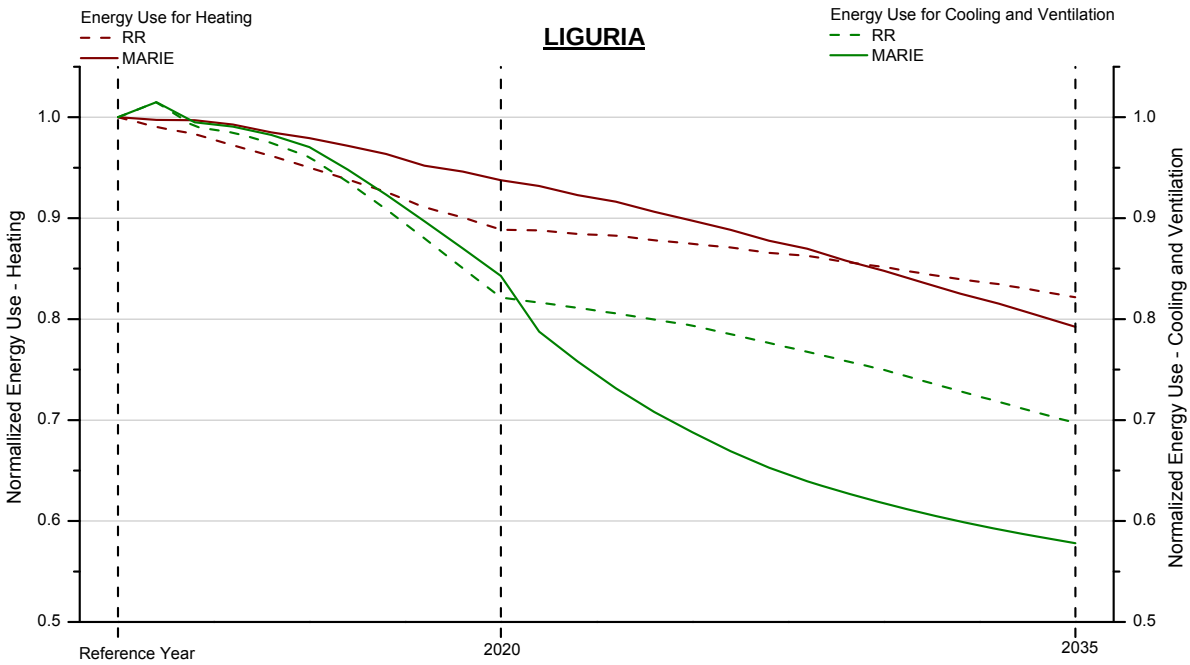


Figure 20 Normalized energy use for heating (left axis) and for cooling and ventilation (right axis). Existing building stock

The benefits of MARIE over RR arrive sooner in cooling and ventilation than they do in heating energy use. This is likely due to the longer lifecycles associated to measures on envelope (which mainly target heating energy use).

3.2.2 PIEDMONT

The following sections show the results of the residential and tertiary sectors for Piedmont. The obtained results are based on the assumptions and the input data that are defined in sections 2.3 and 2.4.

3.2.2.1 Residential

The results obtained for Piedmont are shown in the following figures. In the first one, Figure 21, shows the normalized total energy use. The MARIE scenario shows larger energy savings than RR since the reference year. Moreover, the difference between the two scenarios increases with time.

Figure 21 includes pie charts with the breakdown of total final energy use in the residential sector by end use (heating, domestic hot water, cooling, lighting and appliances). The pie charts in the figure correspond to the reference year and the outlooks for 2035 according to the two scenarios. Heating is by far the largest energy use, and represents the 80% of the total final energy use of the sector in the reference year. The variation of the breakdowns of energy use between the reference year and the 2035 projections is negligible, and the most important energy use continues being space heating.

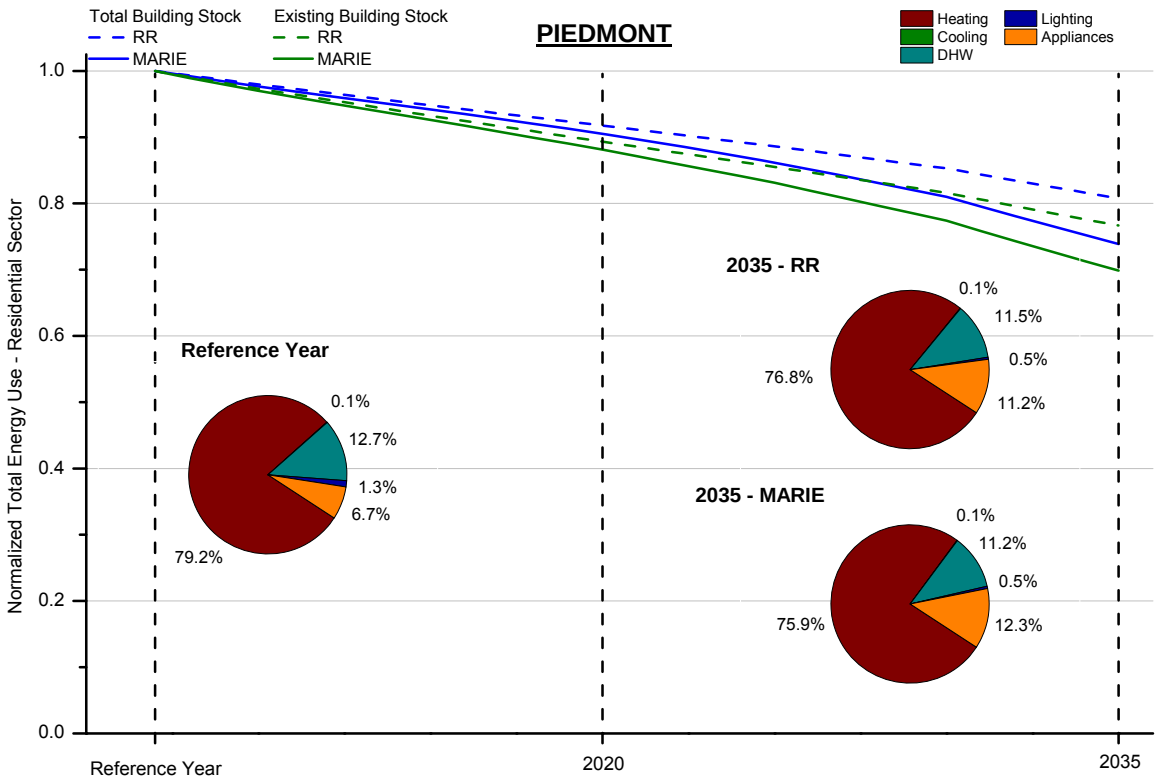


Figure 21 Normalized total energy use for the residential sector. Inner pie charts: left, breakdown by energy use in reference year; top right, breakdown by energy use in 2035 for the Rapid Results scenario; bottom right, breakdown by energy use in 2035 for the MARIE scenario.

Figure 22 shows normalized values of final energy use for heating and heating load. The measures in the two scenarios lead to different results between the heating load and the energy use for heating. Heating energy use is “substantially” lower in MARIE with respect to RR since the reference year, while the difference between scenarios arrives later in terms of heating load. The results could be explained analyzing the measures applied in each scenario:

- In the first years, the measures on heating equipment in MARIE seem more effective than these in RR. Although in the RR the rate of equipment replacement is higher than in MARIE scenario, the type of heating devices was different for the two scenarios (mainly condensing boilers in RR vs. centralized heat pumps in MARIE). The heating equipment is defined with two parameters: the efficiency and the coverage factor. In Piedmont centralized systems (coverage factor=100%) are already very common in the reference year. Therefore equipment efficiency plays an important role in the reduction of the heating energy use. Even if there are fewer replacements with MARIE, the much higher efficiency of heat pumps over boilers drives the total final energy use to a lower value.

- Beyond 2020, the effects of the new building code combined with the high rate of integral refurbishment in the MARIE scenario (represented by the heating load) build on the effects of the heating equipment measures, further increasing the benefits of the MARIE scenario over RR.

Figure 23 shows the breakdown of heating energy use by heating equipment type. The penetration of condensing boilers is substantial in both scenarios, but most importantly in RR. On the other hand, the share of biomass and heat pumps increases more in MARIE. Note that, in terms of final energy use, the share of heat pumps remains very small – this is partly due to the very high efficiency of these systems.

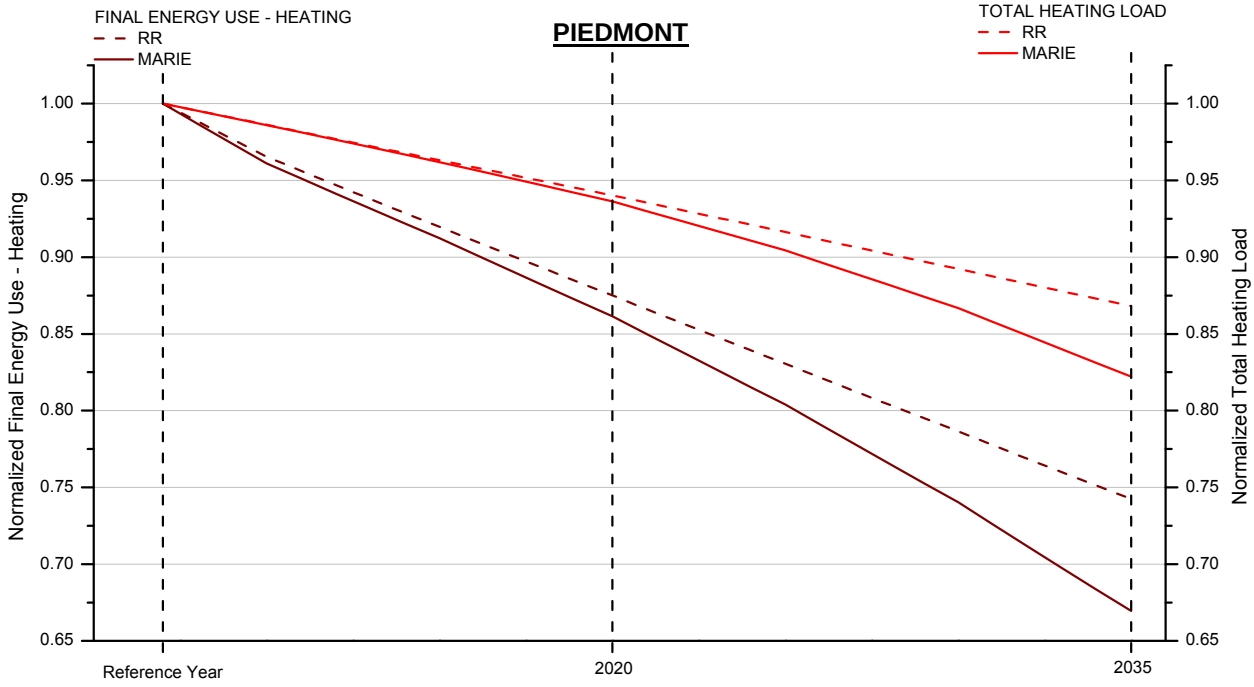


Figure 22 Heating results for the existing stock. Normalized final energy use for heating on left axis. Normalized total heating load on right axis

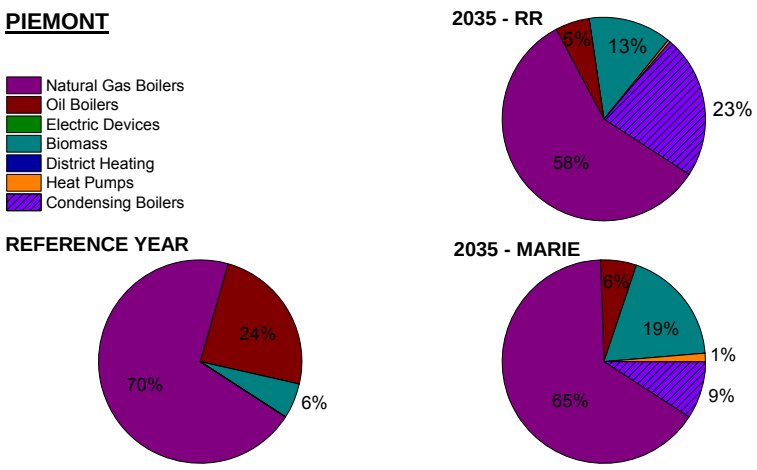


Figure 23 Breakdown of energy use by heating equipment in Reference Year and 2035, for Rapid Results and MARIE scenarios.

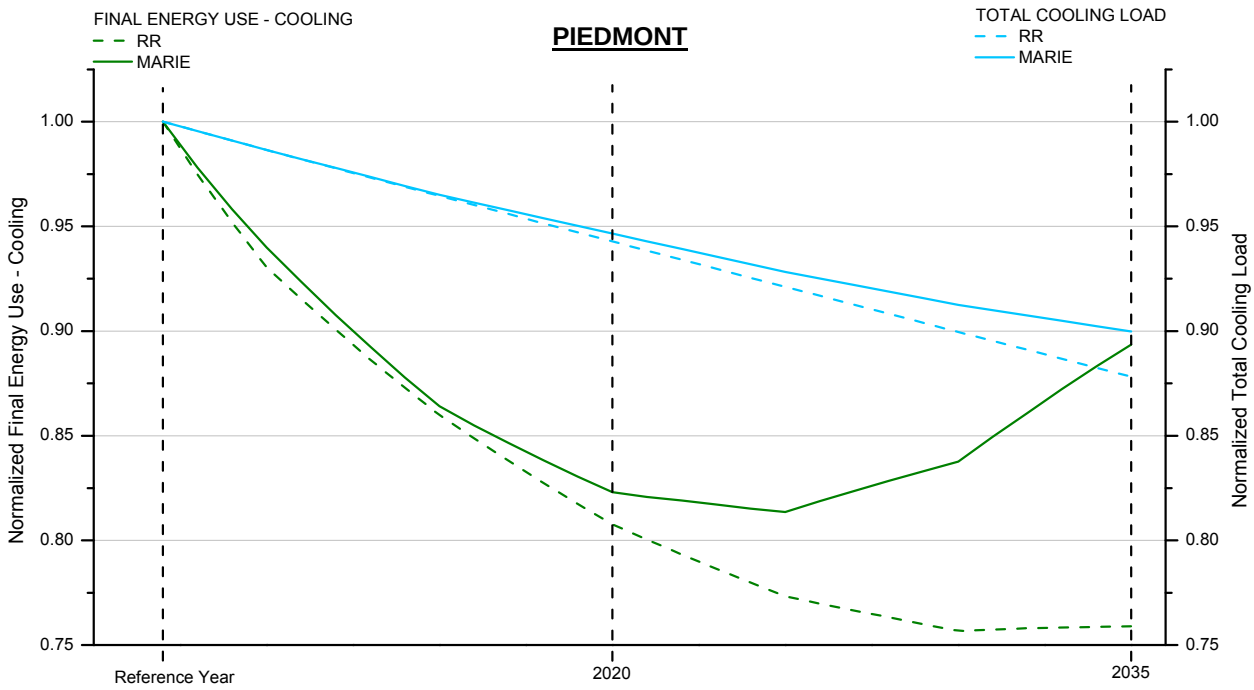


Figure 24 Cooling results for the existing stock. Normalized final energy use for heating on left axis. Normalized total cooling load on right axis.

Figure 24 shows normalized values of final energy use for cooling and cooling load. It should be noted that cooling is a negligible energy use in the residential sector (it is less than 1% of the final energy use). Therefore, while results in Figure 24 may be useful to evaluate the consequences of the two strategies on this specific energy use, they have virtually no impact on the overall building energy use.

Results show that the RR scenario achieves larger energy savings than the MARIE scenario. The factors related in these results are the following:

- Cooling loads of refurbished buildings are higher than the cooling loads of the existing building in the stock (insulation reduces heating loads but slightly increases cooling loads. See Annex 3 for details). Since in the MARIE scenario the refurbishment rate is higher than in RR, cooling load of the total building stock with MARIE is also higher (the general downtrends in Figure 24 are due to the demolition of buildings that were in the stock in the reference year).

- The number of dwellings equipped with cooling system increases over the years. This study assumed that heat pumps (both centralized and decentralized) introduced for heating purposes are also used for cooling. The larger share of centralized heat pumps in MARIE results also in a larger share of covered cooling loads (Table 14) (i.e., higher comfort). The MARIE scenario includes education and awareness measures for users. However, these are not enough to balance the increasing energy use linked to the higher comfort.

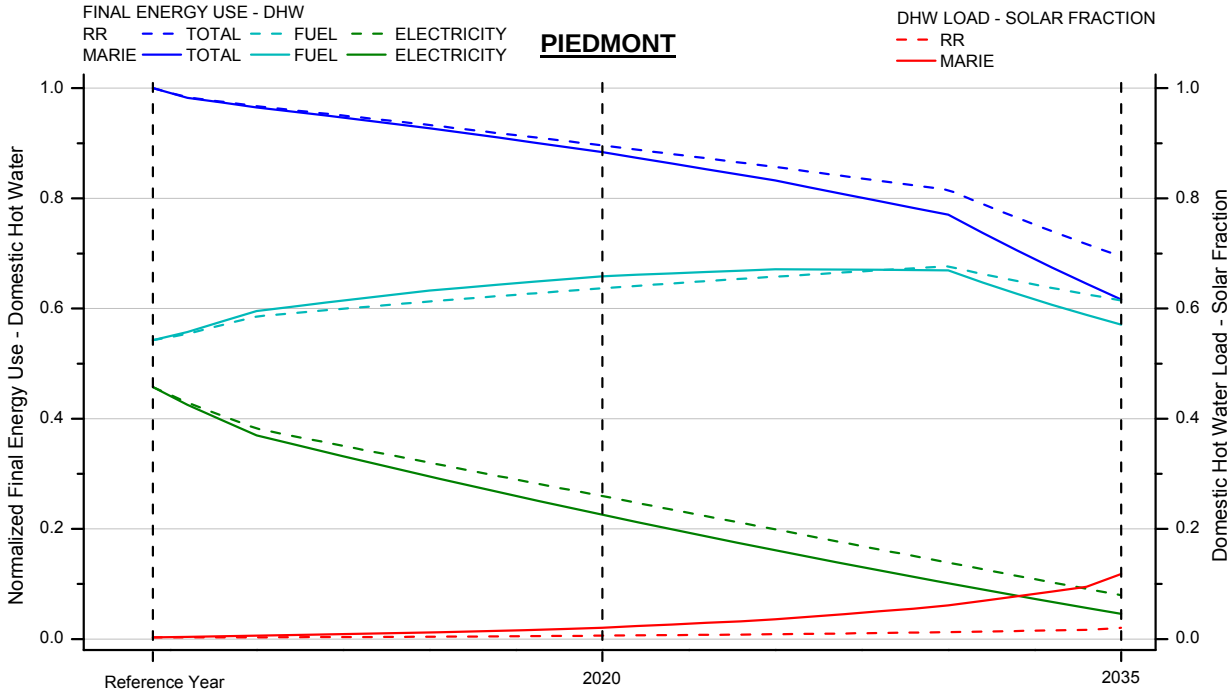


Figure 25 Domestic hot water results for the existing stock. Breakdown of normalized final energy use for DHW by energy source on left axis. Fraction of domestic hot water load covered by solar thermal on right axis

Figure 25 shows the breakdown of domestic hot water (DHW) energy use by energy source (fuel vs. electricity). Note that the final energy use breakdown does not include the energy provided by solar thermal systems, since this is considered a reduction of DHW load. Figure 25 also shows the fraction of DHW load that is covered with solar thermal systems. The assumptions on domestic hot water systems can be found in Section 2.3.1.3.

3.2.2.2 Tertiary

Figure 26 shows normalized values of total final energy use in the tertiary sector for the existing buildings in the stock in the reference year. The figure also includes pie charts with the breakdown of total final energy use in the tertiary sector by end use (heating, cooling and ventilation, and “others”). The pie charts in the figure correspond to the reference year and the outlooks for 2035 according to the two scenarios.

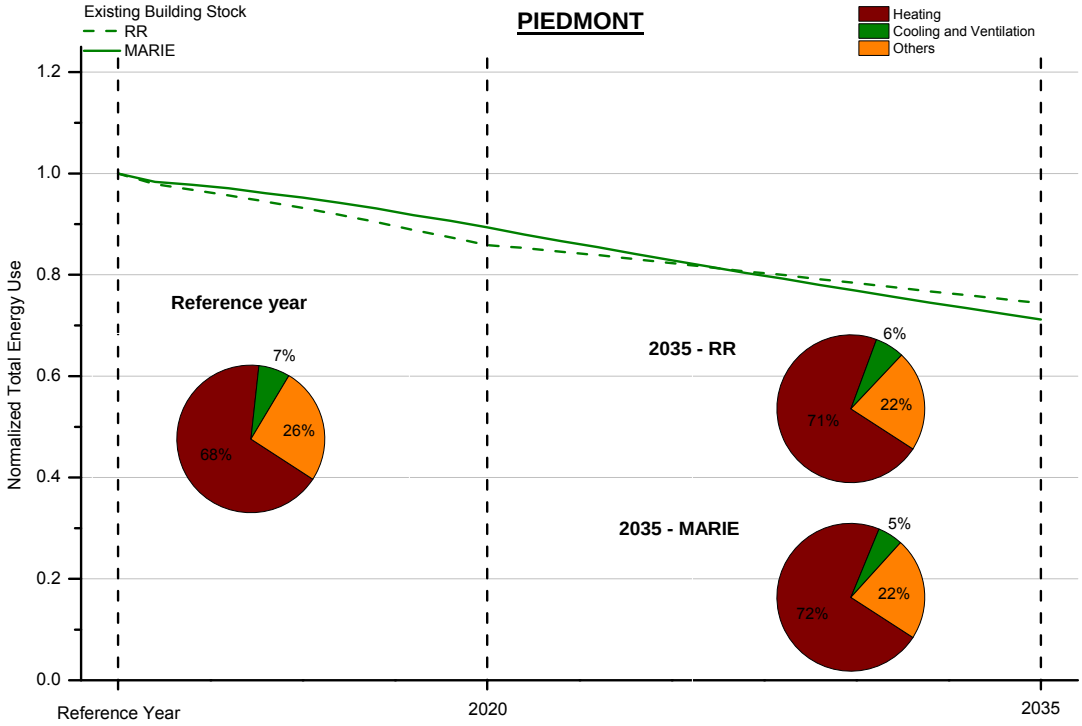


Figure 26 Normalized total energy use for the tertiary sector (total building stock and existing building stock). Inner pie charts: left, breakdown by energy use in reference year; top right, breakdown by energy use in 2035 for the Rapid Results scenario; bottom right, breakdown by energy use in 2035 for the MARIE scenario

RR provides larger energy savings than MARIE in the first years of simulation. However, in the long run, the MARIE measures are more effective at reducing final energy use. Similarly to the residential sector, heating is the dominant energy use in tertiary. However, cooling and ventilation show a much larger share.

Figure 27 shows projections of normalized final energy use for heating and cooling and ventilation according to the two scenarios.

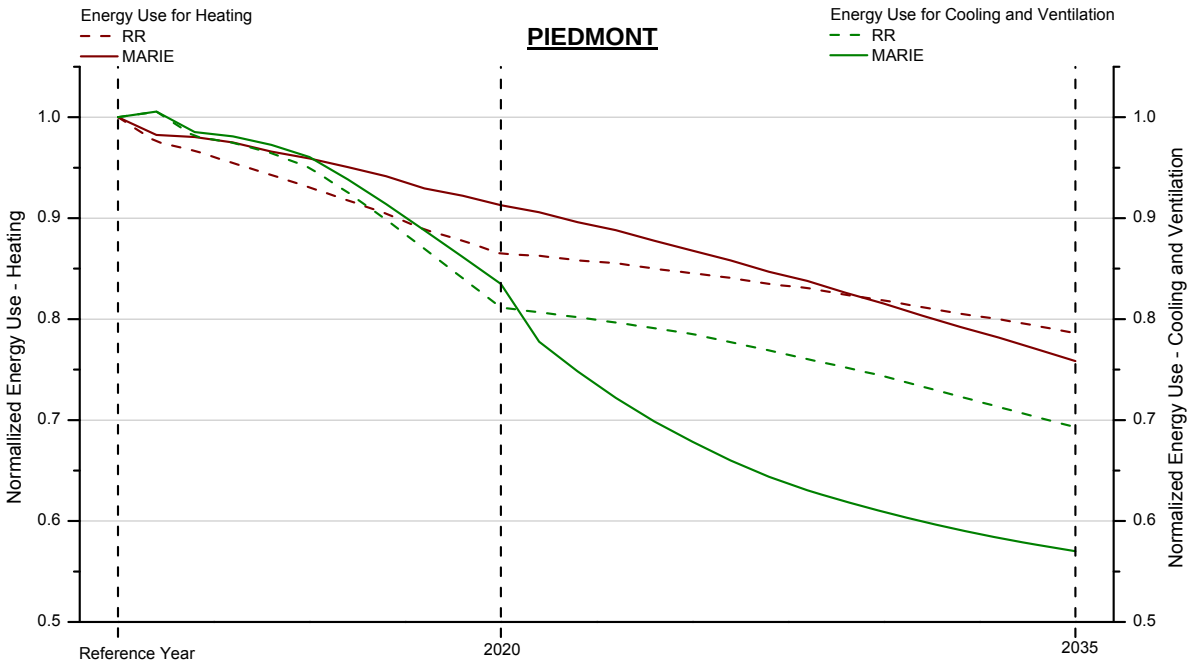


Figure 27 Normalized energy use for heating (left axis) and for cooling and ventilation (right axis). Existing building stock

The benefits of MARIE over RR arrive sooner in cooling and ventilation than they do in heating energy use. This is likely due to the longer lifecycles associated to measures on envelope (which mainly target heating energy use).

3.2.3 BASILICATA

The following sections show the results of the residential and tertiary sectors for Basilicata. The obtained results are based on the assumptions and the input data that are defined in sections 2.3 and 2.4.

3.2.3.1 Residential

The results obtained for Basilicata are shown in the following figures. In the first one, Figure 28, shows the normalized total energy use. Up to 2020, both scenarios follow almost identical trends, however beyond this year, the energy savings achieved with the MARIE scenario gradually increase over those obtained with the RR scenario.

Figure 28 includes pie charts with the breakdown of total final energy use in the residential sector by end use (heating, domestic hot water, cooling, lighting and appliances). The pie charts in the figure correspond to the reference year and the outlooks for 2035 according to the two scenarios. Heating is largest energy use, and represents around ¾ of the total final energy use of the sector in the reference year. The variation of the breakdowns of energy use between the reference year and the 2035 projections is very small, and the most important energy use continues being space heating.

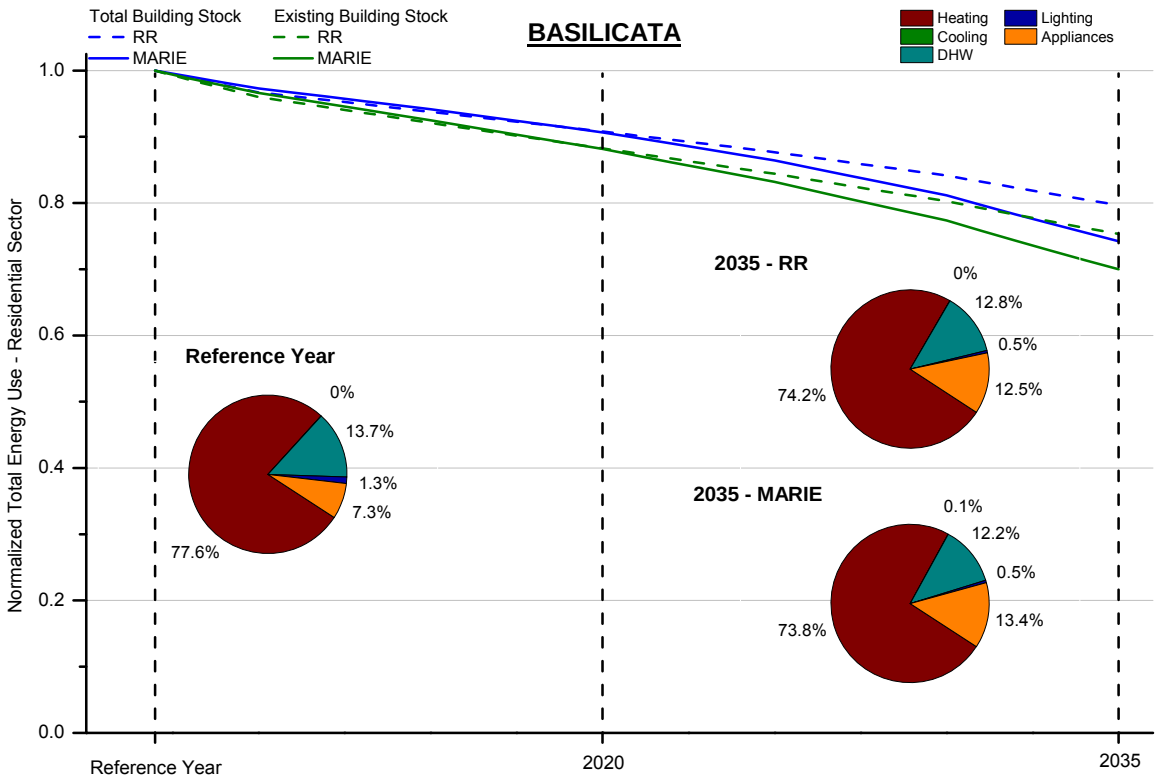


Figure 28 Normalized total energy use for the residential sector. Inner pie charts: left, breakdown by energy use in reference year; top right, breakdown by energy use in 2035 for the Rapid Results scenario; bottom right, breakdown by energy use in 2035 for the MARIE scenario.

Figure 29 shows normalized values of final energy use for heating and heating load. The MARIE scenario achieves lower heating load over all the years as a consequence of the higher energy efficiency refurbishment rate in the MARIE scenario. However, in terms of energy use for heating, the trends between scenarios are somewhat different: RR is slightly better than MARIE until 2020. Since the heating loads are very similar in this period (measures to enhance energy refurbishment rate are slow), the reason why RR has obtained less energy use for heating than MARIE is the equipment replacement measures (heating equipment replacement rates are higher in RR). Starting around 2020, the energy savings in MARIE are larger than in RR. This fact is a consequence of the introduction of the new building code and the high rate of integral refurbishment.

Figure 30 shows the breakdown of energy use for heating by heating equipment type. In the reference year there are basically two types of heating equipment: natural gas boilers (3/4) and biomass systems (1/4). In 2035, the fraction of natural gas boilers decreases in favour of condensing boilers and the centralized heat pumps. Differences between scenarios are very small, and natural gas boilers remain the predominant heating equipment type.

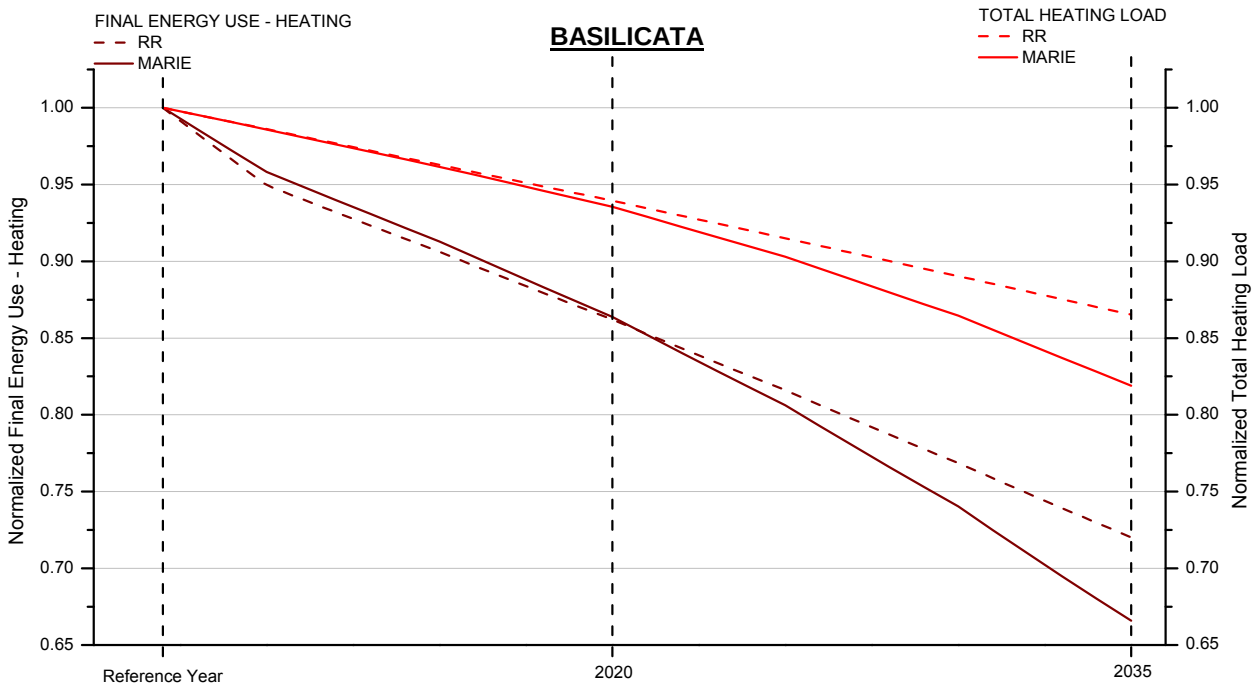


Figure 29 Heating results for the existing stock. Normalized final energy use for heating on left axis. Normalized total heating load on right axis

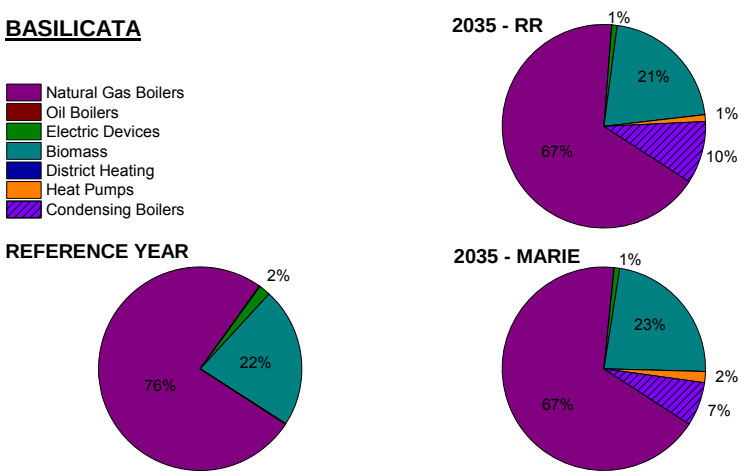


Figure 30 Breakdown of energy use by heating equipment in Reference Year and 2035, for Rapid Results and MARIE scenarios.

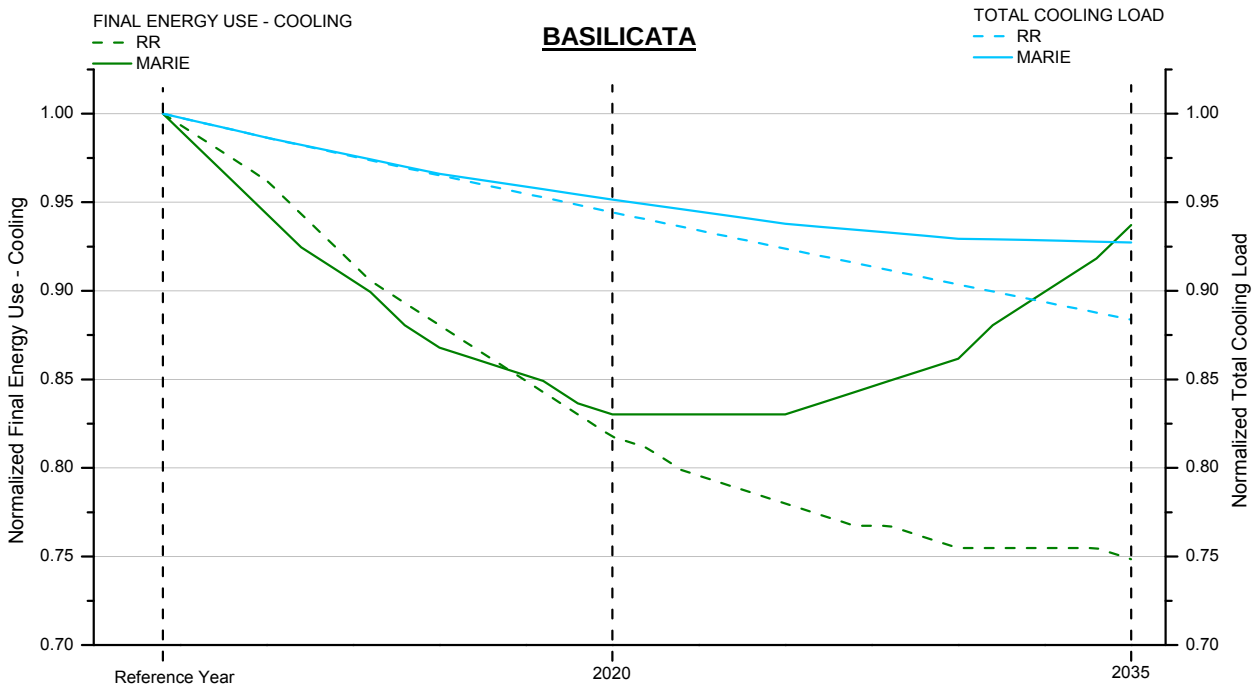


Figure 31 Cooling results for the existing stock. Normalized final energy use for heating on left axis. Normalized total cooling load on right axis.

Figure 31 shows normalized values of final energy use for cooling and cooling load. It should be noted that cooling is a negligible energy use in the residential sector (it is less than 1% of the final energy use). Therefore, while results in Figure 31 may be useful to evaluate the consequences of the two strategies on this specific energy use, they have virtually no impact on the overall building energy use.

Results show that the RR scenario achieves larger energy savings than the MARIE scenario. The factors related in these results are the following:

- Cooling loads of refurbished buildings are higher than the cooling loads of the existing building in the stock (insulation reduces heating loads but slightly increases cooling loads. See Annex 3 for details). Since in the MARIE scenario the refurbishment rate is higher than in RR, cooling load of the total building stock with MARIE is also higher (the general downtrends in Figure 31 are due to the demolition of buildings that were in the stock in the reference year).

- The number of dwellings equipped with cooling system increases over the years. This study assumed that heat pumps (both centralized and decentralized) introduced for heating purposes are also used for cooling. The larger share of centralized heat pumps in MARIE results also in a larger share of covered cooling loads (Table 14) (i.e., higher comfort). The MARIE scenario includes education and awareness measures for users. However, these are not enough to balance the increasing energy use linked to the higher comfort.

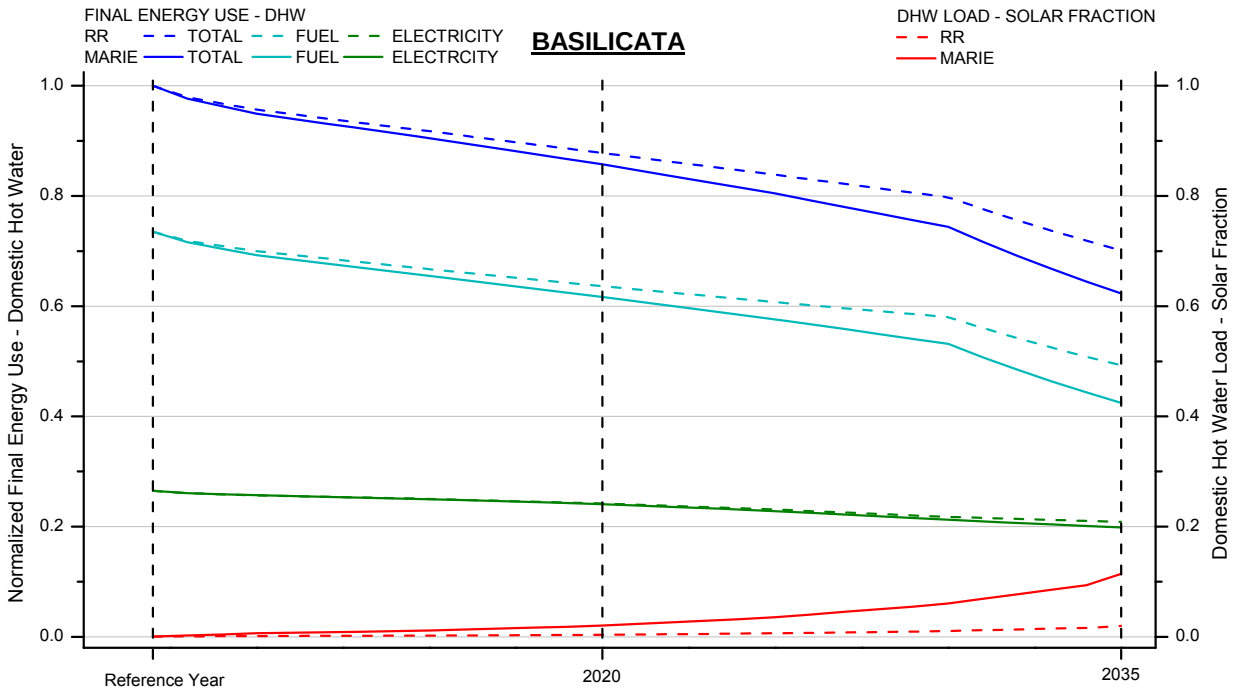


Figure 32 Domestic hot water results for the existing stock. Breakdown of normalized final energy use for DHW by energy source on left axis. Fraction of domestic hot water load covered by solar thermal on right axis

Figure 32 shows the breakdown of domestic hot water (DHW) energy use by energy source (fuel vs. electricity). Note that the final energy use breakdown does not include the energy provided by solar thermal systems, since this is considered a reduction of DHW load. Figure 32 also shows the fraction of DHW load that is covered with solar thermal systems. The assumptions on domestic hot water systems can be found in Section 2.3.1.3.

3.2.3.2 Tertiary

Figure 33 shows normalized values of total final energy use in the tertiary sector for the existing buildings in the stock in the reference year. The figure also includes pie charts with the breakdown of total final energy use in the tertiary sector by end use (heating, cooling and ventilation, and “others”). The pie charts in the figure correspond to the reference year and the outlooks for 2035 according to the two scenarios.

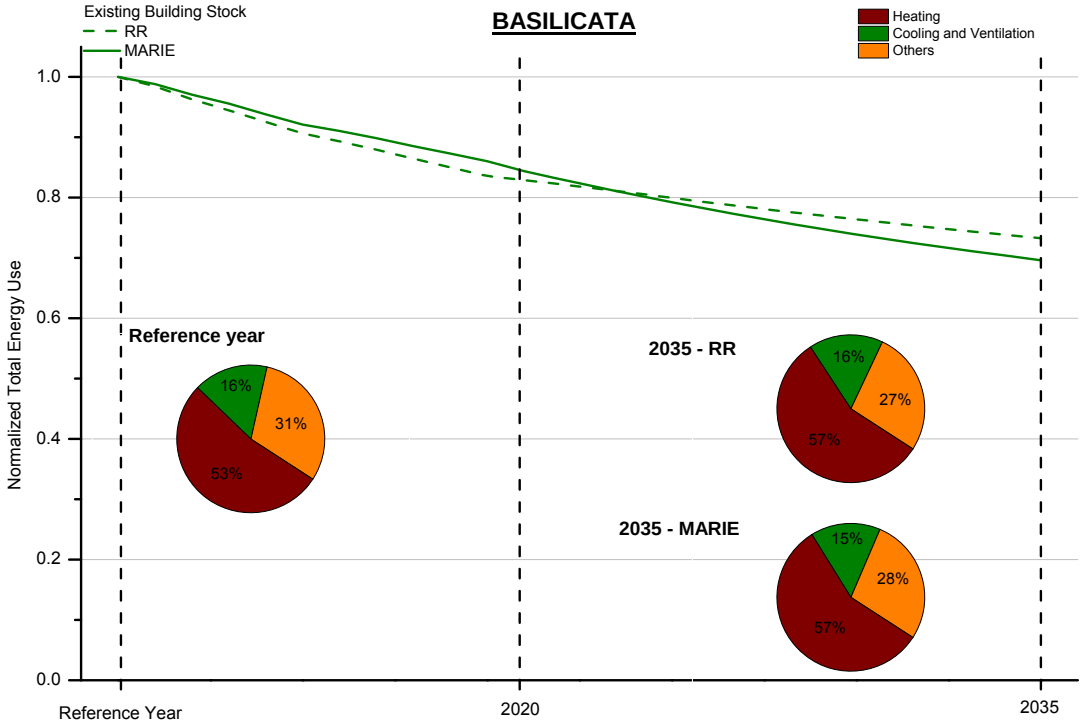


Figure 33 Normalized total energy use for the tertiary sector (total building stock and existing building stock). Inner pie charts: left, breakdown by energy use in reference year; top right, breakdown by energy use in 2035 for the Rapid Results scenario; bottom right, breakdown by energy use in 2035 for the MARIE scenario

RR provides larger energy savings than MARIE in the first years of simulation. However, in the long run, the MARIE measures are more effective at reducing final energy use. Similarly to the residential sector, heating is the dominant energy use in tertiary. However, cooling and ventilation show a much larger share.

Figure 34 shows projections of normalized final energy use for heating and cooling and ventilation according to the two scenarios.

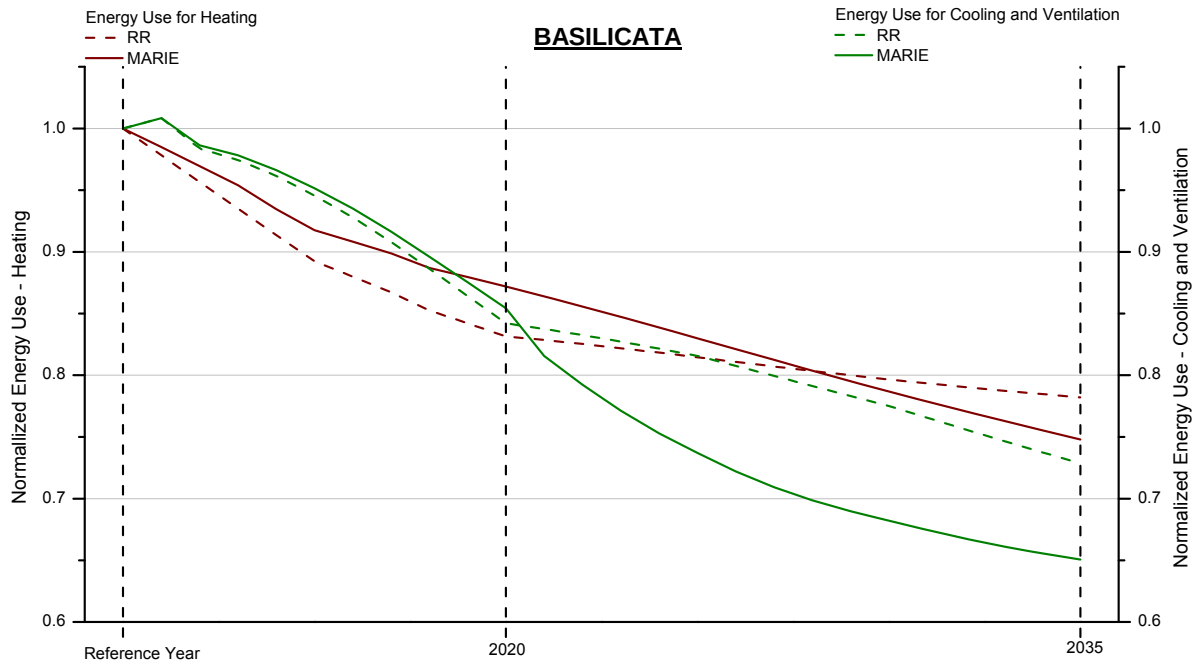


Figure 34 Normalized energy use for heating (left axis) and for cooling and ventilation (right axis). Existing building stock

The benefits of MARIE over RR arrive sooner in cooling and ventilation than they do in heating energy use. This is likely due to the longer lifecycles associated to measures on envelope (which mainly target heating energy use).

3.2.4 CATALONIA

The following sections show the results of the residential and tertiary sectors for Catalonia. The obtained results are based on the assumptions and the input data that are defined in sections 2.3 and 2.4.

3.2.4.1 Residential

The results obtained for Catalonia are shown in the following figures. In the first one, Figure 35, shows the normalized total energy use. Up to 2020, both scenarios follow very similar trends, however beyond this year, the energy savings achieved with the MARIE scenario gradually increase over those obtained with the RR scenario.

Figure 35 includes pie charts with the breakdown of total final energy use in the residential sector by end use (heating, domestic hot water, cooling, lighting and appliances). The pie charts in the figure correspond to the reference year and the outlooks for 2035 according to the two scenarios. Heating is largest energy use, and represents around 1/2 of the total final energy use of the sector in the reference year. The 2035 outlooks show a larger share of appliances, while lighting tends to decrease. Heating remains the dominant energy use.

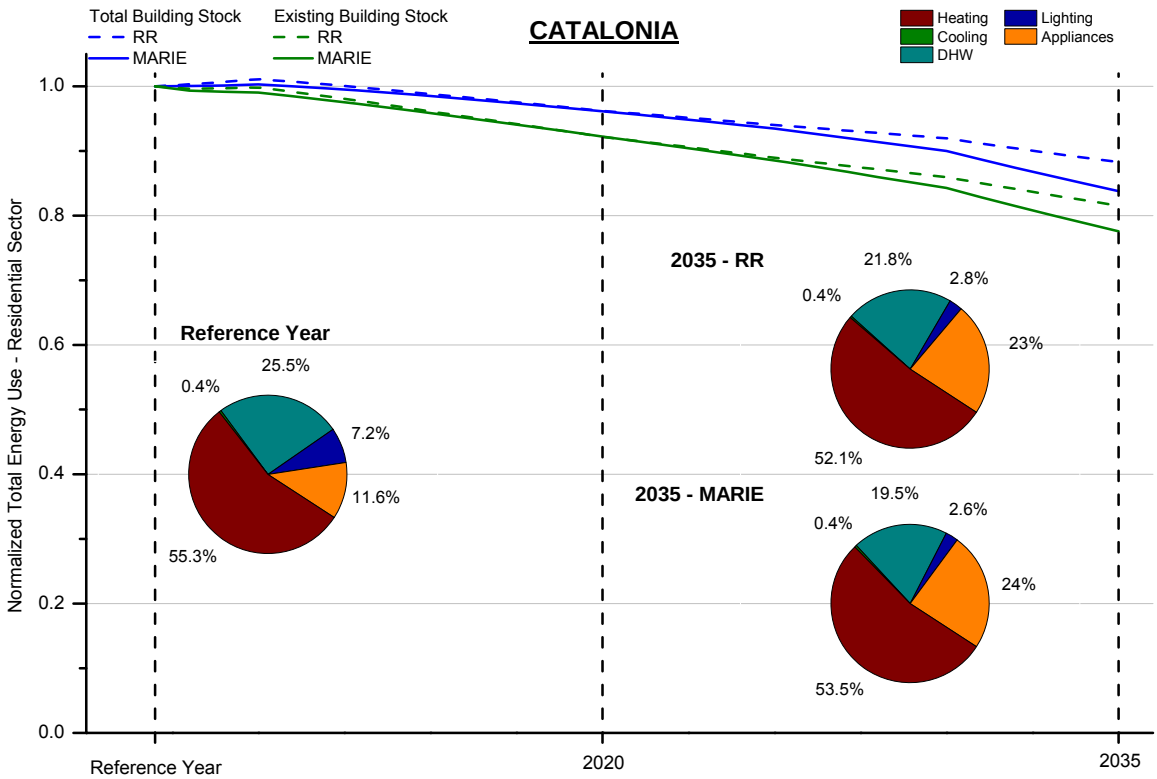


Figure 35 Normalized total energy use for the residential sector. Inner pie charts: left, breakdown by energy use in reference year; top right, breakdown by energy use in 2035 for the Rapid Results scenario; bottom right, breakdown by energy use in 2035 for the MARIE scenario.

Figure 36 shows normalized values of final energy use for heating and heating load. The MARIE scenario achieves lower heating load over all the years as a consequence of the higher energy efficiency refurbishment rate in the MARIE scenario. The difference between scenarios in terms of heating load increases with time. However, in terms of energy use for heating, the trends between scenarios are somewhat different: RR shows better results than MARIE until the last years of the analysis (note, however, that the benefits of MARIE steadily increase in the long run). The better energy results of RR in the first years can be explained by the more intense equipment replacement policies in this scenario, which make the final energy use in RR lower than in MARIE despite the fact that the heating loads are similar. Energy results in MARIE decrease as soon as the building energy refurbishment policies achieve substantial reductions of heating loads over RR,

Figure 37 shows the breakdown of the heating energy use by heating equipment type. For the reference year, the energy use for heating is basically divided among natural gas boiler (61%), electric devices (20%) and oil boilers (14%). In 2035, both scenarios reduce the fraction of energy use by oil boilers and electric devices. MARIE shows a lower fraction of decentralized systems (see “electric devices”) and higher fractions of biomass systems and centralized heat pumps (due to the larger number of integrally refurbished buildings with energy certificate).

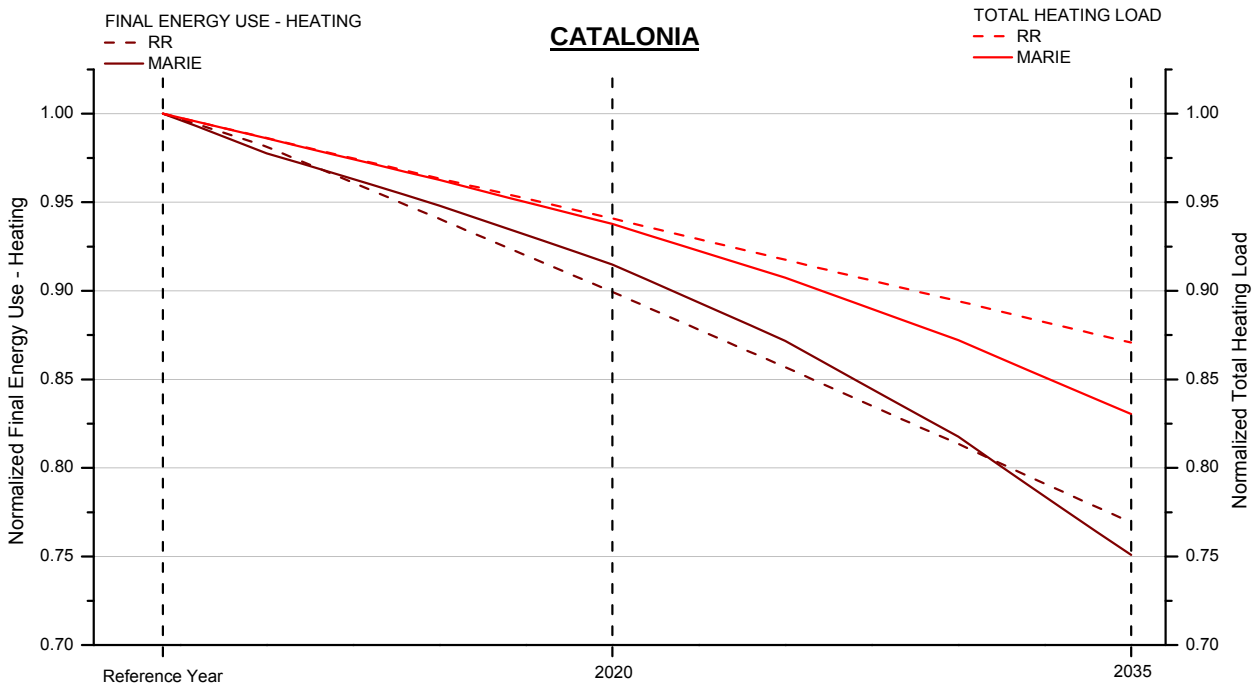


Figure 36 Heating results for the existing stock. Normalized final energy use for heating on left axis. Normalized total heating load on right axis

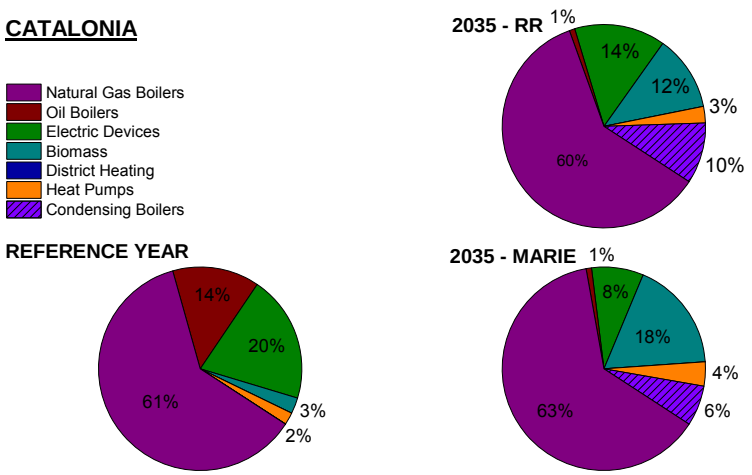


Figure 37 Breakdown of energy use by heating equipment in Reference Year and 2035, for Rapid Results and MARIE scenarios.

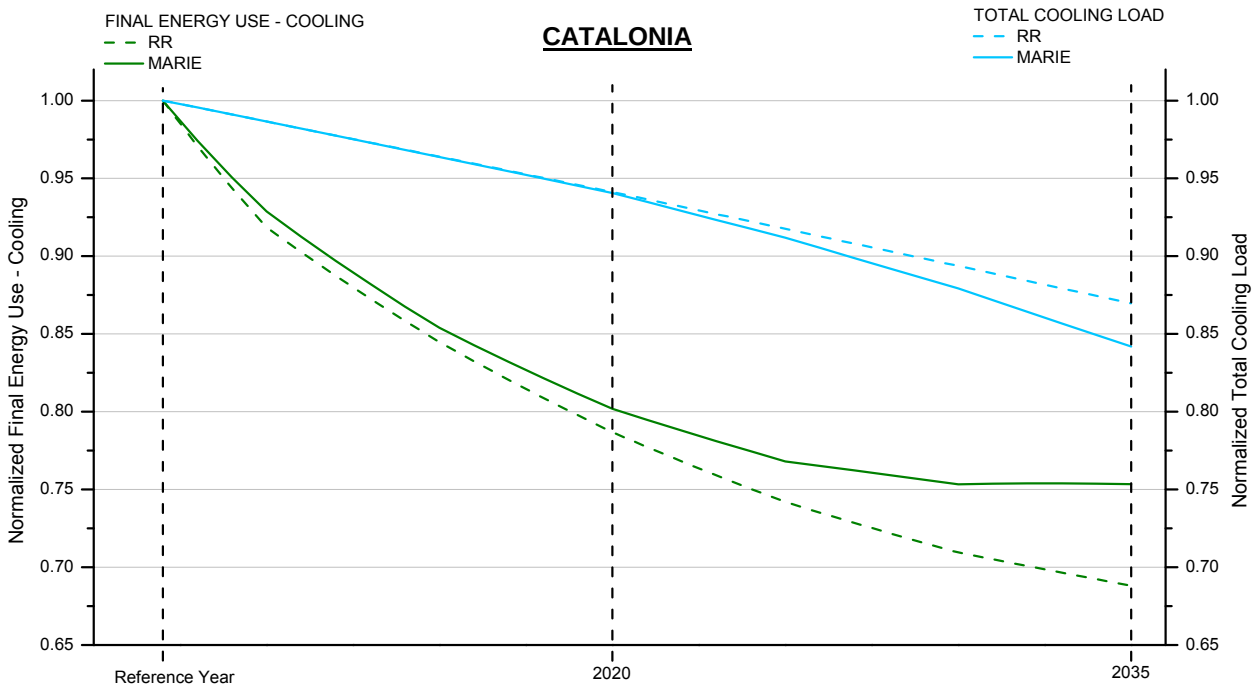


Figure 38 Cooling results for the existing stock. Normalized final energy use for heating on left axis. Normalized total cooling load on right axis.

Figure 38 shows normalized values of final energy use for cooling and cooling load. It should be noted that cooling is a negligible energy use in the residential sector (it is less than 1% of the final energy use). Therefore, while results in Figure 38 may be useful to evaluate the consequences of the two strategies on this specific energy use, they have virtually no impact on the overall building energy use.

Results show that the RR scenario achieves larger energy savings than the MARIE scenario, although cooling loads with MARIE are lower (beyond 2020). The factors related in these results are the following:

- Cooling loads of refurbished buildings are lower than these of the buildings in the current building stock. This is particularly true for buildings refurbished after 2020 (see Annex 3 for details). Since in the MARIE scenario the refurbishment rate is higher than in RR, in the long run cooling load of the total building stock in MARIE tends to decrease further than in RR.

- The number of dwellings equipped with cooling system increases over the years. In terms of energy use, this study assumed that heat pumps (both centralized and decentralized) introduced for heating purposes are also used for cooling. The larger share of centralized heat pumps in MARIE results also in a larger share of covered cooling loads (Table 14) (i.e., higher comfort). The MARIE scenario includes education and awareness measures for users. However, these are not enough to balance the increasing energy use linked to the higher comfort.

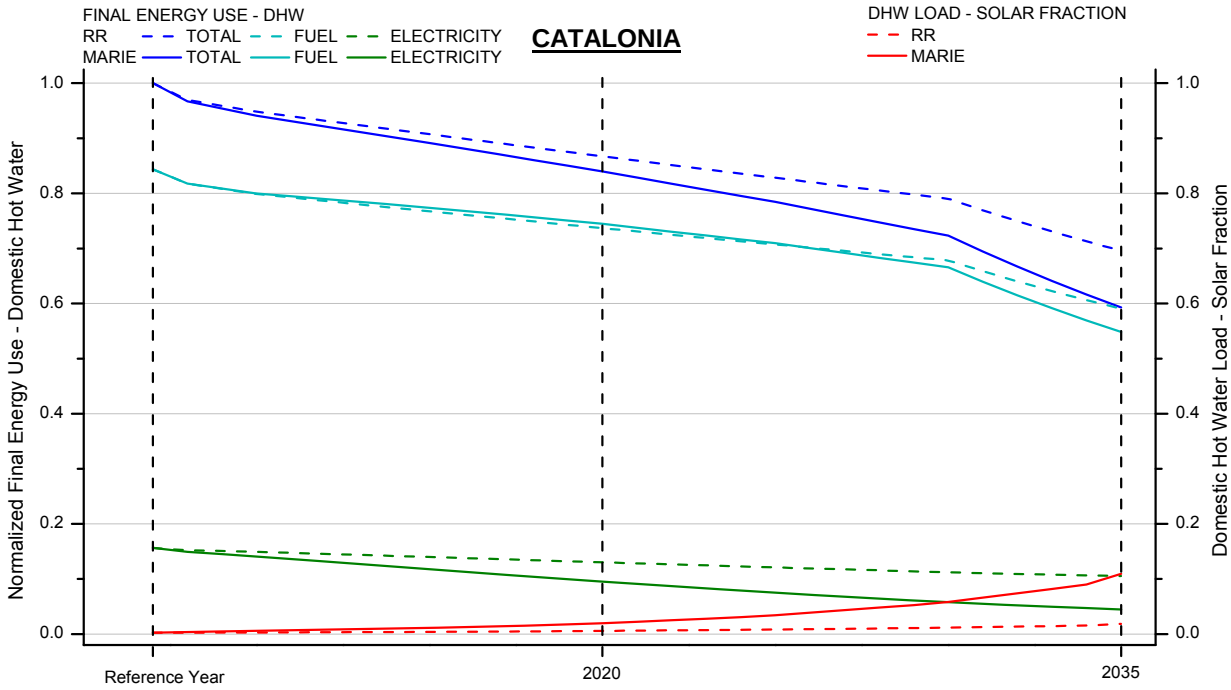


Figure 39 Domestic hot water results for the existing stock. Breakdown of normalized final energy use for DHW by energy source on left axis. Fraction of domestic hot water load covered by solar thermal on right axis

Figure 39 shows the breakdown of domestic hot water (DHW) energy use by energy source (fuel vs. electricity). Note that the final energy use breakdown does not include the energy provided by solar thermal systems, since this is considered a reduction of DHW load. Figure 39 also shows the fraction of DHW load that is covered with solar thermal systems. The assumptions on domestic hot water systems can be found in Section 2.3.1.3.

3.2.4.2 Tertiary

Figure 40 shows normalized values of total final energy use in the tertiary sector for the existing buildings in the stock in the reference year. The figure also includes pie charts with the breakdown of total final energy use in the tertiary sector by end use (heating, cooling and ventilation, and “others”). The pie charts in the figure correspond to the reference year and the outlooks for 2035 according to the two scenarios.

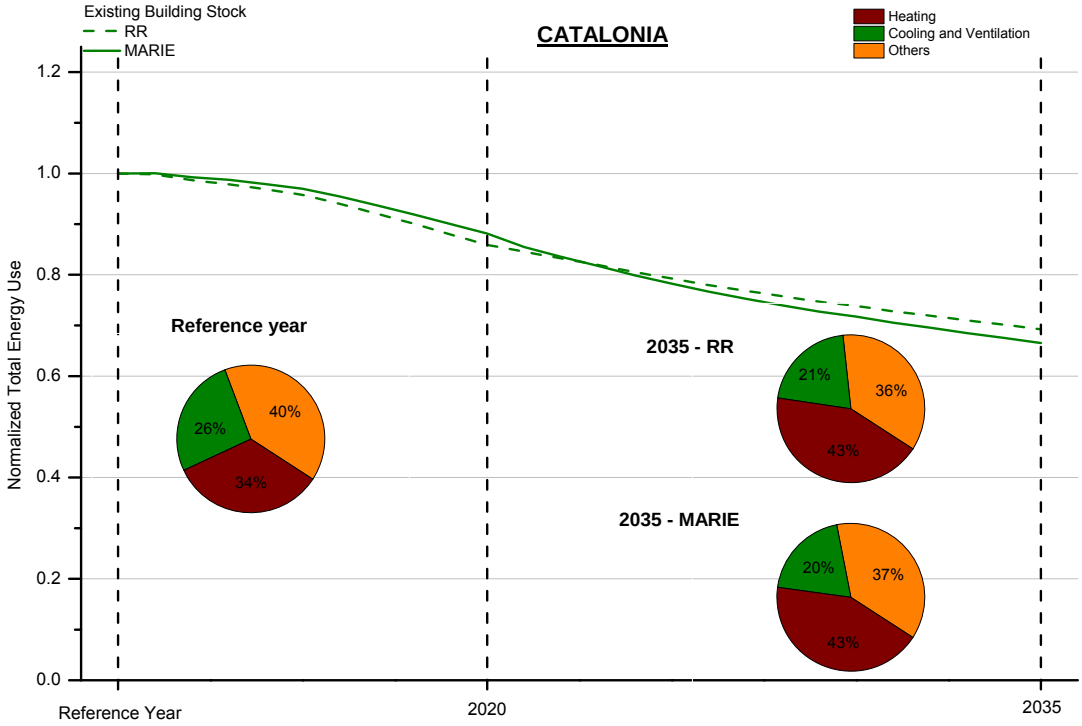


Figure 40 Normalized total energy use for the tertiary sector (total building stock and existing building stock). Inner pie charts: left, breakdown by energy use in reference year; top right, breakdown by energy use in 2035 for the Rapid Results scenario; bottom right, breakdown by energy use in 2035 for the MARIE scenario

RR provides larger energy savings than MARIE in the first years of simulation. However, in the long run, the MARIE measures are more effective at reducing final energy use. Final energy use is fairly evenly split among heating, cooling and ventilation, and “others”. The share of cooling and ventilation energy use in the tertiary sector is much higher than in residential.

Figure 41 shows projections of normalized final energy use for heating and cooling and ventilation according to the two scenarios.

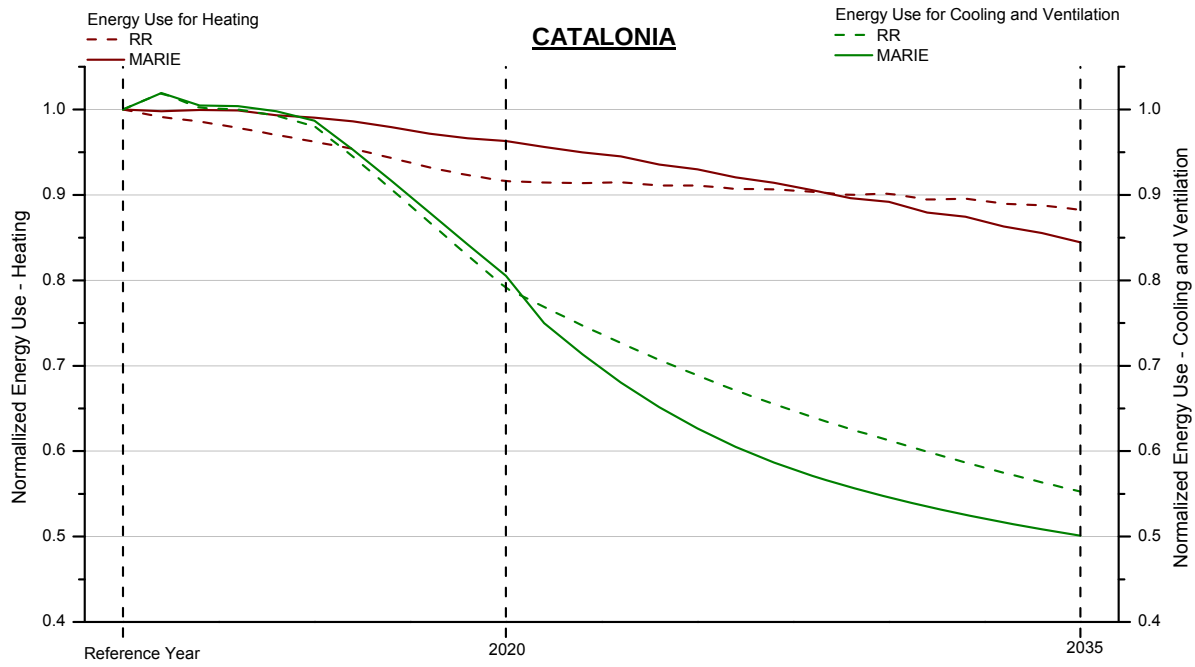


Figure 41 Normalized energy use for heating (left axis) and for cooling and ventilation (right axis). Existing building stock

The benefits of MARIE over RR arrive sooner in cooling and ventilation than they do in heating energy use. This is likely due to the longer lifecycles associated to measures on envelope (which mainly target heating energy use).

Figure 41 also shows that, in both scenarios, cooling and ventilation energy use sees a much larger reduction than heating energy use. This is consistent with the pie charts in Figure 40, which show decreasing shares of cooling and ventilation energy use.

3.2.5 ANDALUSIA

The following sections show the results of the residential and tertiary sectors for Andalusia. The obtained results are based on the assumptions and the input data that are defined in sections 2.3 and 2.4.

3.2.5.1 Residential

The results obtained for Andalusia are shown in the following figures. In the first one, Figure 42, shows the normalized total energy use. The MARIE scenario shows larger energy savings than RR since the reference year. Moreover, the difference between the two scenarios increases with time.

Figure 42 includes pie charts with the breakdown of total final energy use in the residential sector by end use (heating, domestic hot water, cooling, lighting and appliances). The pie charts in the figure correspond to the reference year and the outlooks for 2035 according to the two scenarios. Heating, domestic hot water, and appliances are the largest energy users, with

relatively similar shares. The 2035 projections foresee an increase in the share of energy use in appliances in lieu of domestic hot water and heating.

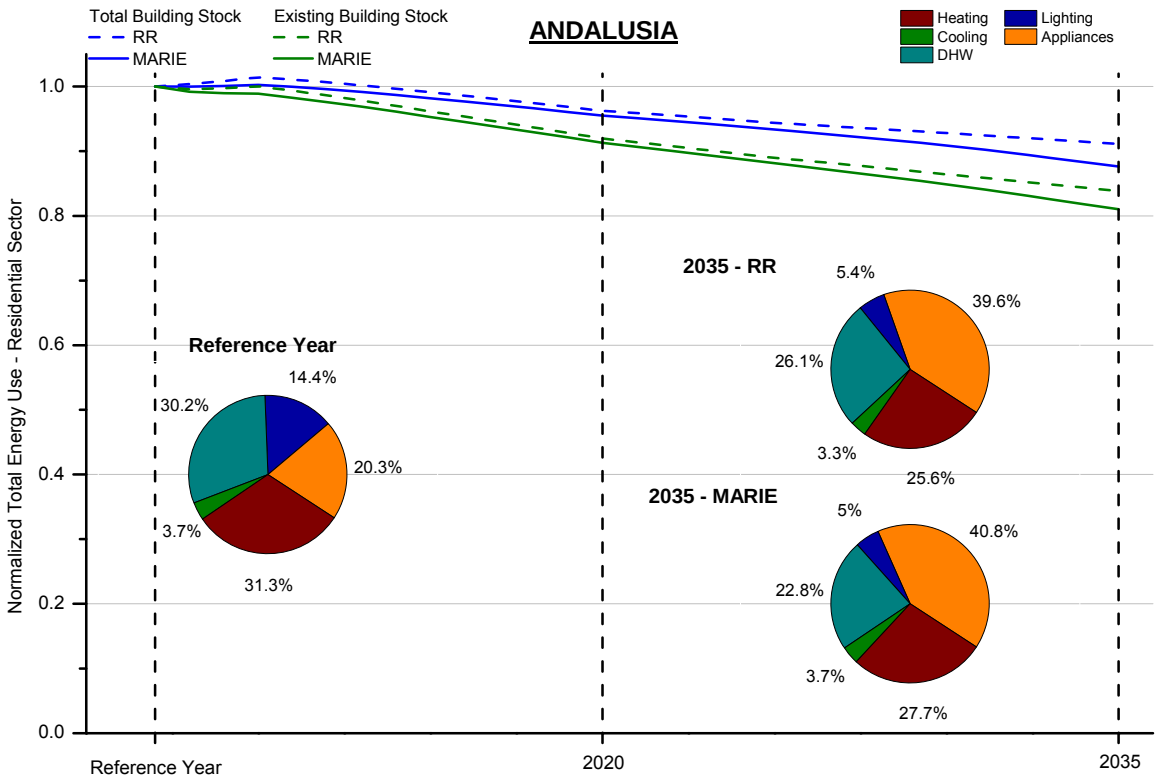


Figure 42 Normalized total energy use for the residential sector. Inner pie charts: left, breakdown by energy use in reference year; top right, breakdown by energy use in 2035 for the Rapid Results scenario; bottom right, breakdown by energy use in 2035 for the MARIE scenario.

Figure 43 shows normalized values of final energy use for heating and heating load. The results obtained in terms of heating load and these in terms of final energy use for heating show opposite trends. For the heating load, MARIE scenario provides better results (lower heating load) than RR. On the other hand, the final energy use for heating in the RR scenario is lower than in MARIE. The main reason for the higher heating energy use in MARIE is that in this scenario there are more centralized systems (see the decrease of electric devices in Figure 44), which, unlike decentralized systems, are assumed to cover 100% of the heating load. The higher energy use in MARIE is therefore a consequence of an increase in thermal comfort. In both scenarios electric devices are considered decentralized systems, and over the years these are replaced by biomass systems, condensing boilers and heat pumps. The category “heat pump” includes centralize and decentralize systems, and the fractions of them are different between scenarios. In MARIE the fraction of centralized heat pump is higher than in RR.

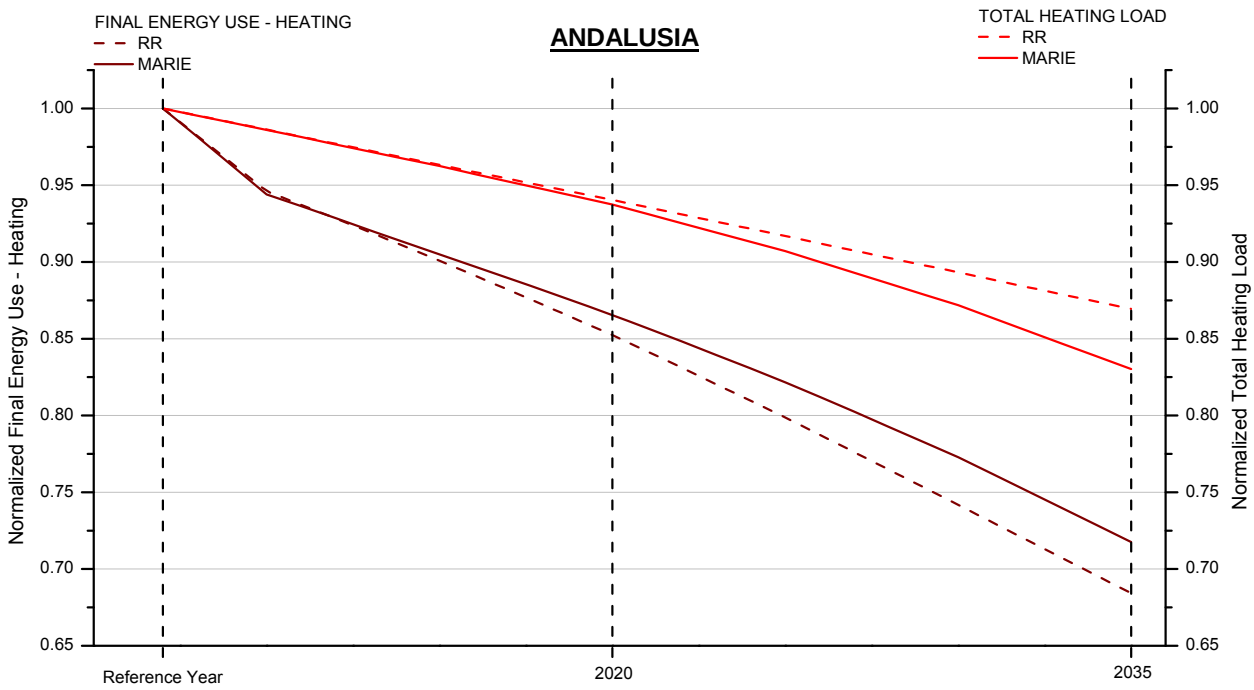


Figure 43 Heating results for the existing stock. Normalized final energy use for heating on left axis. Normalized total heating load on right axis

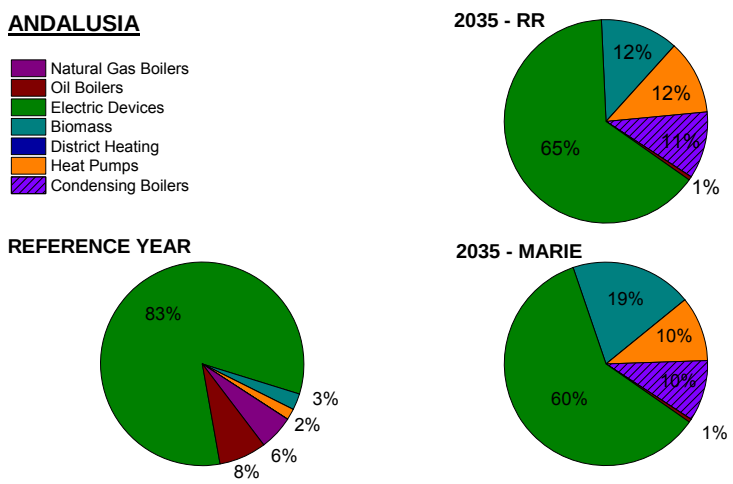


Figure 44 Breakdown of energy use by heating equipment in Reference Year and 2035, for Rapid Results and MARIE scenarios.

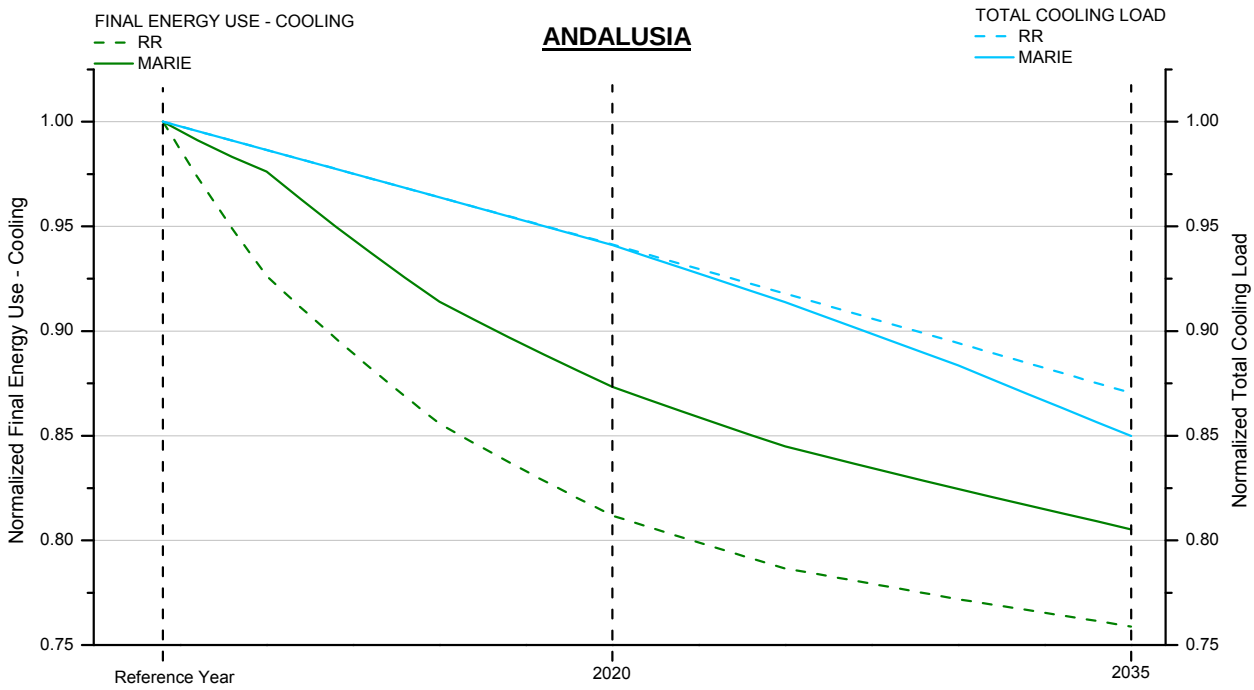


Figure 45 Cooling results for the existing stock. Normalized final energy use for heating on left axis. Normalized total cooling load on right axis.

Figure 45 shows normalized values of final energy use for cooling and cooling load. It should be noted that cooling is among the lowest energy uses in the residential sector (around 3-4% of the final energy use). Therefore, while results in Figure 45 may be useful to evaluate the consequences of the two strategies on this specific energy use, they have little impact on the overall building energy use.

Results show that the RR scenario achieves larger energy savings than the MARIE scenario, although cooling loads with MARIE are lower (beyond 2020). The factors related in these results are the following:

- Cooling loads of refurbished buildings up to 2020 are about the same as the cooling loads of the existing building in the stock (insulation reduces heating loads but slightly increases cooling loads). However, refurbished buildings after 2020 have relative lower cooling loads (see Annex 3 for details). Since in the MARIE scenario the refurbishment rate is higher than in RR, in the long run cooling load of the total building stock in MARIE tends to decrease further than in RR

- The number of dwellings equipped with cooling system increases over the years. In terms of energy use, this study assumed that heat pumps (both centralized and decentralized) introduced for heating purposes are also used for cooling. The larger share of centralized heat pumps in MARIE results also in a larger share of covered cooling loads (Table 14) (i.e., higher comfort). The MARIE scenario includes education and awareness measures for users. However, these are not enough to balance the increasing energy use linked to the higher comfort.

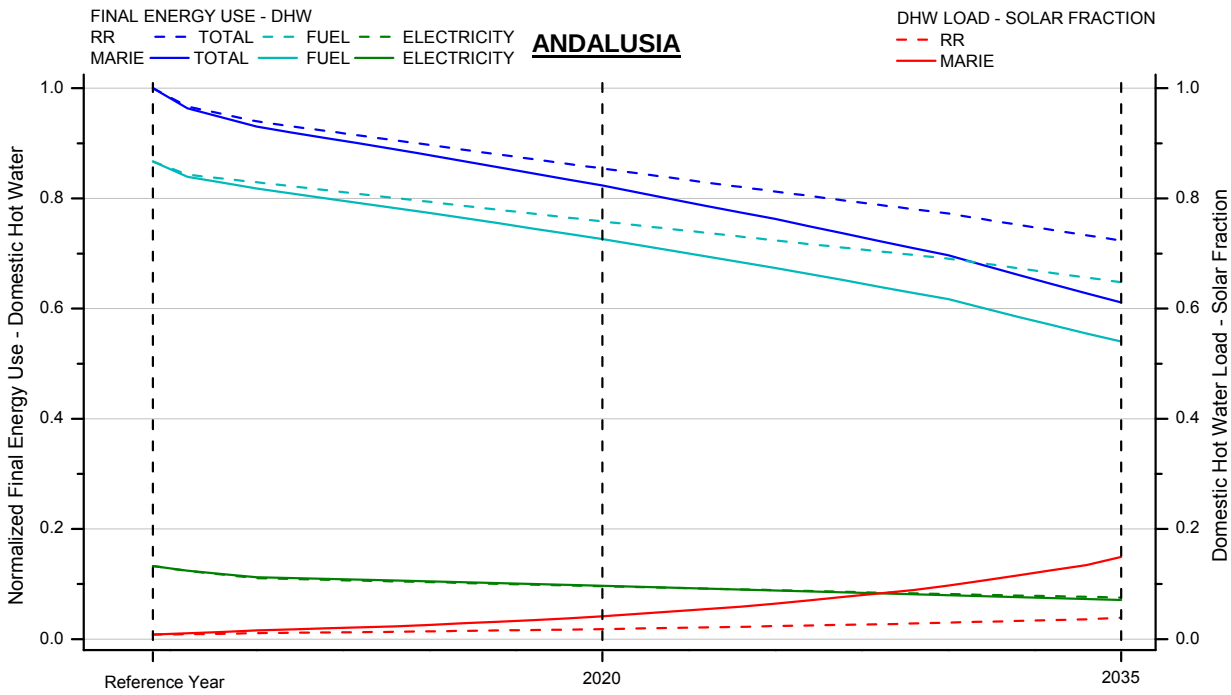


Figure 46 Domestic hot water results for the existing stock. Breakdown of normalized final energy use for DHW by energy source on left axis. Fraction of domestic hot water load covered by solar thermal on right axis

Figure 46 shows the breakdown of domestic hot water (DHW) energy use by energy source (fuel vs. electricity). Note that the final energy use breakdown does not include the energy provided by solar thermal systems, since this is considered a reduction of DHW load. Figure 46 also shows the fraction of DHW load that is covered with solar thermal systems. The assumptions on domestic hot water systems can be found in Section 2.3.1.3.

3.2.5.2 Tertiary

Figure 47 shows normalized values of total final energy use in the tertiary sector for the existing buildings in the stock in the reference year. The figure also includes pie charts with the breakdown of total final energy use in the tertiary sector by end use (heating, cooling and ventilation, and “others”). The pie charts in the figure correspond to the reference year and the outlooks for 2035 according to the two scenarios.

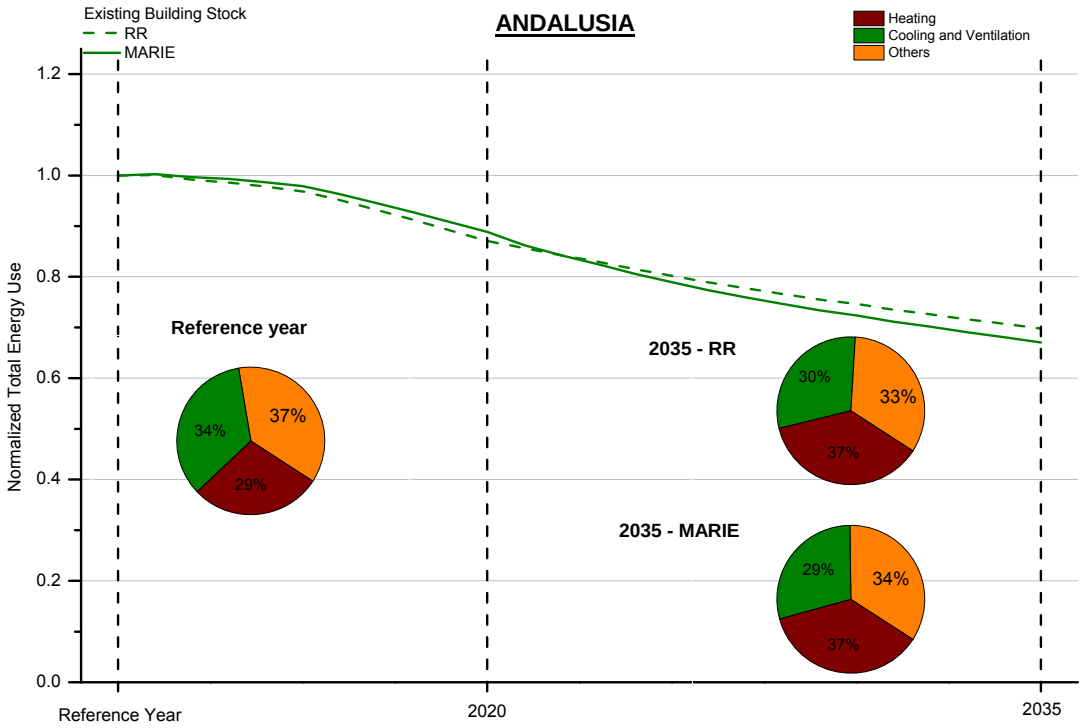


Figure 47 Normalized total energy use for the tertiary sector (total building stock and existing building stock). Inner pie charts: left, breakdown by energy use in reference year; top right, breakdown by energy use in 2035 for the Rapid Results scenario; bottom right, breakdown by energy use in 2035 for the MARIE scenario

RR provides larger energy savings than MARIE in the first years of simulation. However, in the long run, the MARIE measures are more effective at reducing final energy use. Final energy use is fairly evenly split among heating, cooling and ventilation, and “others”. The share of cooling and ventilation energy use in the tertiary sector is much higher than in residential.

Figure 48 shows projections of normalized final energy use for heating and cooling and ventilation according to the two scenarios.

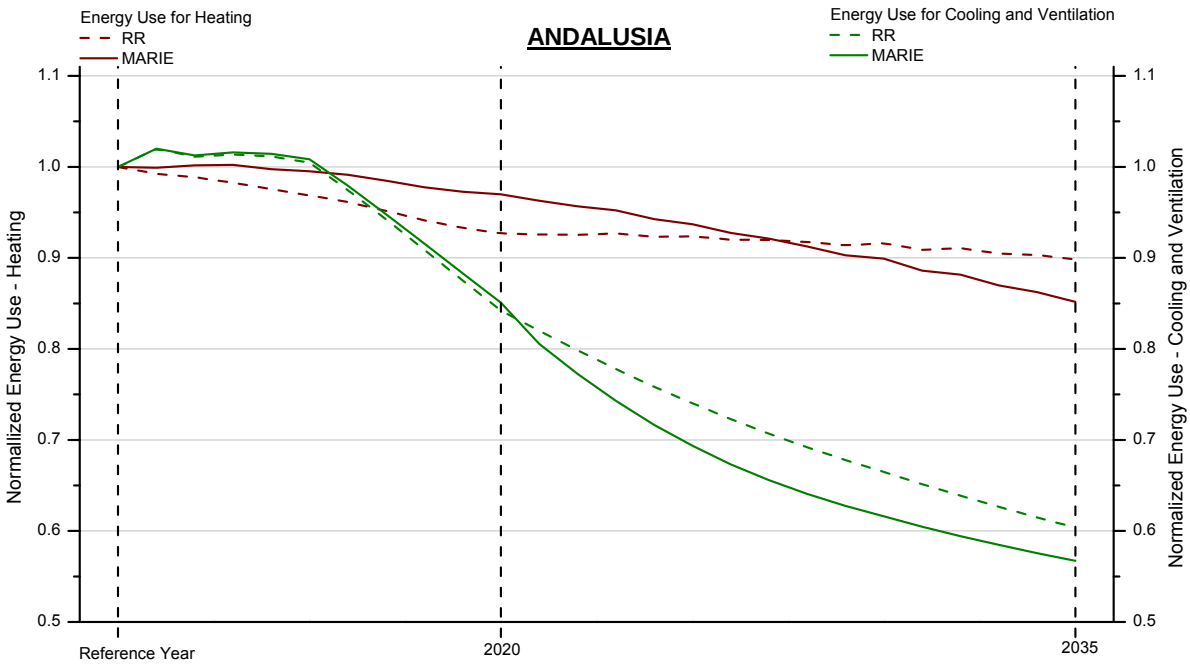


Figure 48 Normalized energy use for heating (left axis) and for cooling and ventilation (right axis). Existing building stock

The benefits of MARIE over RR arrive sooner in cooling and ventilation than they do in heating energy use. This is likely due to the longer lifecycles associated to measures on envelope (which mainly target heating energy use).

Figure 48 also shows that, in both scenarios, cooling and ventilation energy use sees a much larger reduction than heating energy use. This is consistent with the pie charts in Figure 47, which show decreasing shares of cooling and ventilation energy use.

3.2.6 PACA

The following sections show the results of the residential and tertiary sectors for PACA. The obtained results are based on the assumptions and the input data that are defined in sections 2.3 and 2.4.

3.2.6.1 Residential

The results obtained for PACA are shown in the following figures. In the first one, Figure 49, shows the normalized total energy use. The MARIE scenario shows larger energy savings than RR since the reference year. Moreover, the difference between the two scenarios increases with time.

Figure 49 includes pie charts with the breakdown of total final energy use in the residential sector by end use (heating, domestic hot water, cooling, lighting and appliances). The pie charts in the figure correspond to the reference year and the outlooks for 2035 according to the two scenarios. Heating is largest energy use, and represents around 60% of the total final energy

use of the sector in the reference year. The variation of the breakdowns of energy use between the reference year and the 2035 projections is relatively small. Appliance energy use tends to increase; however, space heating remains the most important energy use.

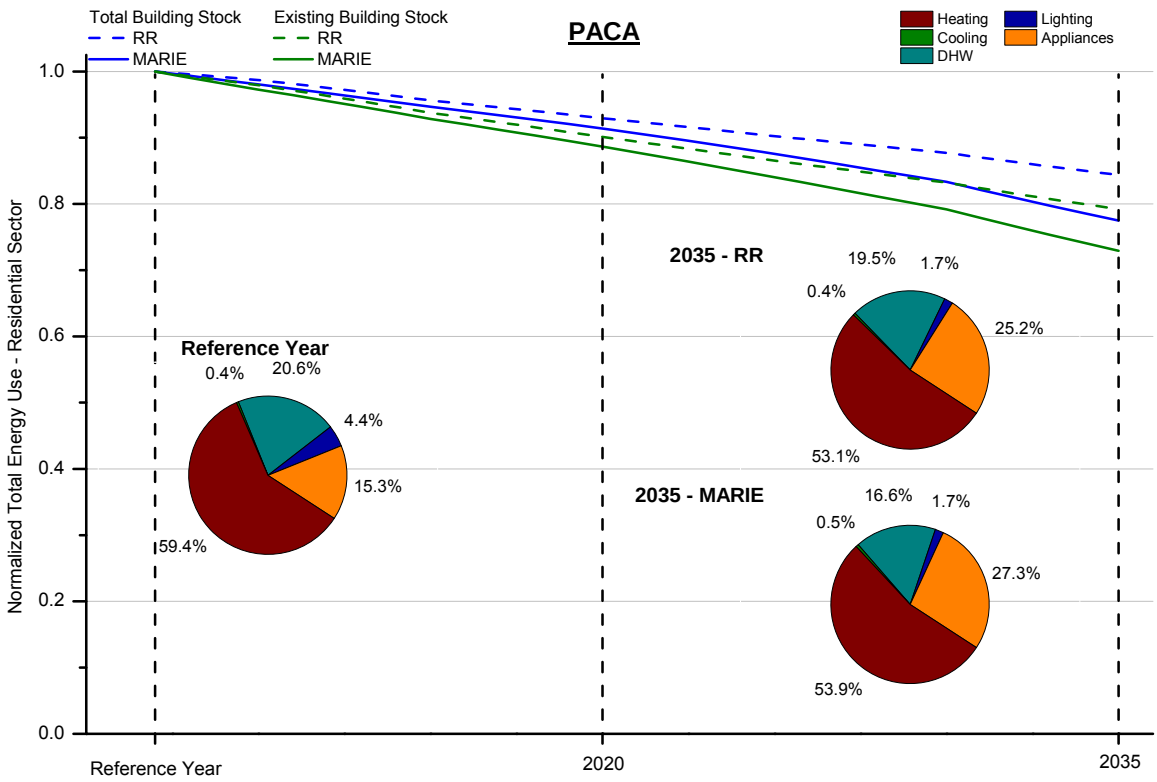


Figure 49 Normalized total energy use for the residential sector. Inner pie charts: left, breakdown by energy use in reference year; top right, breakdown by energy use in 2035 for the Rapid Results scenario; bottom right, breakdown by energy use in 2035 for the MARIE scenario.

Figure 50 shows normalized values of final energy use for heating and heating load. The measures in the two scenarios lead to different results between the heating load and the energy use for heating. Heating energy use is “substantially” lower in MARIE with respect to RR since the reference year, while the difference between scenarios arrives later in terms of heating load. The results could be explained analyzing the measures applied in each scenario:

- In the first years, the measures on heating equipment in MARIE seem more effective than these in RR. Although in the RR the rate of equipment replacement is higher than in MARIE scenario, the type of heating devices was different for the two scenarios (mainly condensing boilers in RR vs. centralized heat pumps and district heating in MARIE). The heating equipment is defined with two parameters: the efficiency and the coverage factor. In PACA centralized systems (coverage factor=100%) are already very common in the reference year. Therefore equipment efficiency plays an important role in the reduction of the heating energy use. Even if there are fewer replacements with MARIE, the much higher efficiency of heat pumps over boilers drives the total final energy use to a lower value.

- Beyond 2020, the effects of the new building code combined with the high rate of integral refurbishment in the MARIE scenario (represented by the heating load) build on

the effects of the heating equipment measures, further increasing the benefits of the MARIE scenario over RR.

Figure 51 shows the breakdown of the heating energy use by heating equipment type. Oil boilers and electric devices tend to decrease in favour of biomass systems, condensing boilers, heat pumps and district heating in both scenarios. Heat pumps, district heating and biomass systems are more popular in MARIE, while condensing boilers are more common in RR. Note that diffusion of heat pumps in the equipment stock is rather substantial in both scenarios (their contribution to energy use remains small because of their high efficiency compared to the other system types). The centralized systems (coverage factor 100%) in PACA region are already very common in the reference year, and the main difference among heating equipment types is in terms of efficiency.

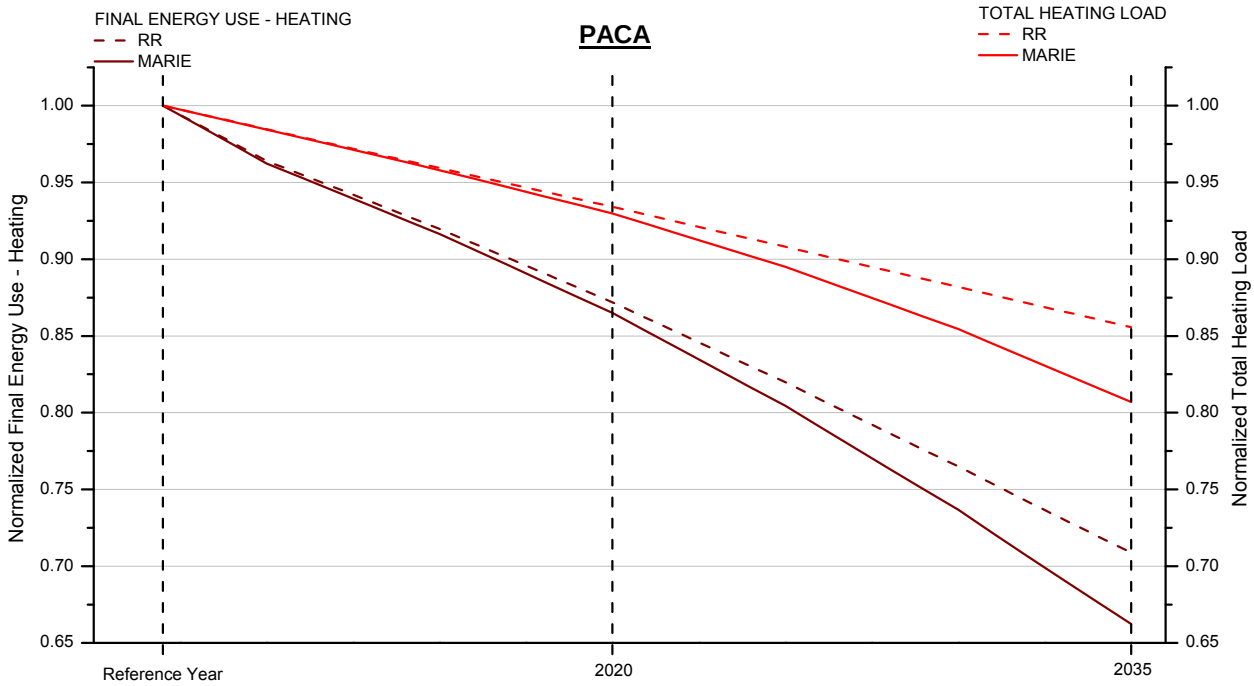


Figure 50 Heating results for the existing stock. Normalized final energy use for heating on left axis. Normalized total heating load on right axis

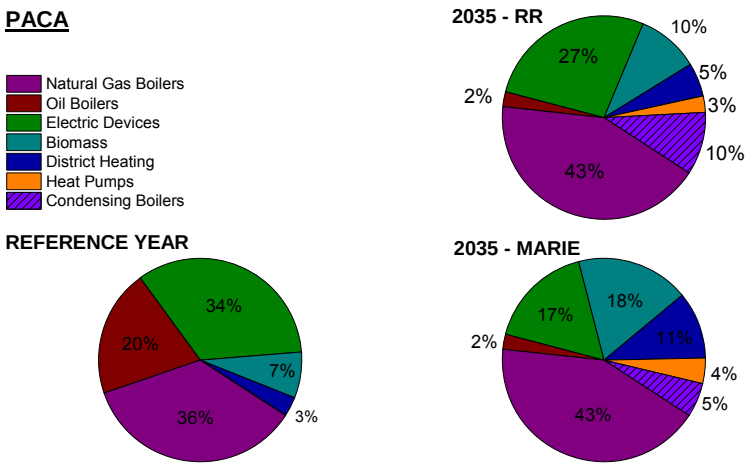


Figure 51 Breakdown of energy use by heating equipment in Reference Year and 2035, for Rapid Results and MARIE scenarios.

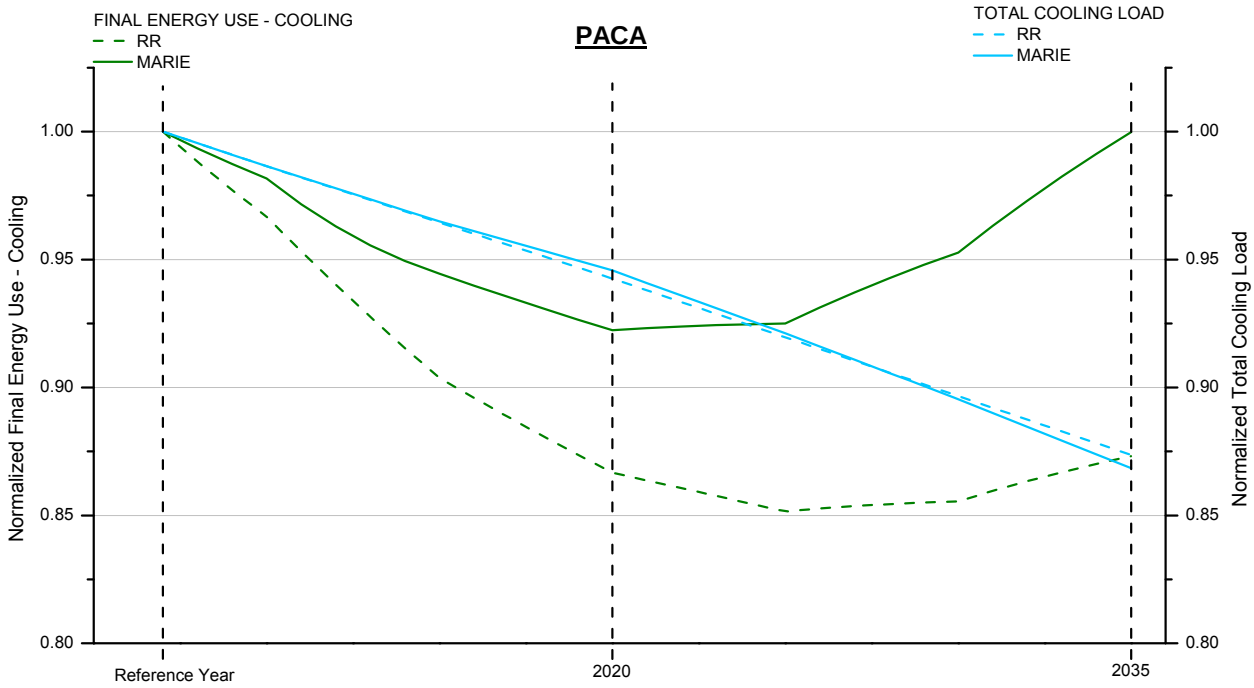


Figure 52 Cooling results for the existing stock. Normalized final energy use for heating on left axis. Normalized total cooling load on right axis.

Figure 52 shows normalized values of final energy use for cooling and cooling load. It should be noted that cooling is a negligible energy use in the residential sector (it is less than 1% of the final energy use). Therefore, while results in Figure 52 may be useful to evaluate the consequences of the two strategies on this specific energy use, they have virtually no impact on the overall building energy use.

Results show that the RR scenario achieves larger energy savings than the MARIE scenario. The factors related in these results are the following:

- Cooling loads of refurbished buildings until 2020 are higher than the cooling loads of the existing building in the stock (insulation reduces heating loads but slightly increases

cooling loads), while buildings refurbished after 2020 show lower cooling loads (See Annex 3 for details). Since in the MARIE scenario the refurbishment rate is higher than in RR, cooling load of the total building stock with MARIE is more sensitive to changes in the cooling loads of the recently refurbished buildings.

- The number of dwellings equipped with cooling system increases over the years. This study assumed that heat pumps (both centralized and decentralized) introduced for heating purposes are also used for cooling. The larger share of centralized heat pumps in MARIE results also in a larger share of covered cooling loads (Table 14) (i.e., higher comfort). The MARIE scenario includes education and awareness measures for users. However, these are not enough to balance the increasing energy use linked to the higher comfort

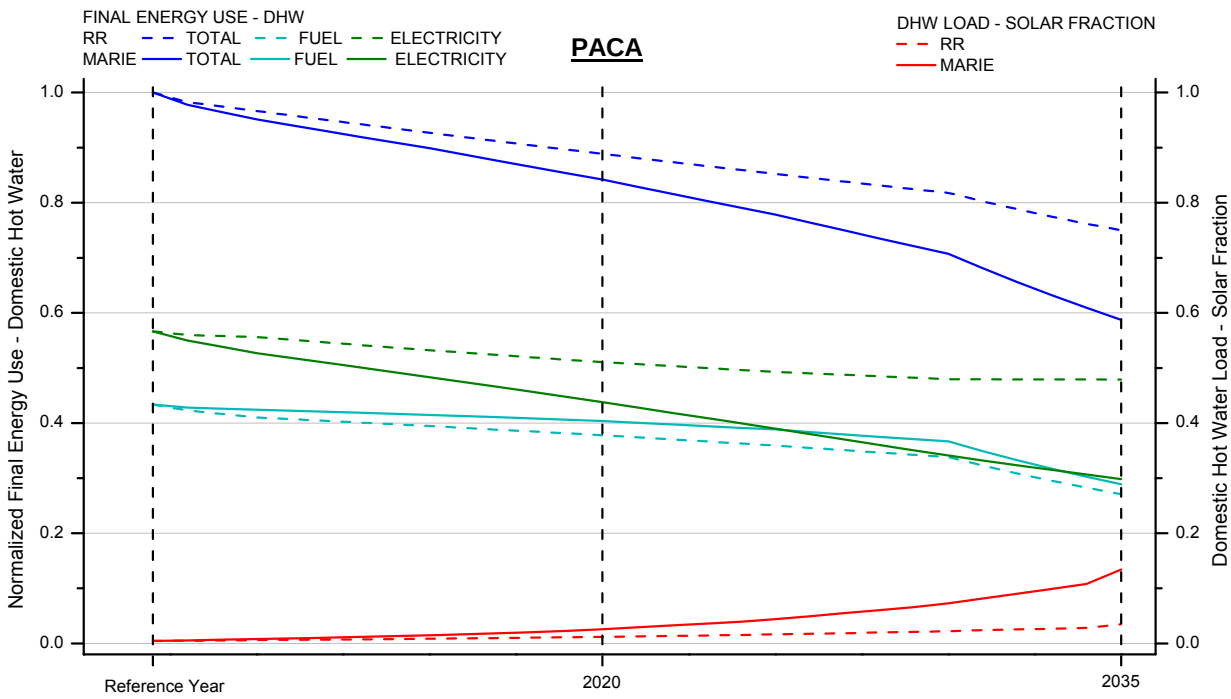


Figure 53 Domestic hot water results for the existing stock. Breakdown of normalized final energy use for DHW by energy source on left axis. Fraction of domestic hot water load covered by solar thermal on right axis

Figure 53 shows the breakdown of domestic hot water (DHW) energy use by energy source (fuel vs. electricity). Note that the final energy use breakdown does not include the energy provided by solar thermal systems, since this is considered a reduction of DHW load. Figure 53 also shows the fraction of DHW load that is covered with solar thermal systems. The assumptions on domestic hot water systems can be found in Section 2.3.1.3.

3.2.6.2 Tertiary

Figure 54 shows normalized values of total final energy use in the tertiary sector for the existing buildings in the stock in the reference year. The figure also includes pie charts with the breakdown of total final energy use in the tertiary sector by end use (heating, cooling and ventilation, and "others"). The pie charts in the figure correspond to the reference year and the outlooks for 2035 according to the two scenarios.

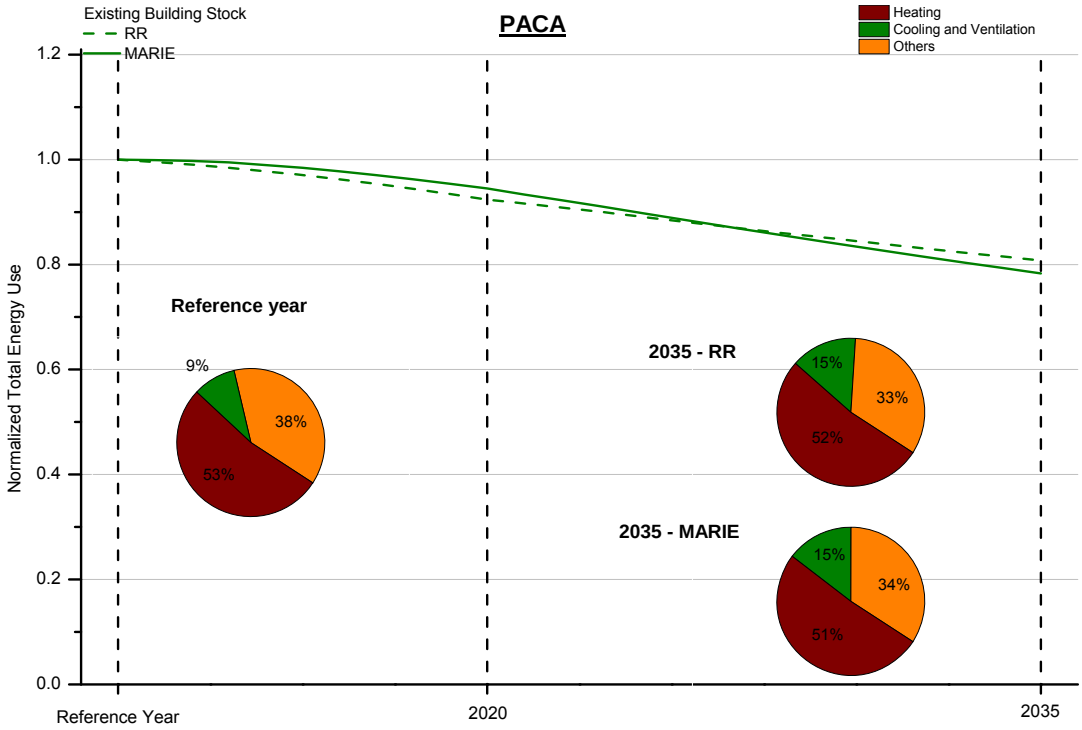


Figure 54 Normalized total energy use for the tertiary sector (total building stock and existing building stock). Inner pie charts: left, breakdown by energy use in reference year; top right, breakdown by energy use in 2035 for the Rapid Results scenario; bottom right, breakdown by energy use in 2035 for the MARIE scenario

RR provides larger energy savings than MARIE in the first years of simulation. However, in the long run, the MARIE measures are more effective at reducing final energy use. Similarly to the residential sector, heating is the dominant energy use in tertiary. However, cooling and ventilation show a much larger share (which increases in both projections).

Figure 55 shows projections of normalized final energy use for heating and cooling and ventilation according to the two scenarios.

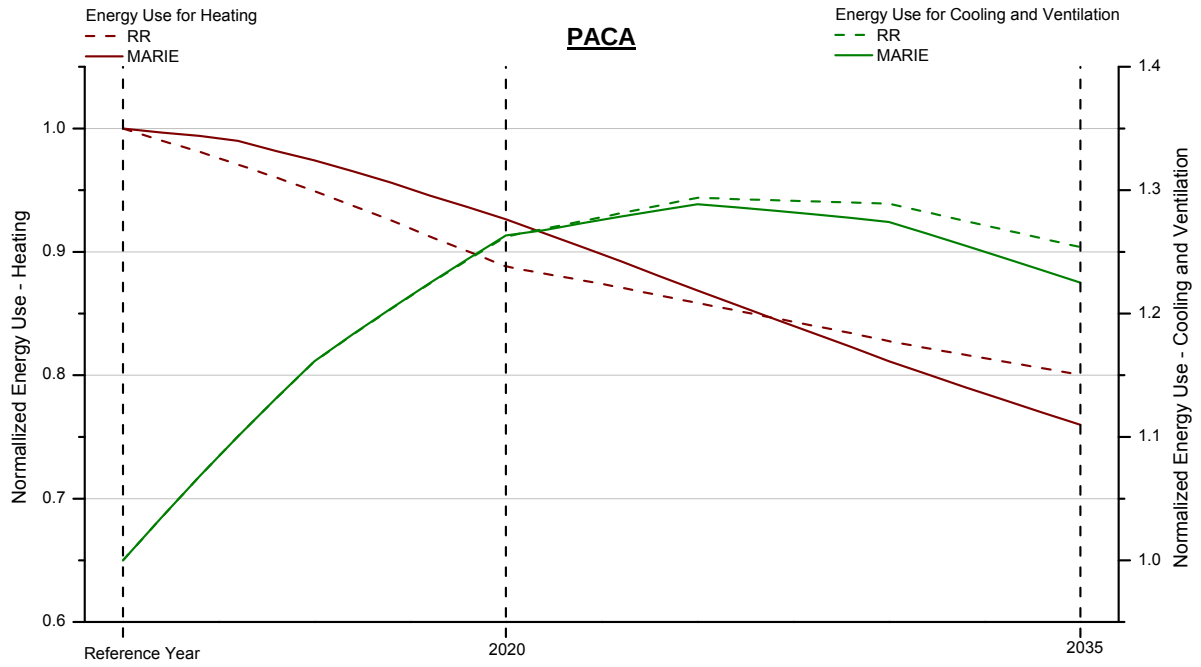


Figure 55 Normalized energy use for heating (left axis) and for cooling and ventilation (right axis). Existing building stock

Cooling and ventilation energy use increase in both scenarios due to the projected increase of the air-conditioned share of floor area. PACA is the region with the largest relative increase of share of air-conditioned floor area (see Section 2.4)

The benefits of MARIE over RR arrive sooner in cooling and ventilation than they do in heating energy use. This is likely due to the longer lifecycles associated to measures on envelope (which mainly target heating energy use).

3.2.7 SLOVENIA

The following sections show the results of the residential and tertiary sectors for Slovenia. The obtained results are based on the assumptions and the input data that are defined in sections 2.3 and 2.4.

3.2.7.1 Residential

The results obtained for Slovenia are shown in the following figures. In the first one, Figure 56, shows the normalized total energy use. The MARIE scenario shows larger energy savings than RR since the reference year. Moreover, the difference between the two scenarios increases with time.

Figure 56 includes pie charts with the breakdown of total final energy use in the residential sector by end use (heating, domestic hot water, cooling, lighting and appliances). The pie charts in the figure correspond to the reference year and the outlooks for 2035 according to the two scenarios. Heating is by far the largest energy use, and represents the 75% of the total final energy use of the sector in the reference year. The variation of the breakdowns of energy use

between the reference year and the 2035 projections is small. Appliance energy use tends to increase; however, space heating remains the largest energy use.

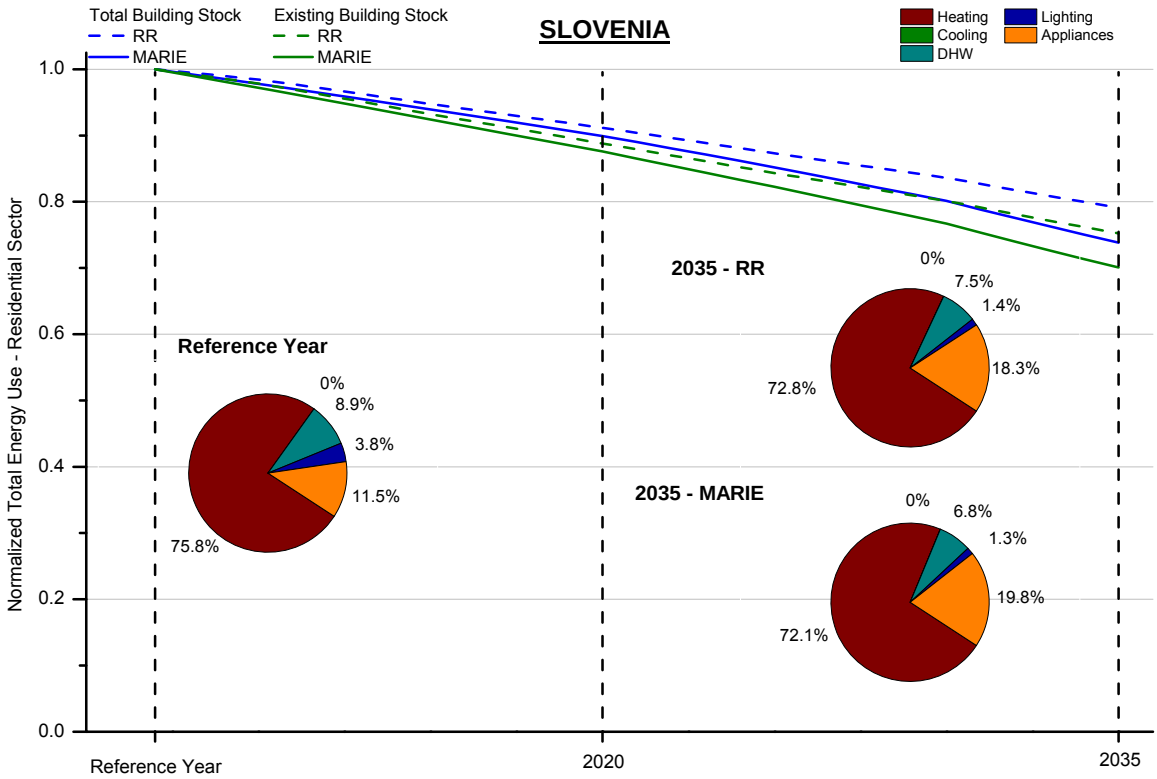


Figure 56 Normalized total energy use for the residential sector. Inner pie charts: left, breakdown by energy use in reference year; top right, breakdown by energy use in 2035 for the Rapid Results scenario; bottom right, breakdown by energy use in 2035 for the MARIE scenario.

Figure 57 shows normalized values of final energy use for heating and heating load. The measures in the two scenarios lead to different results between the heating load and the energy use for heating. Heating energy use is “substantially” lower in MARIE with respect to RR since the reference year, while the difference between scenarios arrives later in terms of heating load. The results could be explained analyzing the measures applied in each scenario:

- In the first years, the measures on heating equipment in MARIE seem more effective than these in RR. Although in the RR the rate of equipment replacement is higher than in MARIE scenario, the type of heating devices was different for the two scenarios (mainly condensing boilers in RR vs. centralized heat pumps and district heating in MARIE). The heating equipment is defined with two parameters: the efficiency and the coverage factor. In Slovenia centralized systems (coverage factor=100%) are already very common in the reference year. Therefore equipment efficiency plays an important role in the reduction of the heating energy use. Even if there are fewer replacements with MARIE, the much higher efficiency of heat pumps over boilers drives the total final energy use to a lower value.

- Beyond 2020, the effects of the new building code combined with the high rate of integral refurbishment in the MARIE scenario (represented by the heating load) build on

the effects of the heating equipment measures, further increasing the benefits of the MARIE scenario over RR.

Figure 58 shows the breakdown of the heating energy use by heating equipment type. Oil boilers and electric devices tend to decrease in favour of the other types in both scenarios. Heat pumps and district heating are more popular in MARIE, while condensing boilers are more common in RR. Biomass increases in the two scenarios, since it is both a good target for subsidies on heating equipment replacement (RR) and a good option for overall high performing buildings (MARIE). The contribution of heat pump systems to energy use remains small because of their high efficiency compared to the other system types. Centralized systems (coverage factor 100%) in Slovenia are already very common in the reference year, therefore, the main difference among heating equipment types is in terms of efficiency.

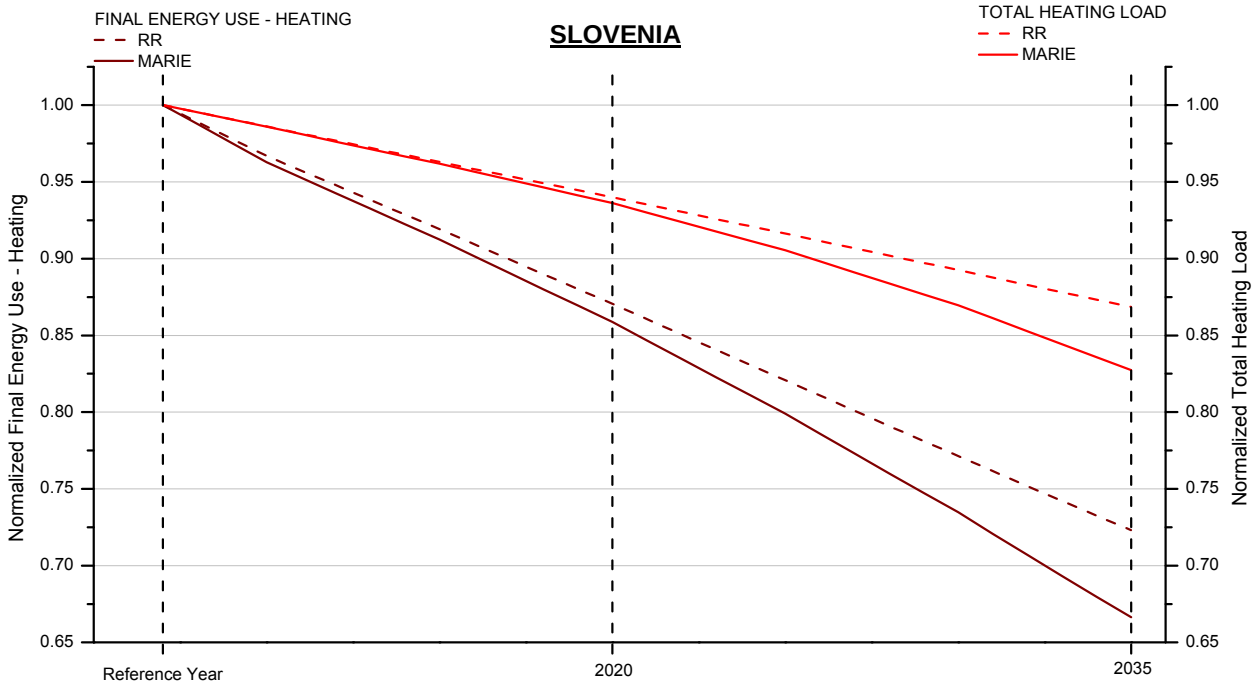


Figure 57 Heating results for the existing stock. Normalized final energy use for heating on left axis. Normalized total heating load on right axis

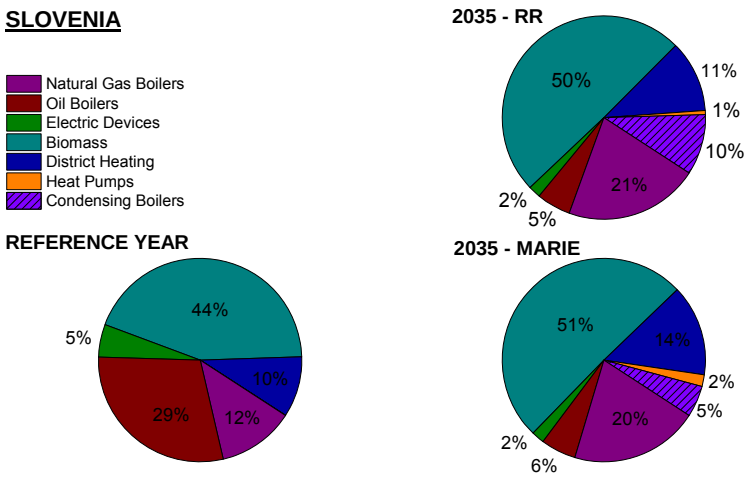


Figure 58 Breakdown of energy use by heating equipment in Reference Year and 2035, for Rapid Results and MARIE scenarios.

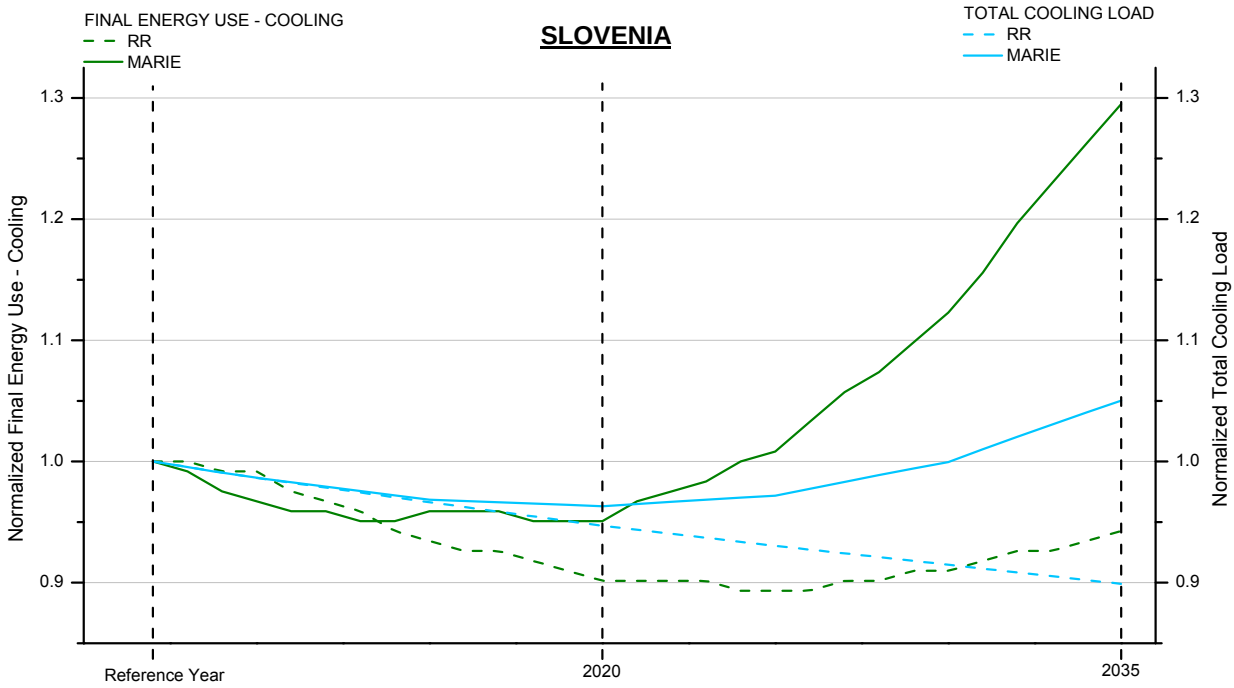


Figure 59 Cooling results for the existing stock. Normalized final energy use for heating on left axis. Normalized total cooling load on right axis.

Figure 59 shows normalized values of final energy use for cooling and cooling load. It should be noted that energy use for cooling in the residential sector is virtually zero in Slovenia. Therefore, while results in Figure 59 may be useful to evaluate the consequences of the two strategies on this specific energy use, they have no impact on the overall building energy use.

Results show that the both the cooling loads and cooling energy use are higher in the MARIE scenario. The factors related in these results are the following:

- Cooling loads of refurbished buildings are higher than the cooling loads of the existing building in the stock (insulation reduces heating loads but slightly increases cooling loads. See Annex 3 for details). Since in the MARIE scenario the refurbishment rate is higher than in RR, cooling load of the total building stock with MARIE is also higher (the downtrend of cooling loads in RR in Figure 59 are due to the demolition of buildings that were in the stock in the reference year).

- The number of dwellings equipped with cooling system increases over the years. This study assumed that heat pumps (both centralized and decentralized) introduced for heating purposes are also used for cooling. The larger share of centralized heat pumps in MARIE results also in a larger share of covered cooling loads (Table 14) (i.e., higher comfort). The MARIE scenario includes education and awareness measures for users. However, these are not enough to balance the increasing energy use linked to the higher comfort.

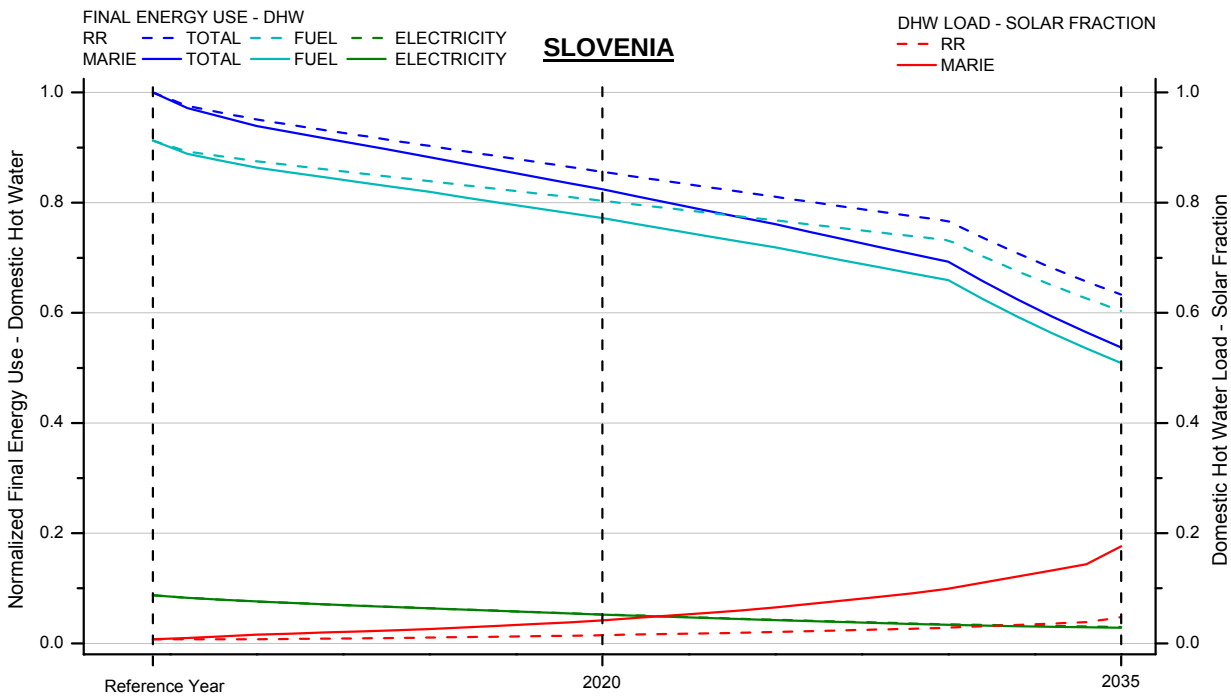


Figure 60 Domestic hot water results for the existing stock. Breakdown of normalized final energy use for DHW by energy source on left axis. Fraction of domestic hot water load covered by solar thermal on right axis

Figure 60 shows the breakdown of domestic hot water (DHW) energy use by energy source (fuel vs. electricity). Note that the final energy use breakdown does not include the energy provided by solar thermal systems, since this is considered a reduction of DHW load. Figure 60 also shows the fraction of DHW load that is covered with solar thermal systems. The assumptions on domestic hot water systems can be found in Section 2.3.1.3.

3.2.7.2 Tertiary

Figure 61 shows normalized values of total final energy use in the tertiary sector for the existing buildings in the stock in the reference year. The figure also includes pie charts with the breakdown of total final energy use in the tertiary sector by end use (heating, cooling and ventilation, and “others”). The pie charts in the figure correspond to the reference year and the outlooks for 2035 according to the two scenarios.

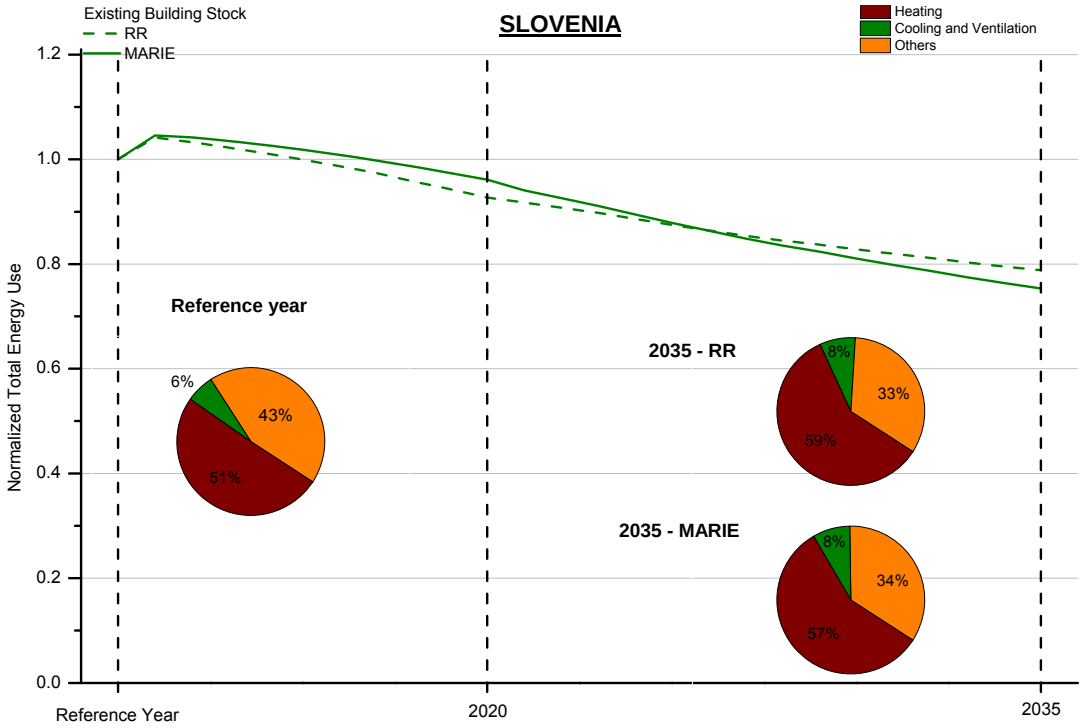


Figure 61 Normalized total energy use for the tertiary sector (total building stock and existing building stock). Inner pie charts: left, breakdown by energy use in reference year; top right, breakdown by energy use in 2035 for the Rapid Results scenario; bottom right, breakdown by energy use in 2035 for the MARIE scenario

RR provides larger energy savings than MARIE in the first years of simulation. However, in the long run, the MARIE measures are more effective at reducing final energy use. Similarly to the residential sector, heating is the dominant energy use in tertiary. However, cooling and ventilation show a much larger share.

Figure 62 shows projections of normalized final energy use for heating and cooling and ventilation according to the two scenarios.

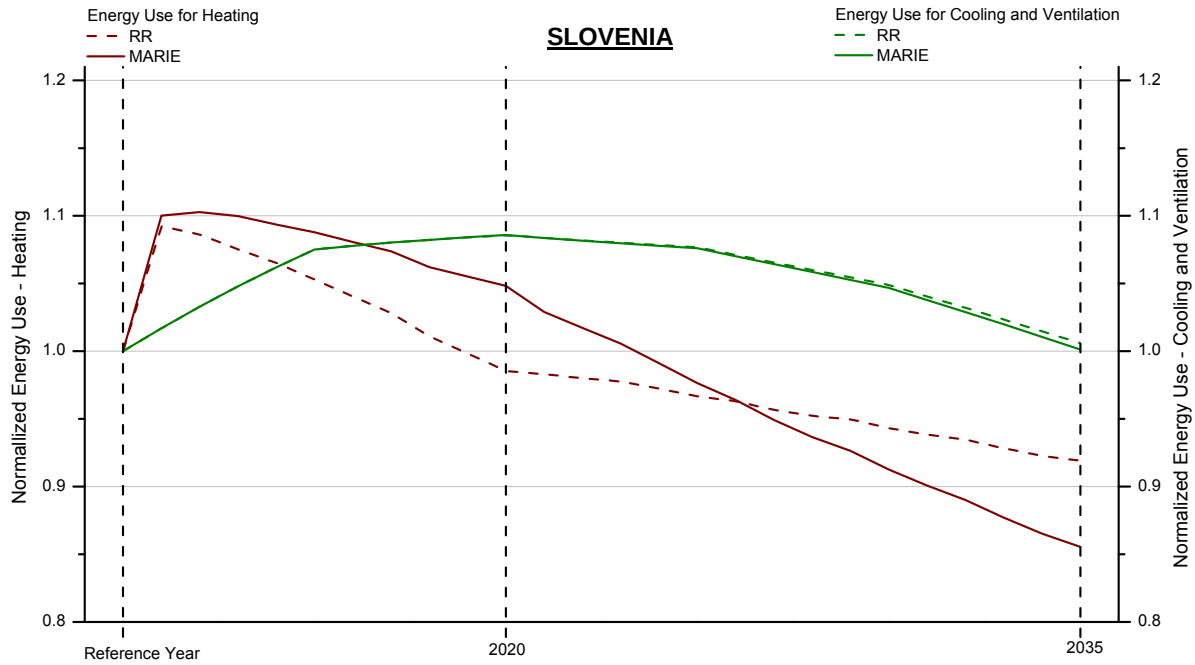


Figure 62 Normalized energy use for heating (left axis) and for cooling and ventilation (right axis). Existing building stock

Cooling and ventilation energy use increase in both scenarios due to the projected increase of the air-conditioned share of floor area. Slovenia is among the regions with the largest relative increase of share of air-conditioned floor area (see Section 2.4).

There is virtually no difference between scenarios in terms of cooling and ventilation energy use. However, MARIE results in substantially larger heating energy savings in the long run.

3.2.8 GREECE

The following sections show the results of the residential and tertiary sectors for Greece. The obtained results are based on the assumptions and the input data that are defined in sections 2.3 and 2.4.

3.2.8.1 Residential

The results obtained for Greece are shown in the following figures. In the first one, Figure 63, shows the normalized total energy use. The MARIE scenario shows larger energy savings than RR since the reference year. Moreover, the difference between the two scenarios increases with time.

Figure 63 includes pie charts with the breakdown of total final energy use in the residential sector by end use (heating, domestic hot water, cooling, lighting and appliances). The pie charts in the figure correspond to the reference year and the outlooks for 2035 according to the two scenarios. Heating is largest energy use, and represents around 65% of the total final energy use of the sector in the reference year. The variation of the breakdowns of energy use between

the reference year and the 2035 projections is relatively small. Appliance energy use tends to increase; however, space heating remains the most important energy use.

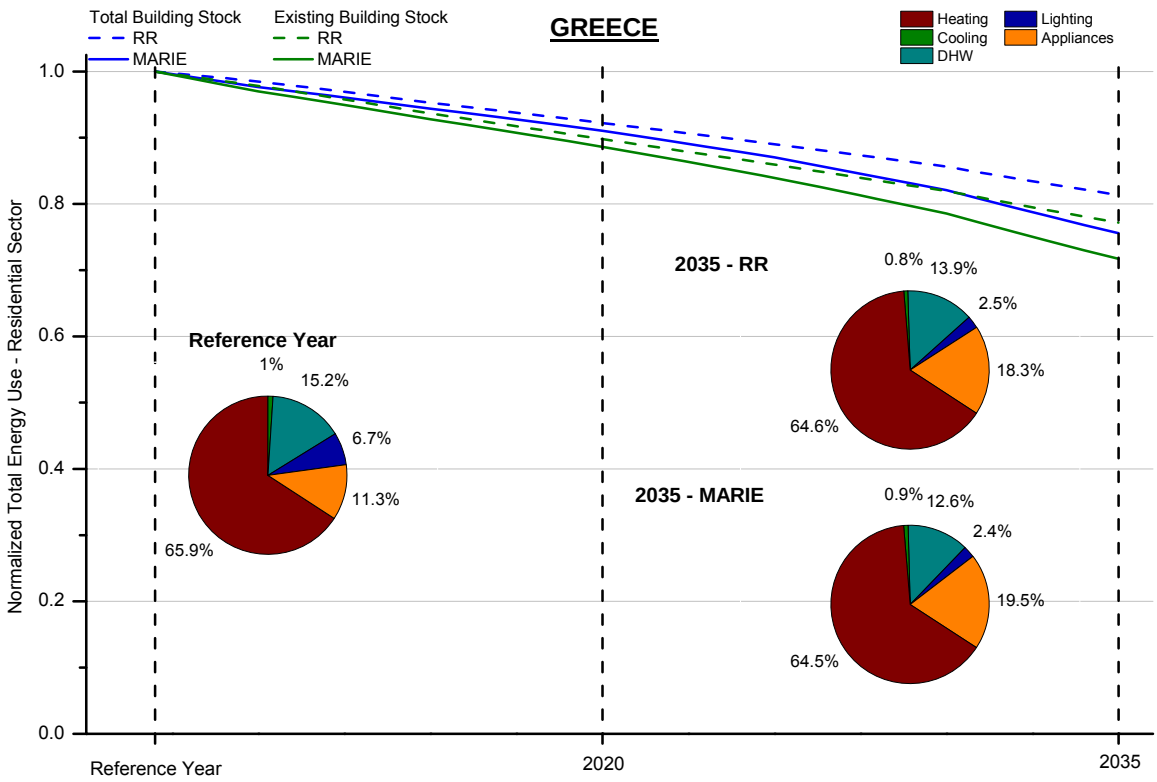


Figure 63 Normalized total energy use for the residential sector. Inner pie charts: left, breakdown by energy use in reference year; top right, breakdown by energy use in 2035 for the Rapid Results scenario; bottom right, breakdown by energy use in 2035 for the MARIE scenario.

Figure 64 shows normalized values of final energy use for heating and heating load. The measures in the two scenarios lead to different results between the heating load and the energy use for heating. Heating energy use is “substantially” lower in MARIE with respect to RR since the reference year, while the difference between scenarios arrives later in terms of heating load. The results could be explained analyzing the measures applied in each scenario:

- In the first years, the measures on heating equipment in MARIE seem more effective than these in RR. Although in the RR the rate of equipment replacement is higher than in MARIE scenario, the type of heating devices was different for the two scenarios (mainly condensing boilers in RR vs. centralized heat pumps and biomass in MARIE). The heating equipment is defined with two parameters: the efficiency and the coverage factor. In Greece centralized systems (coverage factor=100%) are already quite common in the reference year. Therefore equipment efficiency plays an important role in the reduction of the heating energy use. Even if there are fewer replacements with MARIE, the much higher efficiency of heat pumps over boilers drives the total final energy use to a lower value.

- Beyond 2020, the effects of the new building code combined with the high rate of integral refurbishment in the MARIE scenario (represented by the heating load) build on

the effects of the heating equipment measures, further increasing the benefits of the MARIE scenario over RR.

Figure 65 shows the breakdown of the heating energy use by heating equipment type. Oil boilers (the dominant energy source) and electric devices tend to decrease in favour of the other types in both scenarios. Heat pumps and biomass show the largest increase in MARIE, while condensing boilers and natural gas are more common in RR. The contribution of heat pump systems to energy use remains small because of their high efficiency compared to the other system types. Centralized systems (coverage factor 100%) in Greece are already very common in the reference year, therefore, the main difference among heating equipment types is in terms of efficiency.

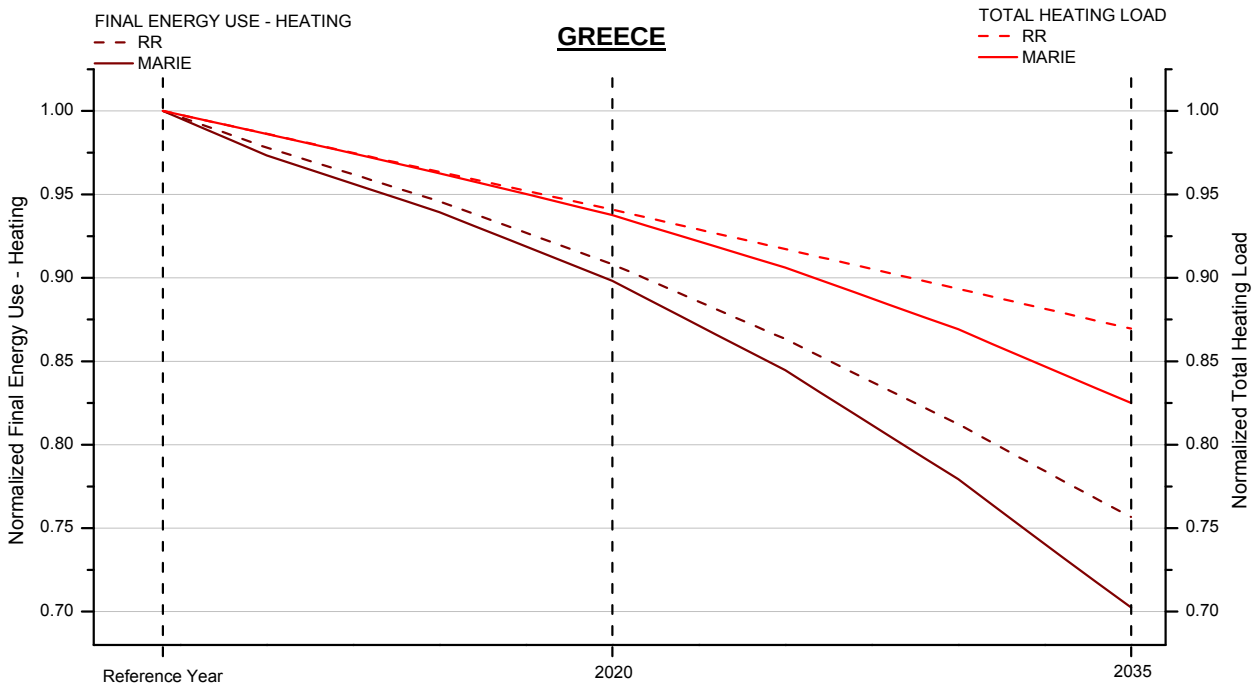


Figure 64 Heating results for the existing stock. Normalized final energy use for heating on left axis. Normalized total heating load on right axis

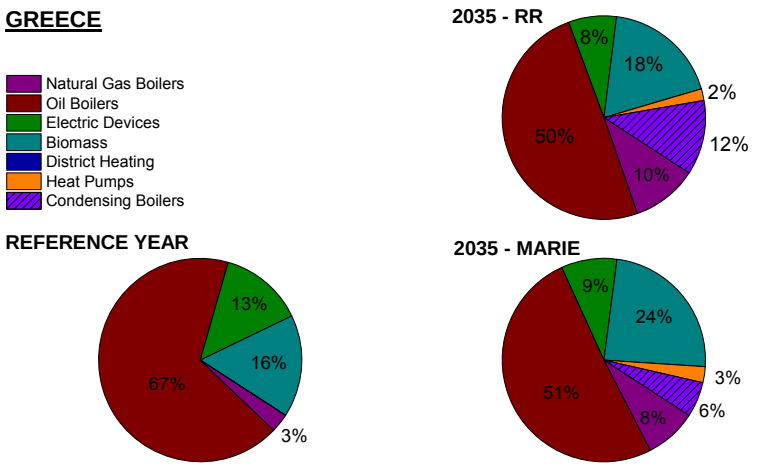


Figure 65 Breakdown of energy use by heating equipment in Reference Year and 2035, for Rapid Results and MARIE scenarios.

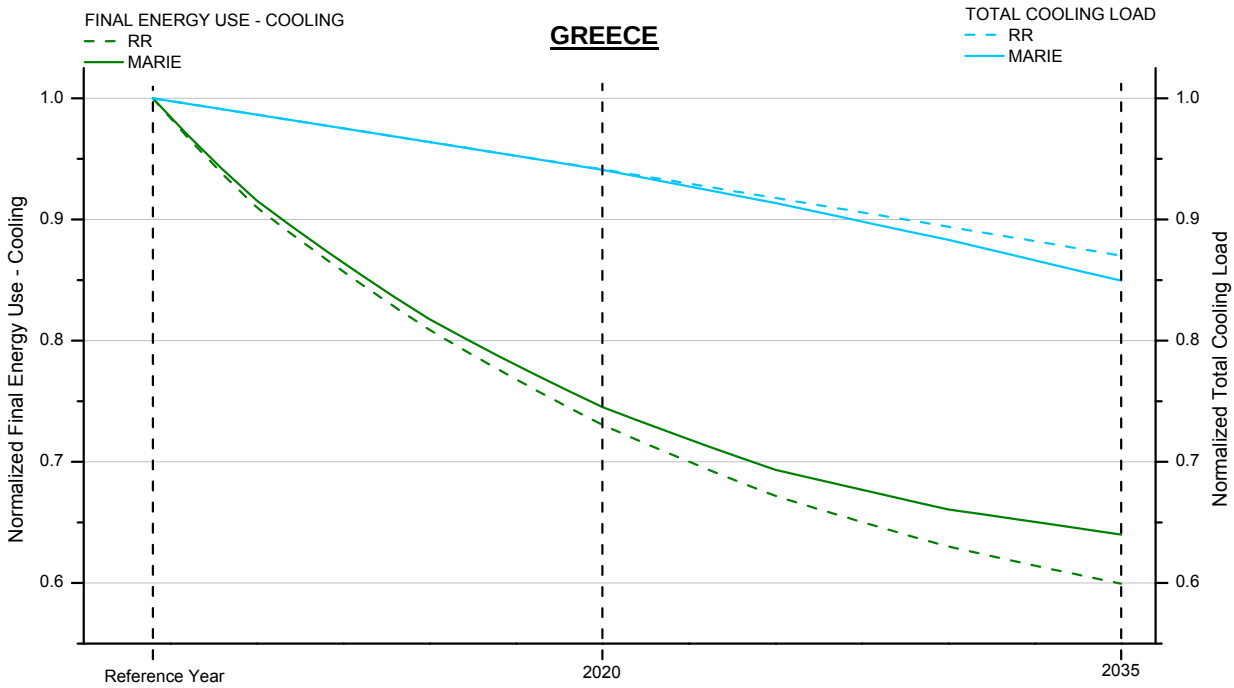


Figure 66 Cooling results for the existing stock. Normalized final energy use for heating on left axis. Normalized total cooling load on right axis.

Figure 66 shows normalized values of final energy use for cooling and cooling load. It should be noted that cooling is a negligible energy use in the residential sector (it is less than 1% of the final energy use). Therefore, while results in Figure 66 may be useful to evaluate the consequences of the two strategies on this specific energy use, they have virtually no impact on the overall building energy use.

Results show that the RR scenario achieves larger energy savings than the MARIE scenario, although cooling loads with MARIE are lower (beyond 2020). The factors related in these results are the following:

- Cooling loads of refurbished buildings are lower than these of the buildings in the current building stock. This is particularly true for buildings refurbished after 2020 (see Annex 3 for details). Since in the MARIE scenario the refurbishment rate is higher than in RR, in the long run cooling load of the total building stock in MARIE tends to decrease further than in RR

- The number of dwellings equipped with cooling system increases over the years. In terms of energy use, this study assumed that heat pumps (both centralized and decentralized) introduced for heating purposes are also used for cooling. The larger share of centralized heat pumps in MARIE results also in a larger share of covered cooling loads (Table 14) (i.e., higher comfort). The MARIE scenario includes education and awareness measures for users. However, these are not enough to balance the increasing energy use linked to the higher comfort.

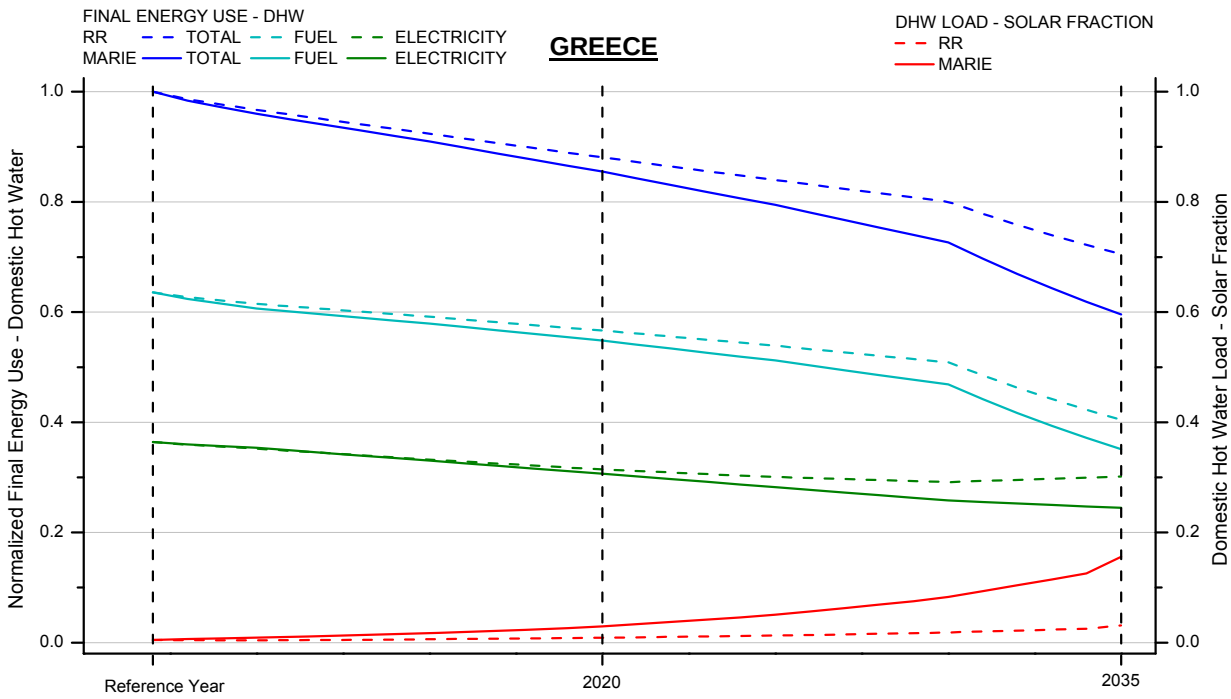


Figure 67 Domestic hot water results for the existing stock. Breakdown of normalized final energy use for DHW by energy source on left axis. Fraction of domestic hot water load covered by solar thermal on right axis

Figure 67 shows the breakdown of domestic hot water (DHW) energy use by energy source (fuel vs. electricity). Note that the final energy use breakdown does not include the energy provided by solar thermal systems, since this is considered a reduction of DHW load. Figure 67 also shows the fraction of DHW load that is covered with solar thermal systems. The assumptions on domestic hot water systems can be found in Section 2.3.1.3.

3.2.8.2 Tertiary

Figure 68 shows normalized values of total final energy use in the tertiary sector for the existing buildings in the stock in the reference year. The figure also includes pie charts with the breakdown of total final energy use in the tertiary sector by end use (heating, cooling and ventilation, and “others”). The pie charts in the figure correspond to the reference year and the outlooks for 2035 according to the two scenarios.

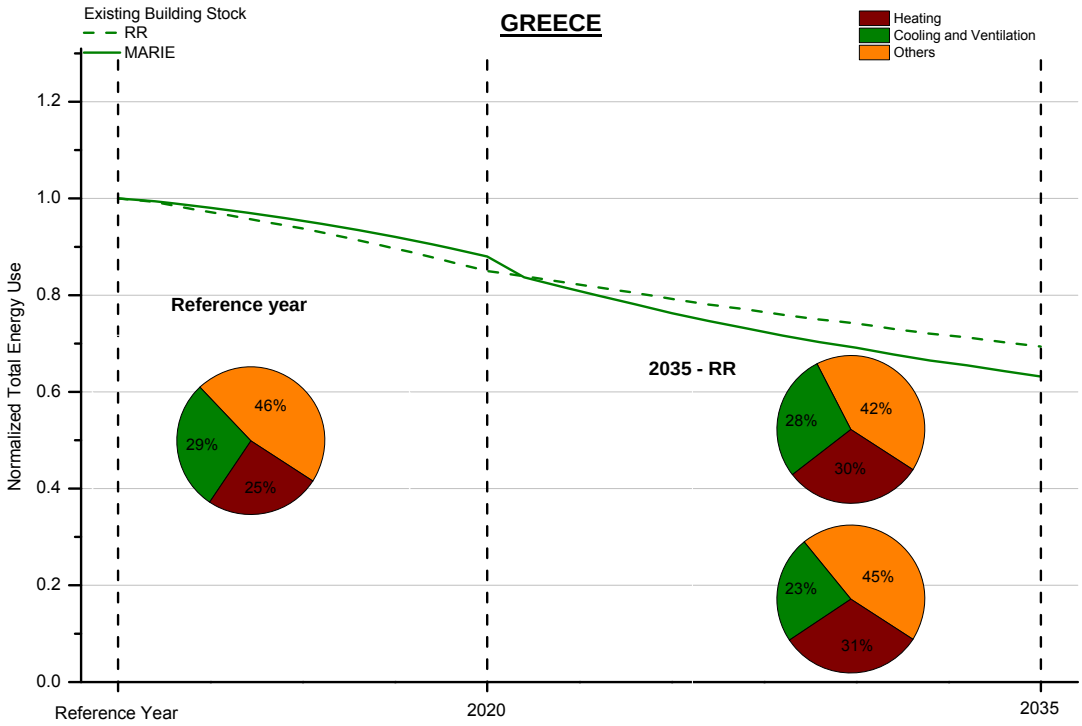


Figure 68 Normalized total energy use for the tertiary sector (total building stock and existing building stock). Inner pie charts: left, breakdown by energy use in reference year; top right, breakdown by energy use in 2035 for the Rapid Results scenario; bottom right, breakdown by energy use in 2035 for the MARIE scenario

RR provides larger energy savings than MARIE in the first years of simulation. However, in the long run, the MARIE measures are more effective at reducing final energy use. Final energy use is fairly evenly split among heating, cooling and ventilation, and “others”. The share of cooling and ventilation energy use in the tertiary sector is much higher than in residential.

Figure 69 shows projections of normalized final energy use for heating and cooling and ventilation according to the two scenarios.

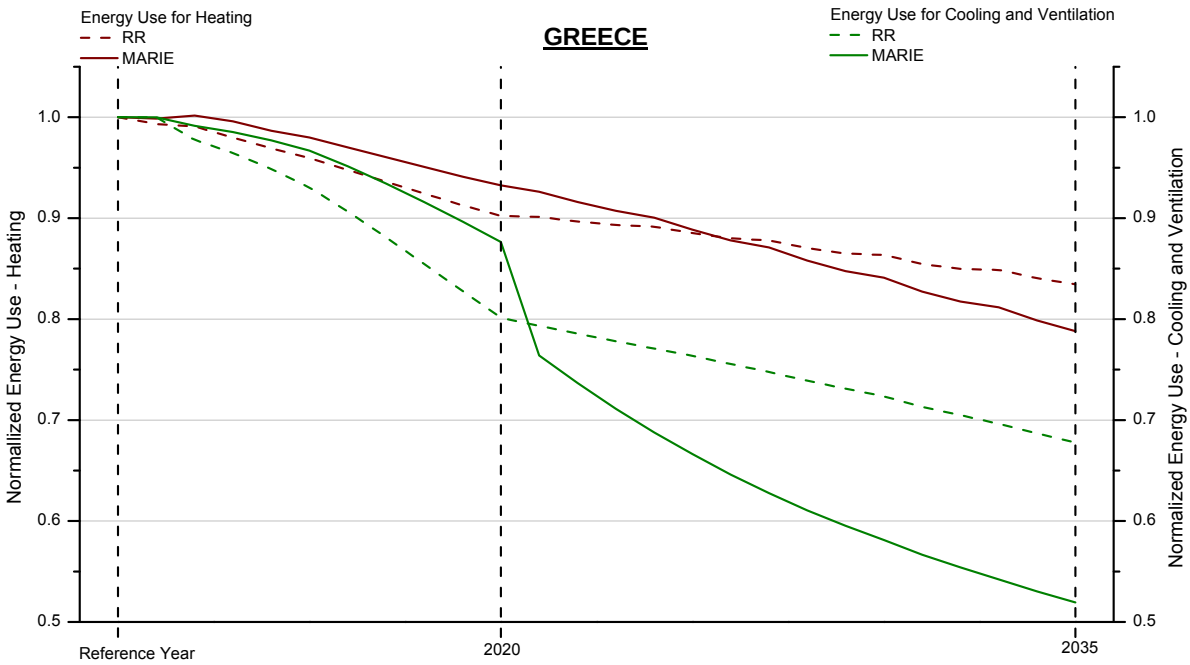


Figure 69 Normalized energy use for heating (left axis) and for cooling and ventilation (right axis). Existing building stock

The benefits of MARIE over RR arrive sooner in cooling and ventilation than they do in heating energy use. This is likely due to the longer lifecycles associated to measures on envelope (which mainly target heating energy use).

Figure 69 also shows that, in both scenarios, cooling and ventilation energy use sees a much larger reduction than heating energy use. This is consistent with the pie charts in Figure 68, which show decreasing shares of cooling and ventilation energy use.

3.2.9 MALTA

The following sections show the results of the residential and tertiary sectors for Malta. The obtained results are based on the assumptions and the input data that are defined in sections 2.3 and 2.4.

3.2.9.1 Residential

The results obtained for Malta are shown in the following figures. In the first one, Figure 70, shows the normalized total energy use. Beyond 2020 the MARIE scenario shows larger energy savings than RR. Moreover, the difference between the two scenarios increases with time. It should be noted that, unlike any other region in this analysis, 2035 outlooks for the total number of buildings (new and existing) increase in both scenarios. The increasing trend in energy use is likely a result of an increasing share of centralized systems in new buildings. Note however that new buildings are not the focus of this study.

Figure 70 includes pie charts with the breakdown of total final energy use in the residential sector by end use (heating, domestic hot water, cooling, lighting and appliances). The pie charts in the figure correspond to the reference year and the outlooks for 2035 according to the two

scenarios. Heating, domestic hot water, and appliances are the largest energy users, with relatively similar shares. The 2035 projections foresee an increase in the share of energy use in appliances in lieu of domestic hot water, heating and lighting.

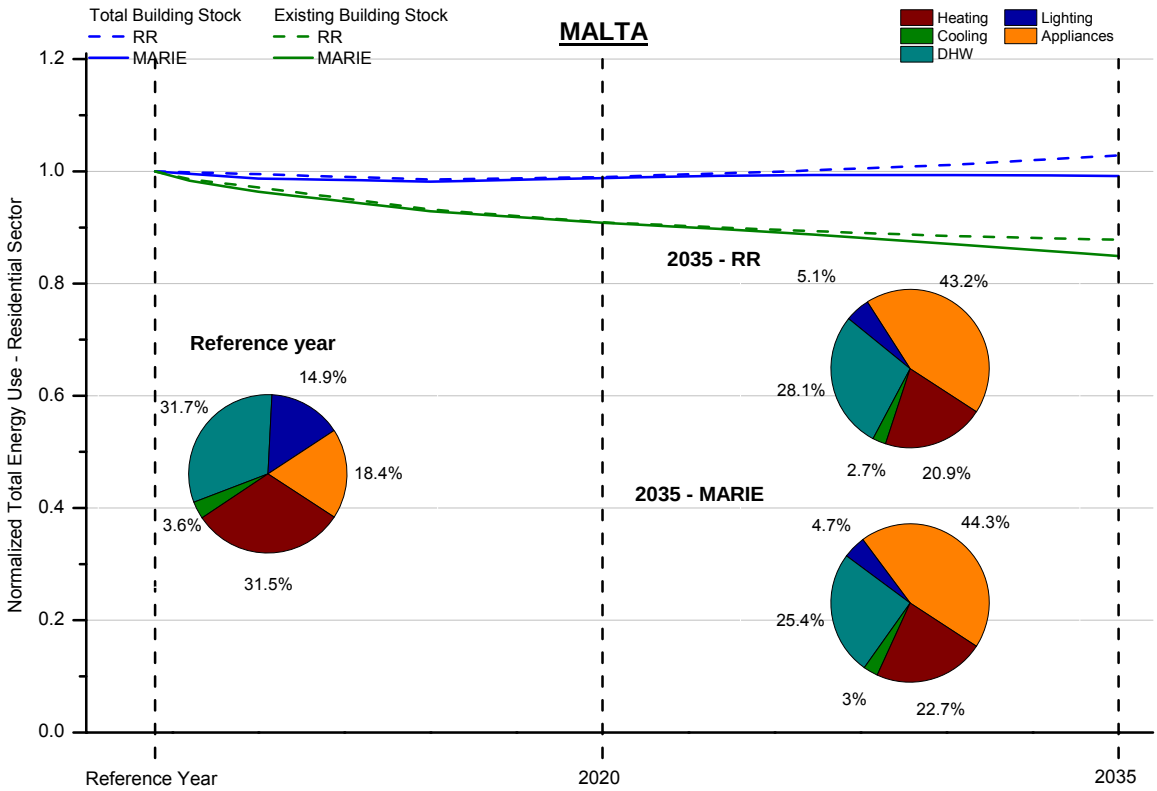


Figure 70 Normalized total energy use for the residential sector. Inner pie charts: left, breakdown by energy use in reference year; top right, breakdown by energy use in 2035 for the Rapid Results scenario; bottom right, breakdown by energy use in 2035 for the MARIE scenario.

Figure 71 shows normalized values of final energy use for heating and heating load. The results obtained in terms of heating load and these in terms of final energy use for heating show opposite trends. For the heating load, MARIE scenario provides better results (lower heating load) than RR. On the other hand, the final energy use for heating in the RR scenario is lower than in MARIE. The main reason for the higher heating energy use in MARIE is that in this scenario there are more centralized systems (see the decrease of electric devices in Figure 72), which, unlike decentralized systems, are assumed to cover 100% of the heating load. The higher energy use in MARIE is therefore a consequence of an increase in thermal comfort. In both scenarios electric devices are considered decentralized systems, and over the years these are replaced by biomass systems and heat pumps. The category “heat pump” includes centralize and decentralize systems, and the fractions of them are different between scenarios. In MARIE the fraction of centralized heat pump is higher than in RR. Since there is no natural gas network in Malta, neither natural gas nor condensing boilers are introduced.

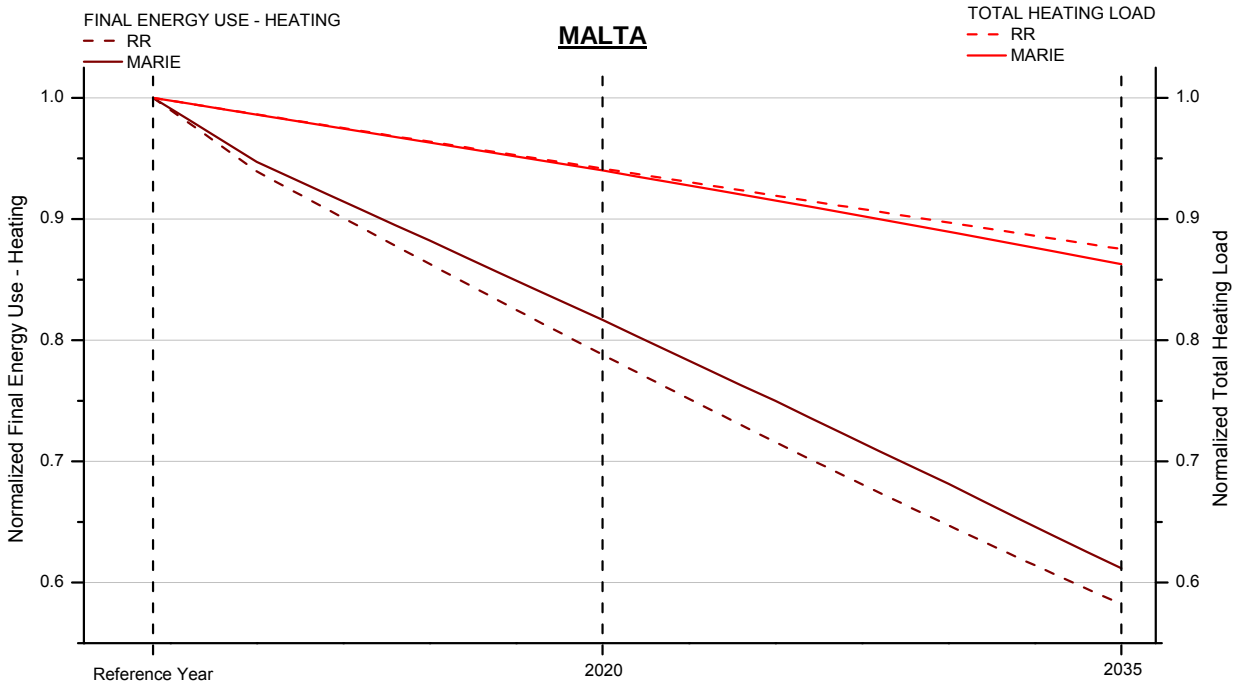


Figure 71 Heating results for the existing stock. Normalized final energy use for heating on left axis. Normalized total heating load on right axis

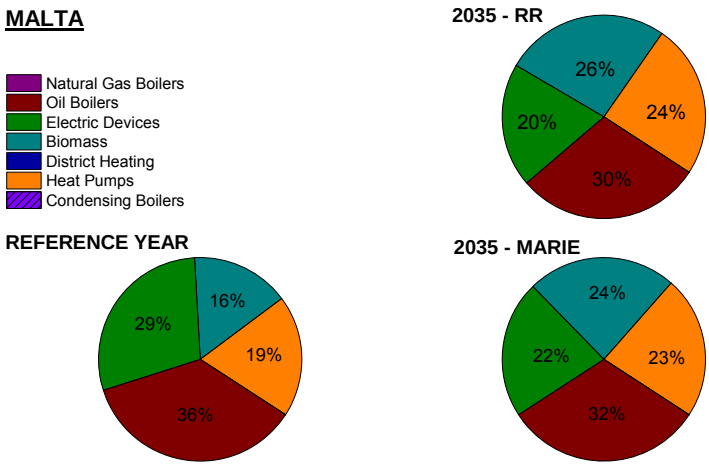


Figure 72 Breakdown of energy use by heating equipment in Reference Year and 2035, for Rapid Results and MARIE scenarios.

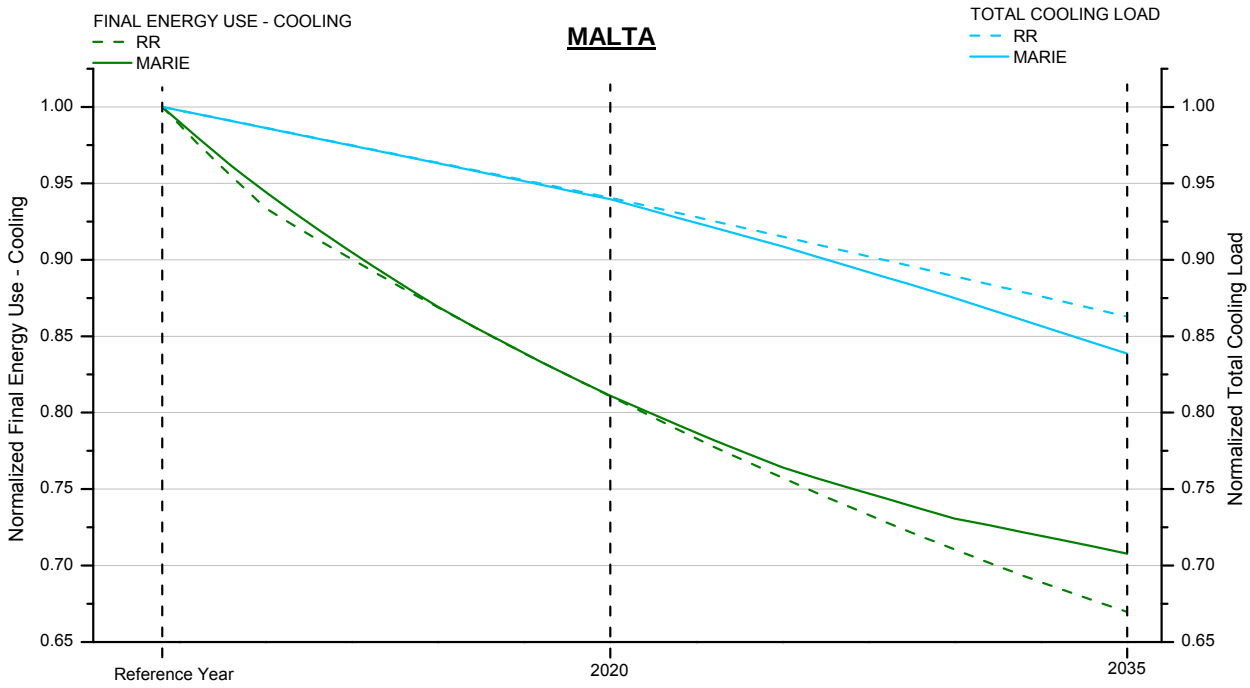


Figure 73 Cooling results for the existing stock. Normalized final energy use for heating on left axis. Normalized total cooling load on right axis.

Figure 73 shows normalized values of final energy use for cooling and cooling load. It should be noted that, although cooling loads in Malta are as high as heating loads, cooling is the lowest energy use in the residential sector (it is around 4% of the final energy use). Therefore, while results in Figure 73 may be useful to evaluate the consequences of the two strategies on this specific energy use, they have little impact on the overall building energy use.

Results show that the RR scenario achieves larger energy savings than the MARIE scenario, although cooling loads with MARIE are lower (beyond 2020). The factors related in these results are the following:

- Cooling loads of refurbished buildings are lower than these of the buildings in the current building stock. This is particularly true for buildings refurbished after 2020 (see Annex 3 for details). Since in the MARIE scenario the refurbishment rate is higher than in RR, in the long run cooling load of the total building stock in MARIE tends to decrease further than in RR

- The number of dwellings equipped with cooling system increases over the years. In terms of energy use, this study assumed that heat pumps (both centralized and decentralized) introduced for heating purposes are also used for cooling. The larger share of centralized heat pumps in MARIE results also in a larger share of covered cooling loads (Table 14) (i.e., higher comfort). The MARIE scenario includes education and awareness measures for users. However, these are not enough to balance the increasing energy use linked to the higher comfort.

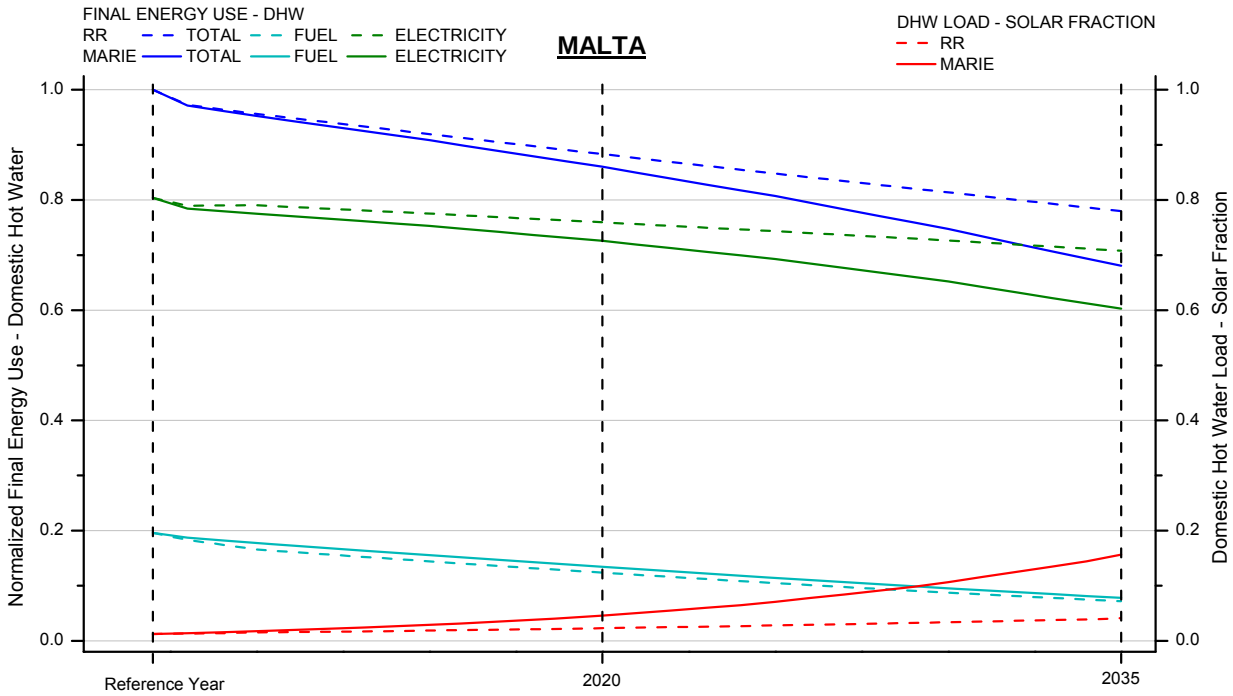


Figure 74 Domestic hot water results for the existing stock. Breakdown of normalized final energy use for DHW by energy source on left axis. Fraction of domestic hot water load covered by solar thermal on right axis

Figure 74 shows the breakdown of domestic hot water (DHW) energy use by energy source (fuel vs. electricity). Note that the final energy use breakdown does not include the energy provided by solar thermal systems, since this is considered a reduction of DHW load. Figure 74 also shows the fraction of DHW load that is covered with solar thermal systems. The assumptions on domestic hot water systems can be found in Section 2.3.1.3.

3.2.9.2 Tertiary

Figure 75 shows normalized values of total final energy use in the tertiary sector for the existing buildings in the stock in the reference year. The figure also includes pie charts with the breakdown of total final energy use in the tertiary sector by end use (heating, cooling and ventilation, and “others”). The pie charts in the figure correspond to the reference year and the outlooks for 2035 according to the two scenarios.

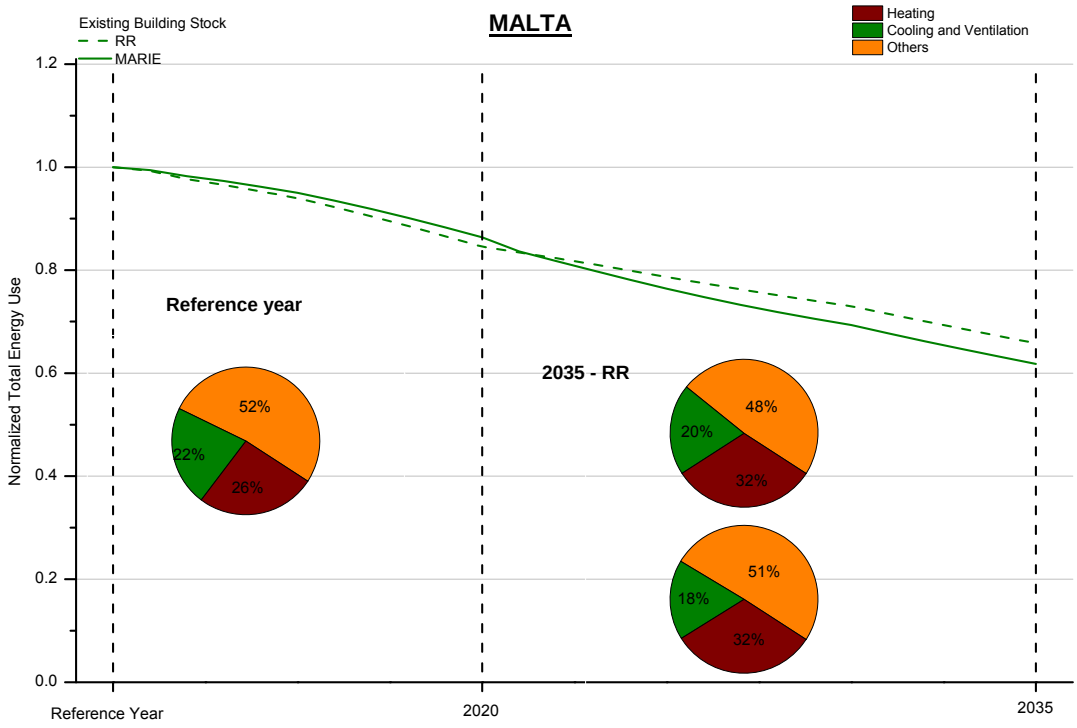


Figure 75 Normalized total energy use for the tertiary sector (total building stock and existing building stock). Inner pie charts: left, breakdown by energy use in reference year; top right, breakdown by energy use in 2035 for the Rapid Results scenario; bottom right, breakdown by energy use in 2035 for the MARIE scenario

RR provides larger energy savings than MARIE in the first years of simulation. However, in the long run, the MARIE measures are more effective at reducing final energy use. “Others” is the end use with the largest share of final energy use. The share of cooling and ventilation energy use in the tertiary sector is much higher than in residential.

Figure 76 shows projections of normalized final energy use for heating and cooling and ventilation according to the two scenarios.

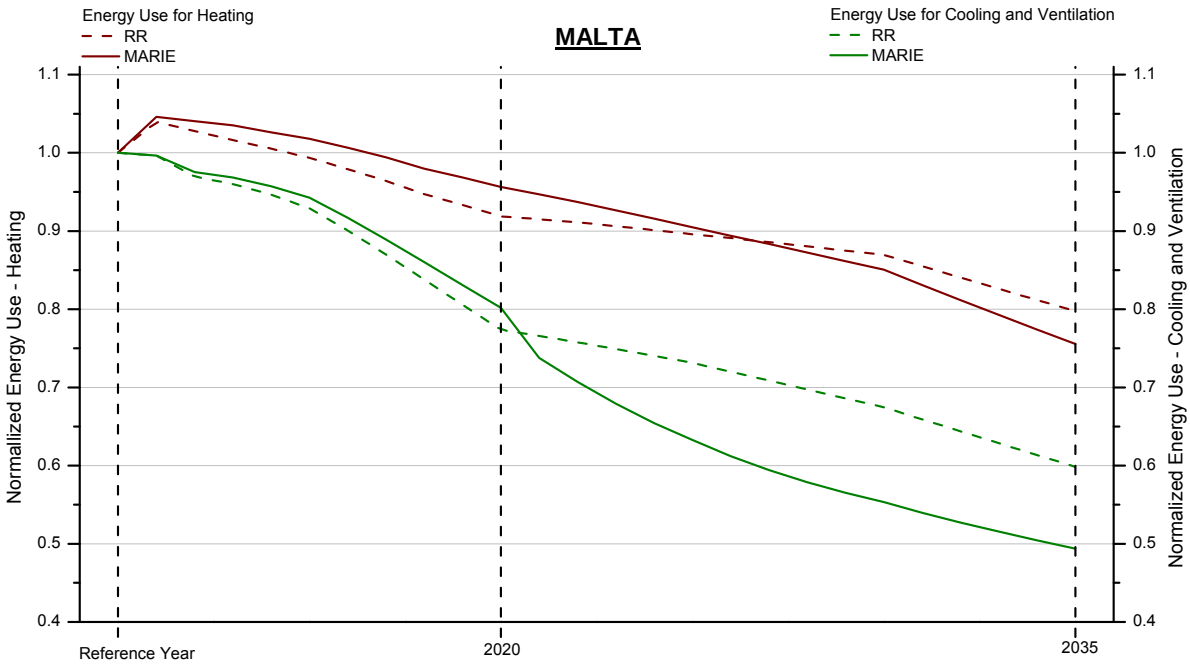


Figure 76 Normalized energy use for heating (left axis) and for cooling and ventilation (right axis). Existing building stock

The benefits of MARIE over RR arrive sooner in cooling and ventilation than they do in heating energy use. This is likely due to the longer lifecycles associated to measures on envelope (which mainly target heating energy use).

Figure 76 also shows that, in both scenarios, cooling and ventilation energy use sees a much larger reduction than heating energy use. This is consistent with the pie charts in Figure 75, which show decreasing shares of cooling and ventilation energy use.

3.3 CROSS-REGIONAL COMPARISON

This section provides a cross-regional comparison of the normalized results, both for the residential and the tertiary sectors. Results show how the characteristics of the individual regions differently affect the impacts of both scenarios on energy use.

3.3.1 RESIDENTIAL

Figure 77 shows normalized values of total final energy use broken down by energy source. All the regions show decreasing trends on energy use in both scenarios.

- In 2020, the final energy use for both scenarios is lower than the reference year. The two scenarios show very similar results.
- In 2035, the MARIE scenario provides larger energy savings than RR in all the regions. The difference between scenarios in 2035 is much larger than in 2020.

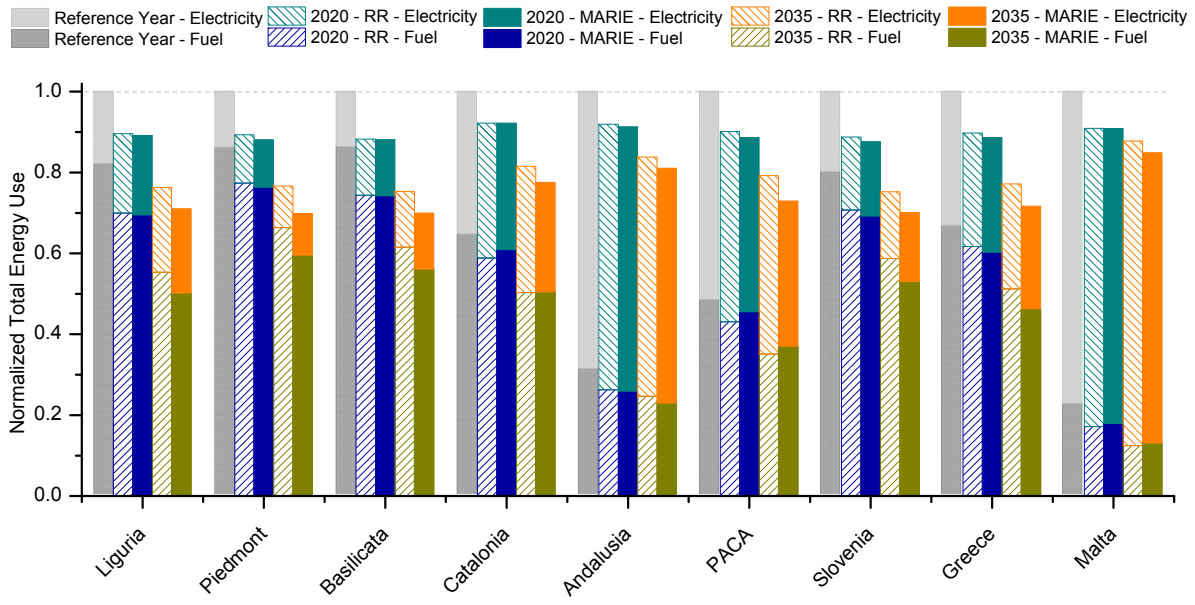


Figure 77 Scenario comparison for normalized total energy use for each region in reference year, 2020 and 2035. Existing building stock. Breakdown by energy sources.

Although all the regions follow the similar trends, there are differences among some of them that are worth exploring.

- Malta and Andalusia show the smallest energy savings in the long run. Moreover, the difference between scenarios is very small. These regions are the warmest of the analysis and 70% of that final energy use is provided by electricity.

- By 2035 the other regions achieve energy savings larger than the 20% of the total final energy use, and the different between scenarios is also larger.

Figure 78 compares final energy use per unit floor area in the reference year and 2035 (MARIE vs. RR). Results in Figure 78 are displayed in absolute terms (kWh/m^2-yr) and broken down by end use so that the differences among regions can be better appreciated. Looking at the results, the regions can be grouped as follows:

- Andalusia and Malta. The final energy use is lower than 75 kWh/m^2-yr. These regions show both the lowest energy use and the lowest energy savings between the reference year and the 2035. Compared to the other regions, appliances and lighting are a substantial fraction of the final energy use (note that there were no measures defined in either scenario for these end uses). Heating energy use is much smaller than in the other regions, and does not show important variations over time.
- Liguria and Catalonia. The final energy use is in the 100-150 kWh/ m^2-yr range. For these regions the highest energy savings are achieved in heating and DHW. Differences between scenarios are relatively small, particularly in Catalonia.
- Piedmont, Basilicata, PACA and Greece. The final energy use is in the 150-200 kWh/ m^2-yr range. For these regions the highest energy savings are achieved through measures targeting heating (the largest end use). Differences between scenarios are higher.

- Slovenia. The final energy use is 250 kWh/ m^2-yr. Slovenia is the coldest region included in the analysis, and also the one with the highest final energy use. Not surprisingly, heating is both the largest end use and the one that offers the largest saving opportunities.

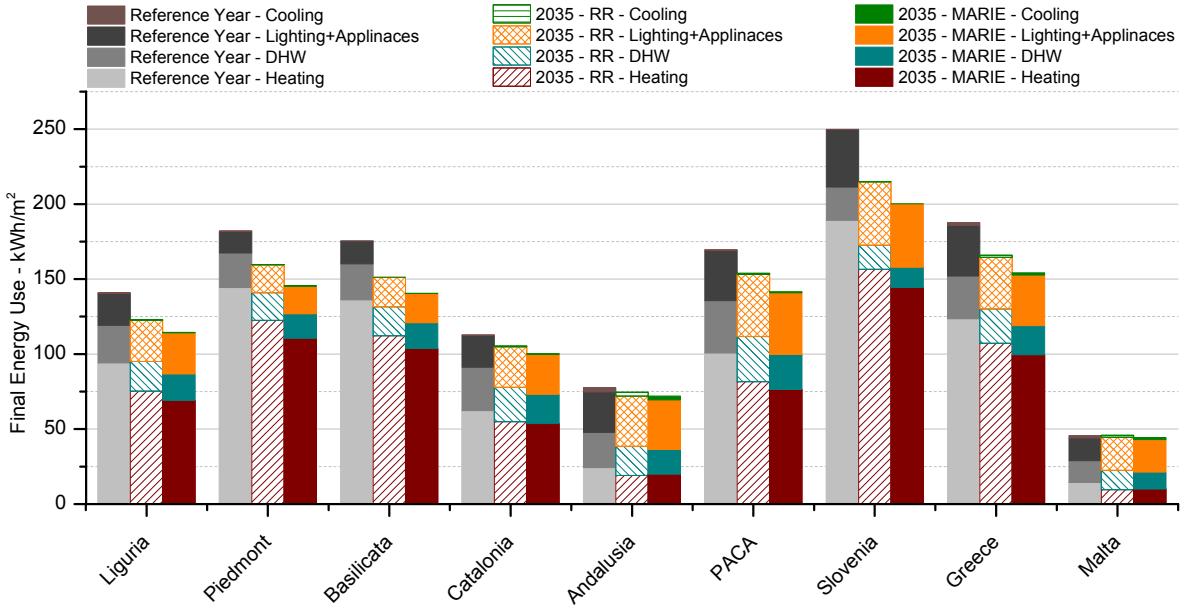


Figure 78 Scenario comparison of final energy use per square meter for each region in reference year and 2035. Breakdown by energy use.

Figure 79 and Figure 80 focus on heating energy use. Figure 79 shows normalized values of heating energy use broken down by energy type (electricity, fossil fuels and biomass). Regions show different behaviors, and can be grouped as follows:

- Andalusia and Malta. The energy savings obtained in RR are larger than these obtained in MARIE. The fraction of centralized heating systems in MARIE is larger than in RR. In the reference year there are less than 10% of centralized heating systems in both regions (these are the two regions with the lowest share of centralized systems). However, the share of centralized systems in the MARIE scenario doubles by 2035. Centralized systems are assumed to provide 100% of the heating load. Therefore, even if new systems are efficient, they use more energy because they provide comfort to a larger share of floor area.

- The other regions show relatively similar patterns: the two scenarios provide about the same energy savings by 2020, while MARIE results in larger savings by 2035. Fossil fuels are the dominant heating source in all these regions except Slovenia, which is strongly based on biomass. Decentralized electric systems are relatively common only in Catalonia, PACA, and Greece.

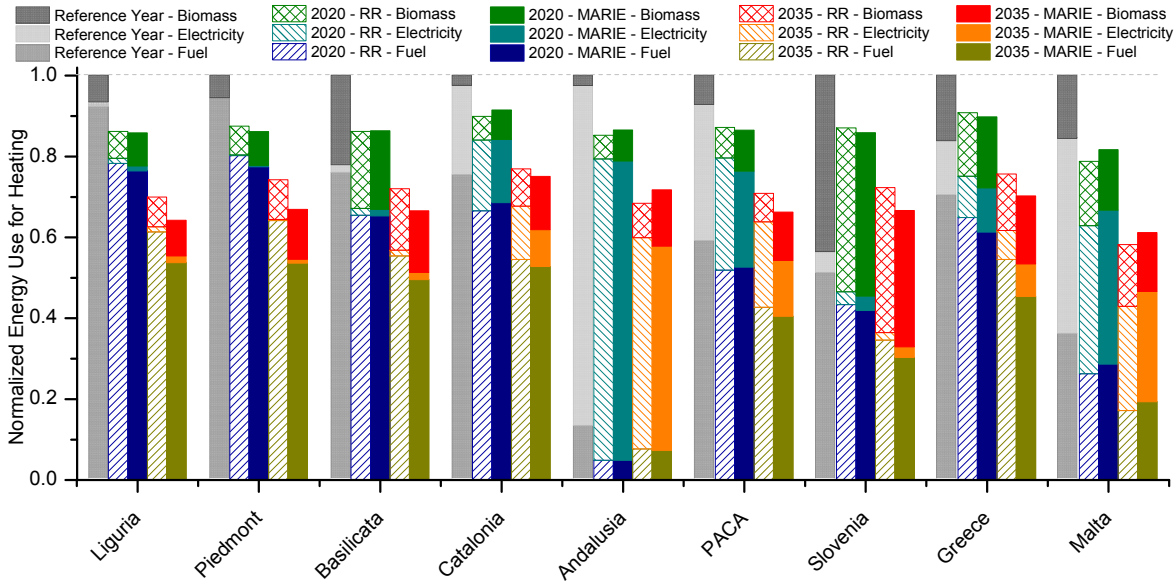


Figure 79 Scenario comparison of normalized energy use for heating for each region in reference year, 2020 and 2035. Existing building stock. Breakdown by energy sources.

Results above suggest that the benefits of MARIE over RR could arrive sooner in regions with large shares of centralized heating systems. Figure 80 illustrates the relationship between the share of centralized heating systems and the year at which MARIE takes over RR as the best performing scenario in terms of heating energy use (break-even point).

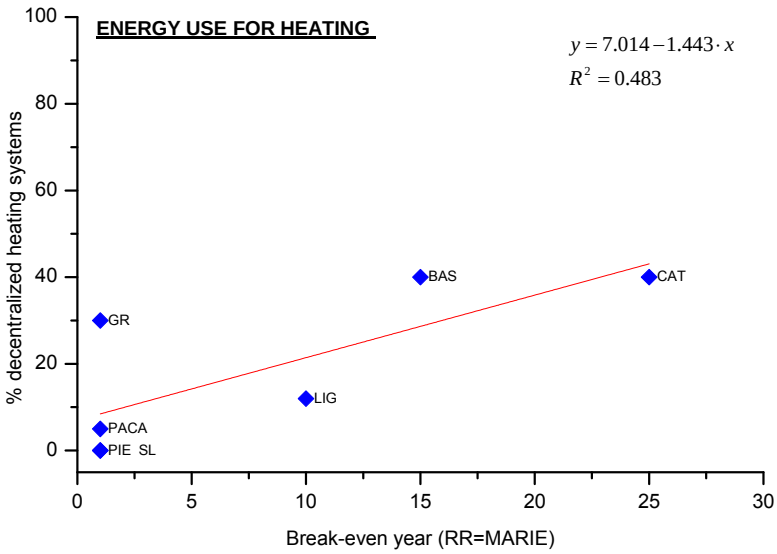


Figure 80 Correlation between heating energy use break-even point (i.e., year in which energy use for heating is the same in both scenarios) and share of rented decentralized heating systems. Andalusia and Malta are not included in this figure because RR is better than MARIE over all the years (90-100% of those heating systems are decentralized). Existing building stock.

Figure 80 shows that the benefits of MARIE over RR in terms of heating energy use generally arrive at a slower pace in regions with large shares of decentralized systems. The regions with

the largest share of decentralized heating systems (Andalusia and Malta) are not even in the figure because their heating energy use in MARIE is always higher than in RR.
It should be noted that, while heating is the most important energy use in most of the regions (and therefore, the focus of the energy efficiency measures in both MARIE and RR), the results above do not represent the overall energy use of the existing stock. As can be observed in Figure 81, decentralized systems are more popular in regions with low heating requirements.

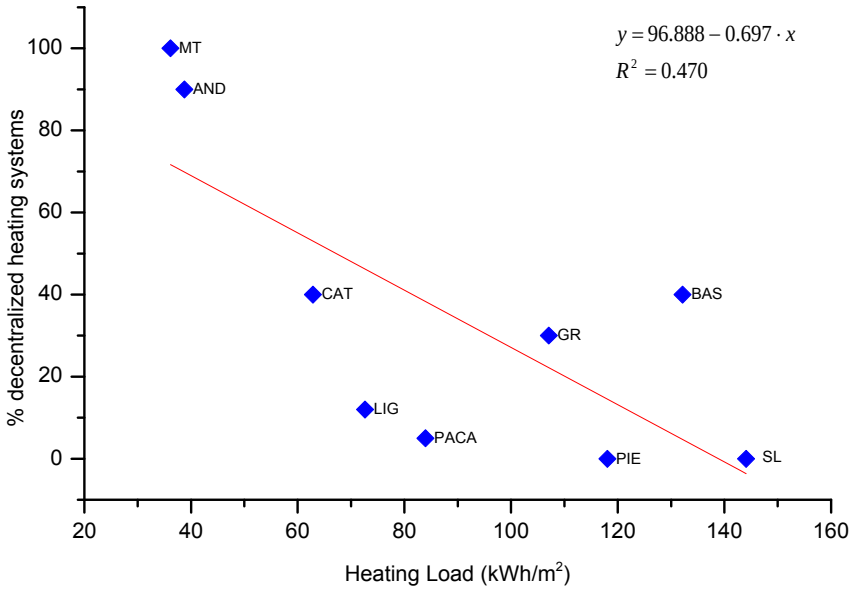


Figure 81 Correlation between specific heating load (kWh/m^2-yr) and share of decentralized systems in the reference year

It should be noted that while the increase in share of centralized systems reduces the energy savings achieved with MARIE, it also improves thermal comfort for occupants. Decentralized systems providing the same comfort standards would also use more energy.

Figure 82 and Figure 83 show normalized values of heating and cooling loads, respectively.

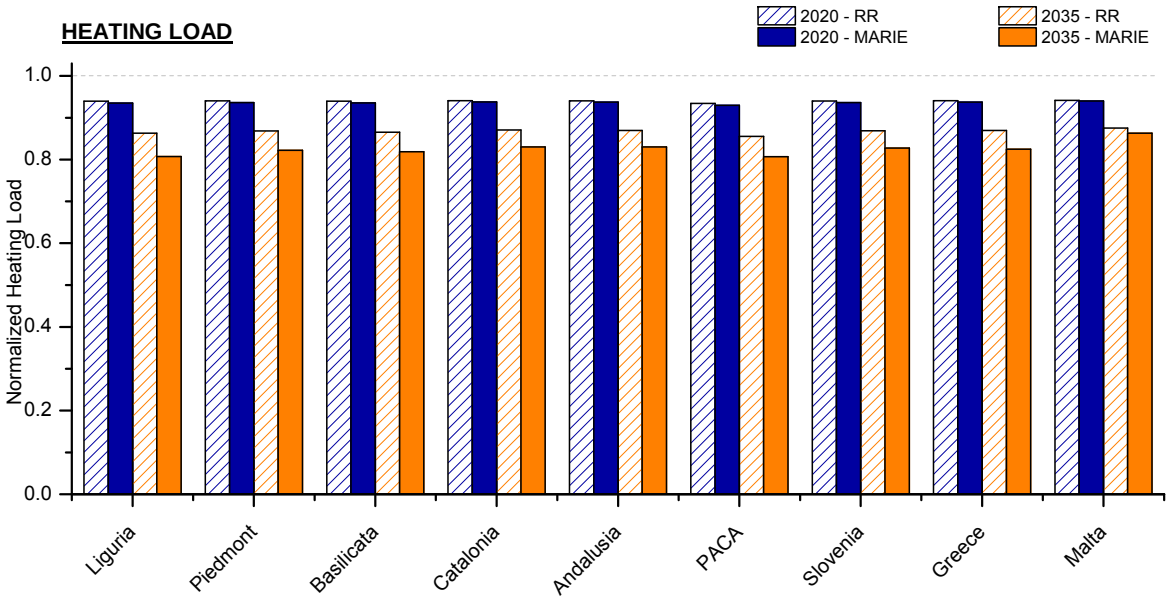


Figure 82 Scenario comparison of the normalized heating load for each region in 2020 and 2035. Existing building stock.

The figure above shows that MARIE is the best performing scenario in terms of heating load reduction in all regions.

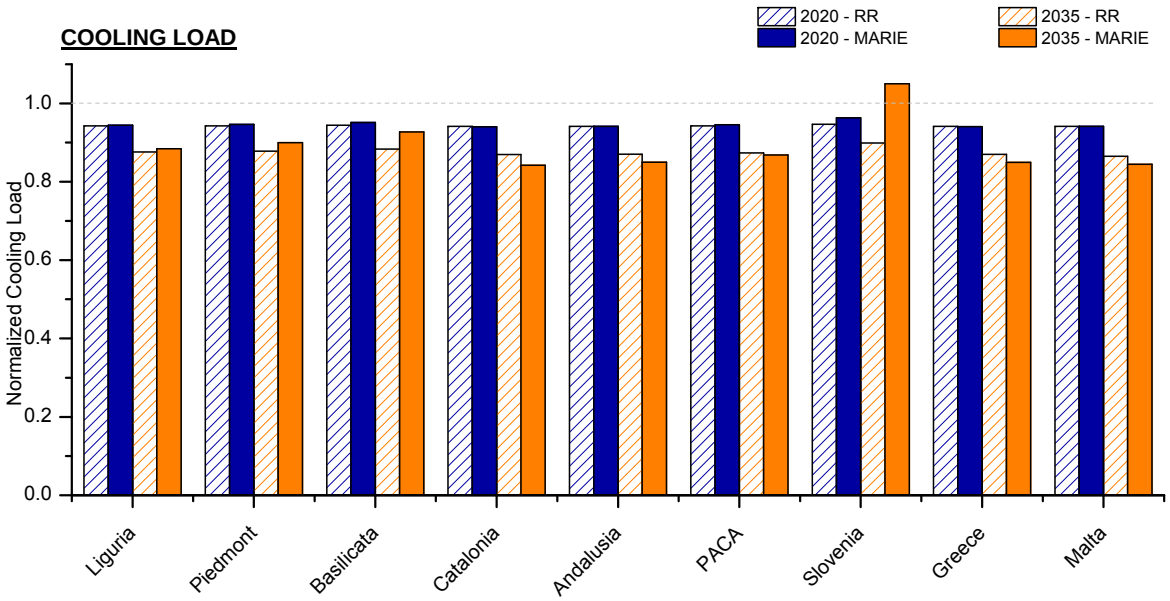


Figure 83 Scenario comparison of the normalized heating load for each region in 2020 and 2035. Existing building stock.

On the other hand, MARIE results in a higher cooling load compared to RR in Liguria, Piedmont, Basilicata and Slovenia. Note that cooling is a marginal energy use in all these regions, therefore, the increase in cooling load is little trade-off for the benefits in terms of heating energy use.

Figure 84 shows normalized values of domestic hot water final energy. Both scenarios provide energy savings compared to the reference year, and MARIE is the best performing scenario in all the regions.

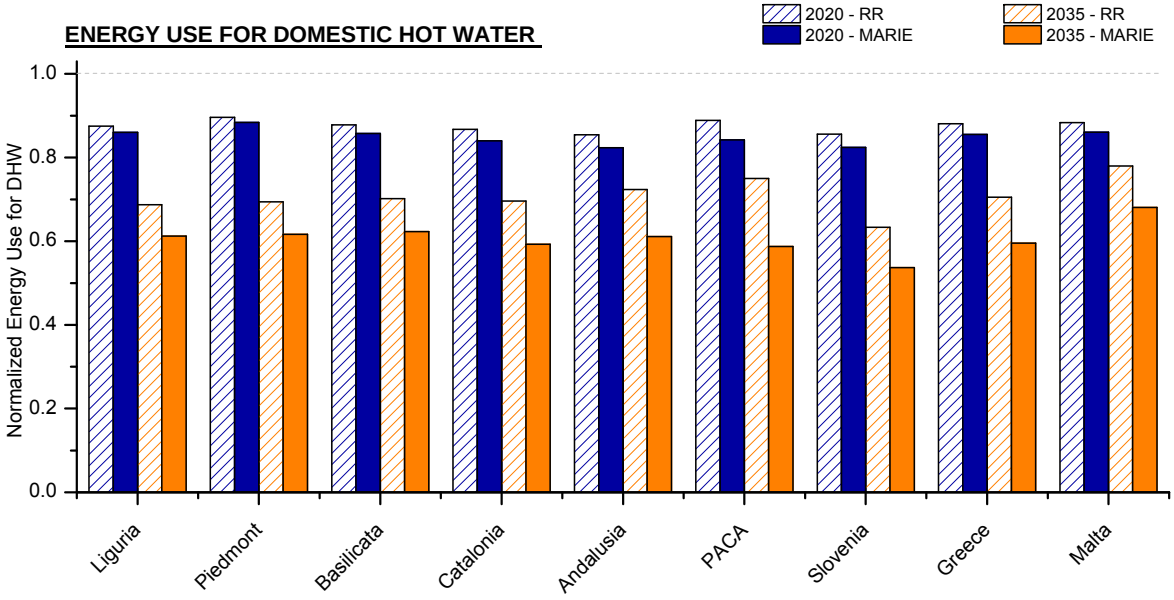


Figure 84 Scenario comparison for normalized energy use for domestic hot water for each region in 2020 and 2035. Existing building stock.

Figure 85 shows the fraction of the domestic hot water load (i.e., heat energy required for domestic hot water) that is provided by solar thermal systems.

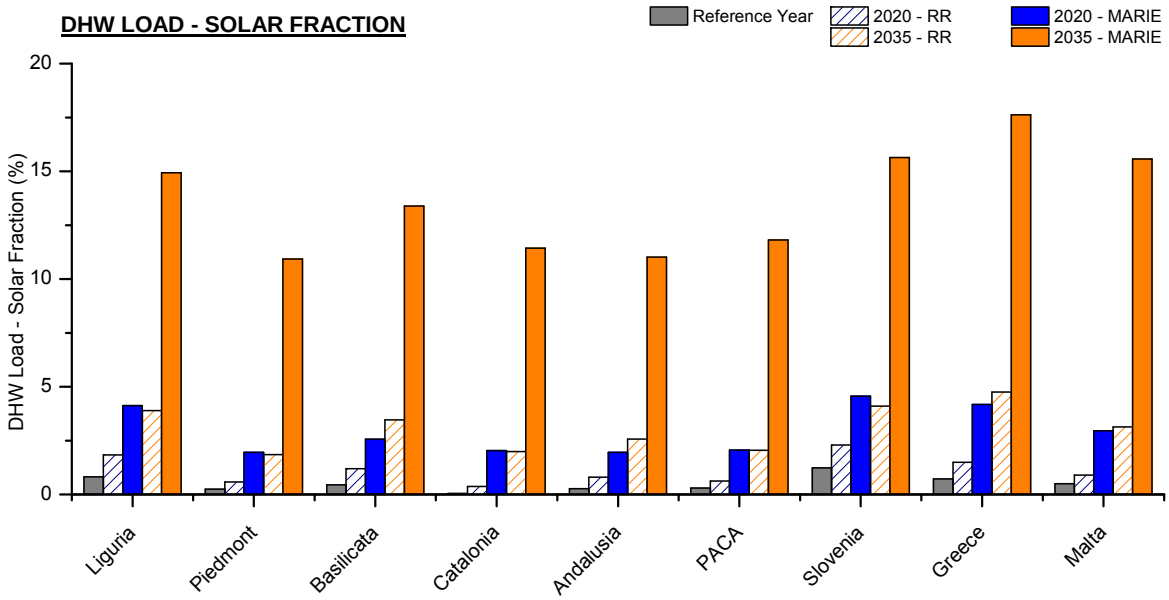


Figure 85 Scenario comparison of the fraction of domestic hot water load covered by solar thermal systems for each region in reference year, 2020 and 2035. Existing building stock.

Results suggest that the faster refurbishment of the building stock in MARIE leads this scenario to enjoy a larger solar fraction than RR.

3.3.2 TERTIARY

Figure 86 shows normalized values of total final energy use broken down by energy source. All the regions show decreasing trends of final energy use in both scenarios. By 2020 RR provides larger energy savings than MARIE in all the regions. However, MARIE is the best performing scenario in 2035.

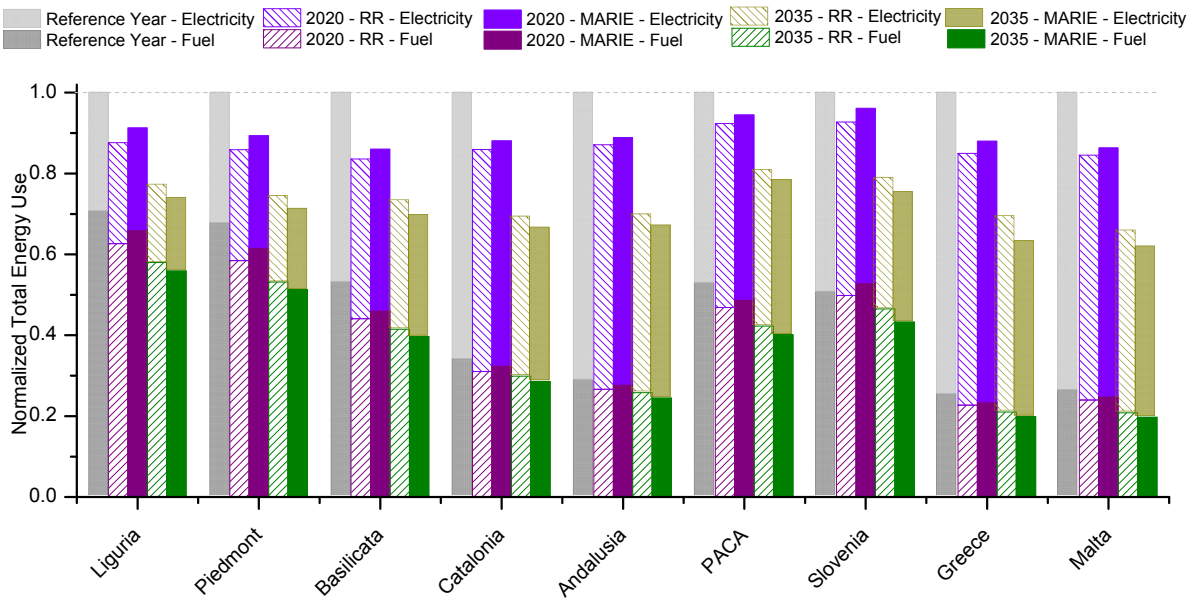


Figure 86 Scenario comparison of the normalized total final energy use in the tertiary sector for each region in 2020 and 2035. Existing building stock

Figure 86 also shows significant differences among regions in terms of energy source split (electricity vs. fuel). Cold regions generally show a large share of fuel energy use compared to electricity.

Figure 87 and Figure 88 show results of total final energy use per employee and per unit floor area, respectively. Results are also broken down by end use (heating and SHW, cooling and ventilation, others – which includes lighting, ICT, cooking, refrigerators, laundry and miscellaneous building mechanical equipment). As explained in Section 2.4, number of employees and floor area are the two global drivers of energy use in the Forecast Tertiary model.

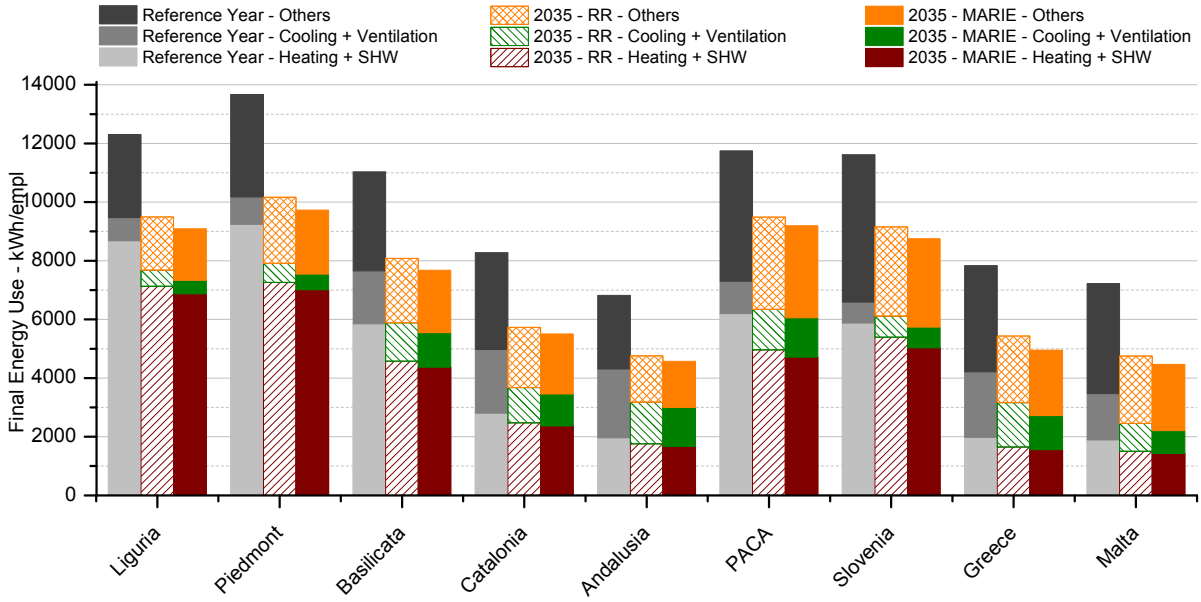


Figure 87 Scenario comparison of total final energy use per employee in the tertiary sector in 2035. Existing building stock

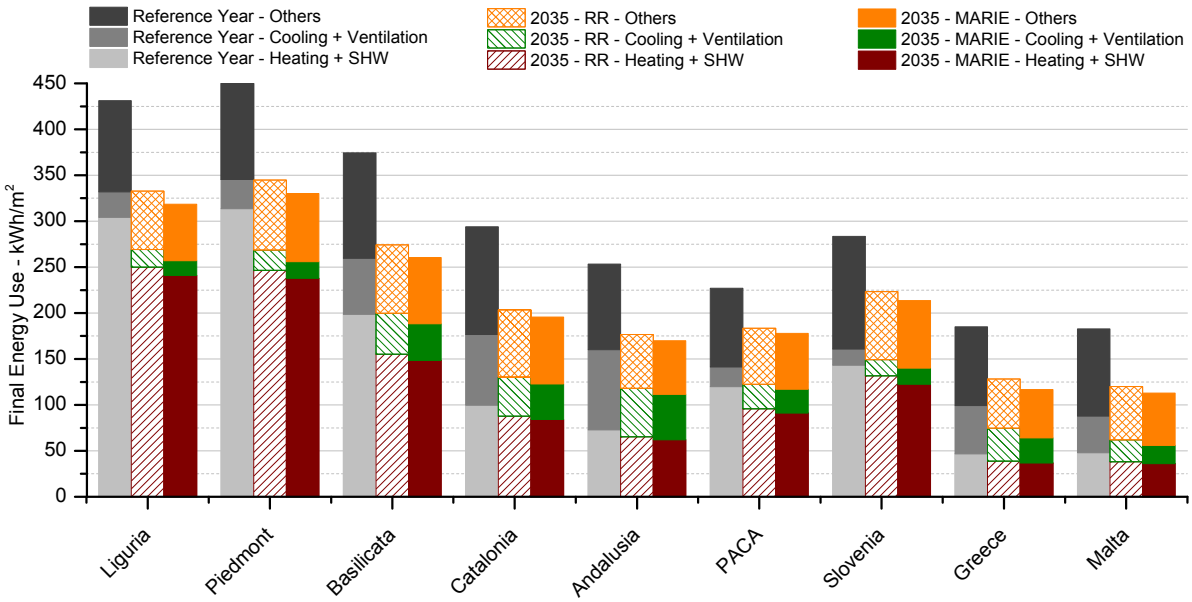


Figure 88 Scenario comparison of total final energy use per unit floor area in the tertiary sector in 2035. Existing building stock

The figures above follow similar yet not identical patterns. The coldest regions are usually among the largest energy users in terms of both energy use per unit floor area and energy use per employee. However, Slovenia (the coldest region in the analysis) is not within the highest energy users (particularly in a per unit floor area basis). Catalonia and Liguria, which have very similar values of HDDs) show substantially different results of tertiary energy use. PACA shows a much higher energy use on a per employee basis than on a per square meter basis. At the

low end of the spectrum, Andalusia, Greece, and Malta exchange positions depending on the calculation basis.

The above differences between figures derive not only from the different trends in the global drivers (m^2 and number of employees), but also from the differences in the structure of the tertiary sector among regions. Sectors differ in energy intensity, specific energy uses (e.g., kitchen) and seasonal profile. Tertiary data by sector as seldom found at a regional scale, therefore the reliability of the above results is compromised by the approximations that had to be made.

It should also be noted that Figure 88 has very little in common with the equivalent figure for the residential sector. This result is consistent with the initial hypothesis that the residential and the tertiary sectors could not be approached with the same method and simulation tool.

4 CONCLUSIONS

1- Need for accurate, detailed, consistent and reliable data at regional level

There is very limited data available at regional level, particularly for the tertiary sector. Data is crucial to support energy planning and decision making. Regional energy bodies should perform comprehensive census to allow for more accurate analysis studies in the future. A common data collection protocol across regions would further ease future cross-regional studies.

2- The first draft of the MEDBEES (i.e., the MARIE scenario) results in larger energy savings than an equally ambitious strategy based on "opposite" policy measures (Rapid Results)

The MARIE scenario shows larger energy use reductions than the Rapid Results scenario in all the analyzed regions, both for the residential and the tertiary sectors. The good evaluation results of the first draft of the MEDBEES validate it as a sound strategy for energy refurbishment in the MED space, and encourage the MARIE consortium to continue working on its detailed definition.

3- The benefits of the MEDBEES arrive slowly, but steadily increase with time

The MARIE scenario shows better results than the Rapid Results scenario in the long run due to the longer cycles associated to the MARIE measures (e.g., market transformation towards easier integral refurbishment). Some energy uses in some regions show better values in RR than in MARIE in the first years of outlook, however, the benefits of MARIE eventually pass those of RR, and the difference tends to increase over time.

4- Even if the MEDBEES was thoroughly implemented, the current lack of private investment capacity would likely prevent the MED regions from meeting the 2020 EU targets. Changing the economic context is beyond the MARIE scope.

The evaluation of both MARIE and Rapid Results is based on the current economic context. Regardless of the strategy, impacts of financial mechanisms on private investment are limited by the current unavailability of private funds. Implementing the MEDBEES would enable investment on energy efficiency refurbishments to some extent; however, maximizing the benefits of the MEDBEES requires more private funds than the currently available. This depends on the overall economic dynamics in the MED space, which is far beyond the reach of the MARIE project. Results show that the MEDBEES is the strategy that provides the largest energy savings. However, it would only be capable of meeting the 2020 EU targets if the overall economy recovered rapidly.

5- Energy efficiency measures for new and existing buildings should be consistent

The scope of this evaluation is limited to refurbishment strategies on the existing building stock. Criteria on the energy efficiency measures for new and existing buildings should be consistent to avoid confusion in the building sector and maximize market transformation. Results of the

present analysis should not be used to evaluate the likelihood of meeting the 2020 energy efficiency targets, since these include both new and existing buildings.

6- Energy refurbishment strategies should be consistent with the broader regional and national energy policies. Savings in final energy use should not be the only target

Energy refurbishment policies target savings in the built environment. This study evaluated the first draft of the MEDBEEs only in terms of final energy use. However, broader regional or national energy policies may (and should) have objectives such as prevention of climate change and resource depletion, for which carbon emissions and primary energy use would be the best indexes, respectively. Fossil fuels, electricity and renewable energy sources have radically different conversion factors from final energy to primary energy and carbon emissions. Furthermore, these factors largely vary across regions due to their different electricity mixes and availability of natural resources. Regions should set up global energy policies that not only help to reduce final energy use, but also promote fuel switching to the energy sources that better suit the overall energy strategy.

7- Regional differences matter

Detailed results show that the regional characteristics largely affect the dynamics of the MEDBEES impacts. Generally speaking, the benefits of the MEDBEES in the residential sector are more rapidly seen in cold regions with a large share of centralized heating systems. The current breakdowns of heating, cooling, and DHW equipment are also key inputs for the analysis.

The differences across regions in the evaluation results of the first draft of the MEDBEES suggest that the strategy should be both adapted and evaluated at a regional level.

8- Heating is the dominant energy use in the residential sector. However, measures to tackle heating energy use should be adapted to the characteristics of the individual regions

Cooling may be a concern in terms of peak power consumption in summer. However, from an annual energy balance perspective, cooling remains a minor energy use in the residential sector, even in the warmest regions.

While in relative terms heating is the largest energy use in almost all the regions, the absolute energy use for heating largely varies across regions. Measures to reduce heating energy use should be adapted to the regional characteristics, since cost effectiveness of measures depends on energy savings in absolute terms (e.g., colder regions are more sensitive to improvements in envelope performance).

Cooling and ventilation is a much larger share of the total final energy use in the tertiary sector, although still smaller than heating in most of the regions. Note, however, that cooling basically uses electricity, which is often worse than fossil fuels and biomass in terms of primary energy, carbon emissions, and cost.

9- Energy use and comfort. Handling the rebound effect in residential heating energy use

The MARIE scenario results in larger heating energy use than RR in the warmest regions (Andalusia and Malta). This rebound effect is due to an increase in the share of centralized heating systems in MARIE (which in turn derives from the larger rate of integral refurbishments). It should be noted, however, that while the increase in share of centralized systems reduces the energy savings achieved with MARIE, it also improves thermal comfort for occupants. Decentralized systems providing the same comfort standards would also use more energy.

Regions with a large share of decentralized heating systems should take into account that integral refurbishment policies would likely lead to larger shares of heated floor area, and thus, to a rebound effect in heating energy use.

5 ACKNOWLEDGMENTS

The authors would like to acknowledge the contributions from the partners of the participant regions, which provided input data for the model as well as local expertise during the regional scenario settings process.

- ARE Liguria, Regional Energy Agency of Liguria (Italy)
- Piedmont Region (Italy)
- Basilicata Region (Italy)
- LIMA Association, Low Impact Mediterranean Architecture (Catalonia, Spain)
- EPSA-COPV, Junta de Andalucía (Spain)
- PACA Region, Provence Alps Cote d'Azur (France)
- GOLEA, Goriska Local Energy Agency (Slovenia)
- ANKO, Regional Development Agency of Western Macedonia (Greece)
- LCA, Local Council Association of Malta (Malta)

The MARIE scenario was based on the common list of barriers and measures defined not only within WP4 and WP5 but also with the very active contribution from other WP members, particularly the WP leaders.

Advisory Group and Scientific Committee members provided key advice in the early stages of the scenario definition process.

In addition to the MURE and Forecast Tertiary simulation tools, ISIS and TEP Energy GmbH provided key support during the scenario definition process. Furthermore, their expertise was crucial to handle the extensive data gaps that existed at regional level.

The overall analysis method was initially developed for Catalonia, and went through several reviews and rounds of feedback before being replicated for the other regions. We would like to express our gratitude to those who most significantly helped us develop the method: Dr. Núria Garrido for the detailed information on the building stock characterization, the LIMA Association for their feedback both on the method and the communication strategy with the partners, ICAEN (the Catalan Energy Agency) for their feedback and advice on forecasting techniques and, last but not least, the Departament de Territori i Sostenibilitat (DTES) for the constant follow up and coordination support.

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7 ANNEX 1 – LIST OF BARRIERS

Table 24 Structural Barriers

STRUCTURAL BARRIERS	
ID	**Description**
S1	No flexibility of budgets to allow large investments in EE (yearly running whereas EE benefits pay back in long term)
S2	Fragmented structure of the supply side at all levels of the chain of value for an efficient way to stimulate both supply and demand sides
S3	Unclear, unstable and short-term oriented operational legislative framework for both offer and demand
S4	Poor integration of European, national, regional and local policies on EE and renewable energy supply, and of the related administrative bodies
S5	Gap between political objectives (3*20 especially) and operational regulations : level, delays, control
S6	Complexity of (1) regulations, (2)implementation and (3) enforcement and verification of compliance
S7	Complex administrative procedures for implementing EE refurbishments
S8	Disconnection between energy efficiency regulations or public incentive schemes from social and behavior issues (and too much linked with technical/academic/financial issues)
S9	Complex decision making for owners renting buildings and not profiting of EE benefits (private renting and social housing)
S10	Complex decision making for multi-owner buildings
S11	Renovation projects are usually conceived as renovation of individual buildings, while better solutions may arise at "neighborhood" scale

Table 25 Technical Barriers

TECHNICAL BARRIERS	
ID	**Description**
T1	Poor level of technical innovation in building sector (creation and dissemination of new processes and techniques)
T2	Lack of technical skills and know-how at all levels of the supply side
T3	Lack of generic skills and organized leadership to address the refurbishment process
T4	Increased market competition for EE products produced outside MED regions due to better value for money
T5	Complexity and uniqueness of most EE refurbishment projects (each case is unique, due to many causes, different possible renovation approaches. E.g., Heritage/cultural value of façades, etc.)

Table 26 Financial Barriers

FINANCIAL BARRIERS	
ID	**Description**
F1	Limited profit margin for ESCOs in small energy refurbishment projects
F2	Bad integration of the real (economical, environmental and social) cost of energy in current energy prices , rendering energy efficiency less profitable
F3	Requirement for large investments for EE refurbishment projects
F4	Lack of public investment and funding capacity
F5	Incapacity of conventional financial instruments to make EE renovations feasible and lack of new/alternative financial models
F6	Lack of private investment capacity

Table 27 Knowledge Barriers

KNOWLEDGE BARRIERS	
ID	**Description**
K1	difficult access and analysis capacity by users to real-time, detailed information on their energy use
K2	Incomplete, unshared, unstable, spread or asymmetric information on EE issues, the best methodology and solutions, providers of available services
K3	Lack of awareness among users on the benefits of EE investments in the long run
K4	Lack of accurate knowledge within politicians, administrative and civil servants
K5	Lack of detailed information on the characteristics of the building stock at regional level
K6	Misconception of the main climate and comfort challenges that the Med area buildings face

Table 28 Behavioral Barriers

BEHAVIORAL BARRIERS	
ID	**Description**
B1	Lack of motivation for energy efficiency in users. The issues of aesthetics, bigger space, fashion and updating, well-being, reducing noise are the most important motivations for refurbishment. As a consequence, there is a distortion between public policies (EE focus only) and consumer behavior
B2	Reluctance of users to accept refurbishment works as they are perceived as intrusive, complex and annoying
B3	Distortion between behavior requirements for use of refurbished building and MED usual way of life (open windows, mobile sun protections, use of control technologies...)
B4	Lack of value of non-material and knowledge-based assets and services such as architecture, engineering, and consulting
B5	Reluctance for collaborative work. New technical and perceived hierarchy between works and professions leading to high reluctance to change practices (but also new opportunities for new professions)

8 ANNEX 2 – LIST OF MEASURES

Table 29 MARIE policy measures

General measures	Sub-Measures	Target Barriers
M.1 AWARENESS AND MARKETING publicity campaigns	Communication and marketing campaigns for users Communication and marketing campaigns for owners and real state agencies (building managers)	K2, K3, K4 B1, B3, B4
M2 TRAINING - qualify human resources and improve customers about ERB	Improve the qualification along the chain of value, from experts to artisans through training courses, seminars and workshops	T1, T2
	Give training, tools and information to companies to help them create a demand for "better solutions" for EE in buildings through training courses and workshops	T3, S2
M3 POLICY COMMITMENTS ensure measures implementation	Increase the involvement of policy makers through specific commitments related to ERB (Energy Renovation of Buildings)	S1, S3, S4, S5, S8
M4 PRIVATE PARTICIPATION Facilitate SME's involvement in MEDBEES	Information and Communication tools implementation to develop the MED market for ERB	K2
	Offer new opportunities to the clusters present in MED regions area, taking into account their differences	S2, S5
M5 PLANNING Identify and use urban planning model to organize and promote ERB	Design and determine information infrastructure to register the physical and energy data from buildings in urban areas	K5
	Design and determine diagnostic and proposal tools for ERB plans at urban scales	S11
M6 LEGISLATION & REGULATIONS adapt legal framework to facilitate ERB	Update, adapt, structure and innovate regional and local regulations and specifications in order to facilitate the EU Directive (2010/31/EU) and the energy renovation of buildings	S3, S4, S5, S6, S7
	Stimulate the Public Sector to become a driver for technological innovation with a correct use of public procurement	S1, T3, F5
M7 FINANCIAL Design and implement new integrated financial schemes for ERB	Stimulate access to finance through private investment mechanisms at building scale	F3, F4, F5, F6
	Develop regional investment plans for Energy Building Renovation based on Public-Private partnership mechanisms	F3, F4, F5
M8 COMPETITIVENESS - improve the competitiveness of enterprises dealing with ERB	Give SMEs access for applied R&D such as new technologies, materials, smart and eco-efficient solutions for buildings	T1, T2, T4

M9 SERVICES- offer better services for enterprises dealing with EE	Foster new and integrated service models to complement present construction, retrofitting and renovation activities, favoring cooperative work and “global” retrofitting (= Offer new types of services, from “Business to Business” to “Business to Consumer”)	S2, T3, K2

9 ANNEX 3 – HEATING AND COOLING LOADS

Table 30 Heating and cooling loads per unit floor area (kWh/m^2-yr) for single and multi family buildings

		Heating and cooling loads (kWh/m2-yr)							
		SINGLE FAMILY (kWh/m2-yr)				MULTI FAMILY (kWh/m2-yr)			
Region	Load	Existing Stock not Refurbished	Refurbishment 1	Refurbishment 2 / New 1	Refurbishment 3 / New 2	Existing Stock not Refurbished	Refurbishment 1	Refurbishment 2 / New 1	Refurbishment 3 / New 2
LIG	Heating	105	89	27	19	62	54	19	13
	Cooling	16	16	18	15	14	14	19	16
PIE	Heating	165	131	60	42	103	85	45	31
	Cooling	8	8	12	9	8	8	13	10
BAS	Heating	185	148	61	42	115	97	44	31
	Cooling	4	4	7	5	4	4	8	6
CAT	Heating	70	59	35	24	45	40	25	17
	Cooling	14	14	11	8	9	9	11	9
AND	Heating	59	51	29	20	28	24	14	10
	Cooling	63	63	59	46	32	32	31	24
PACA	Heating	107	86	37	26	59	49	22	16
	Cooling	26	26	36	23	12	12	17	11
SL	Heating	184	133	68	47	129	104	57	40
	Cooling	1	1	4	3	1	1	5	4
GR	Heating	171	162	76	53	81	77	25	18
	Cooling	51	51	45	36	26	26	26	20
MT	Heating	47	-	39	36	22	-	19	18
	Cooling	54	-	51	39	26	-	26	20