International journal of
Sustainable Energy Planning and Management

A prospective analysis of the employment impacts of energy efficiency retrofit investment in the Portuguese building stock by 2020

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ABSTRACT

Energy efficiency plays a significant role in increasing the security of energy supply and mitigating climate change. Although this role is indubitable, there is an ongoing discussion about the employment impacts of promoting energy efficiency measures, in particular of building retrofit investments. The purpose of this paper is to provide an estimation of the number of net jobs associated with the most common retrofit investment options in the building stock of Portugal. The examined investment options aim at improving the thermal properties of the building envelope and include the insulation of external walls and roof and the substitution of window frames and single glazed windows. The implementation of a methodological framework for the assessment of employment benefits is based on Input-Output (I-O) analysis, providing consistent estimates for depicting the significant contribution of energy saving measures in the building sector (residential, private services and public services) in net employment generation.

Keywords:

Input-Output analysis,
Energy Efficiency,
Buildings,
Retrofit investment,
Employment.

URL: dx.doi.org/10.5278/ijsepm.2014.2.7

1. Introduction

Improving energy efficiency is currently worldwide believed to be the cheapest, fastest and most environmental friendly way to meet a significant portion of the worlds' energy needs. Improved energy efficiency reduces the need for investing in energy supply. Therefore, countries need to pursue energy efficiency policies more diligently in the long-term regardless of the development of fuel prices [1].

The European Union (EU) has set itself the objective of achieving 20% primary energy savings in 2020. In Portugal, the National Energy Strategy (NES 2020) approved by [2] also foresees the approval of a National Energy Efficiency Action Plan (NEEAP) in its energy efficiency guidelines. Moreover, the Portuguese NES 2020 aims to foster the industrial cluster of energy efficiency, creating 21000 new jobs by 2020.

Since there is a strong interest on the promotion of energy efficiency through retrofit investments in buildings, it is somehow of public interest the monitoring of its impact on the employment. Therefore, the aim of this paper is to provide a consistent estimate of the contribution of the previously identified retrofit energy saving measures in the building sector (residential, private services and public services) in net employment generation, i.e., considering both the potential job creation and the potential job destruction resulting from the reduction of energy consumption.

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The paper is organized as follows: section 2, briefly reviews the latest literature on the subject; section 3 presents the methodological framework used herein; section 4 presents the implementation of the methodology in the Portuguese context after a brief characterization of the building sector in Portugal; section 5 provides some illustrative results, and finally section 6 highlights some conclusions and presents future work developments.

2. Review of previous studies

The macroeconomic effects of energy efficiency are mostly expressed in the form of employment or economic growth [3]. A number of studies have sought to estimate the employment potential of several energy efficiency measures in terms of employment factors, though chief methodological challenges remain when determining job creation [4]. In this context, [5] presented an analysis of the employment impacts of two types of energy conservation efforts, namely retrofitting of buildings and increased energy efficiency in the industrial sector in the United States of America (USA). [6] evaluated several dimensions of low cost techniques in building construction in India and estimated the generation of on-site employment that occurred from these interventions. [7] provided a template for economic evaluation of domestic energy-efficiency programs. In their study they estimated the number of jobs resulting from the implementation of various energy efficiency technologies in the Irish dwelling stock over a ten-year period. [8] analyzed the macroeconomic impacts of increasing energy efficiency in the USA's residential and commercial building stock, using Input-Output (I-O) analysis. [9] examined the social impacts (employment and fiscal revenues) of an energy conservation program in Germany. [10] estimated the net employment impacts of a large-scale energy efficiency retrofit programme in Hungary, simulating five scenarios. [11] presented the results of the implementation of an efficiency strategy in Germany until 2020, which is focused on cost-effective measures. The outcomes obtained show that improved energy efficiency results in a variety of positive effects on the economy and the environment, namely on additional employment and economic growth. [12] have demonstrated in their study that there is a triple win available of warmer homes, greater energy efficiency and economic growth if carbon taxes revenue can be used to benefit consumers and fuel poor households in particular in United Kingdom (UK). [13] analyzed the potential of a national building energy rating and disclosure policy to create jobs and reduce energy-related expenditures in commercial and multifamily residential buildings in USA.

Among the energy efficiency measures available, energy retrofit measures are known to be some of the most cost effective ways of saving energy and reducing greenhouse gas emissions. In addition, such measures can result in a significant number of local and national employment opportunities. According to [14] energy efficiency retrofit investments in buildings can be more labour-intensive than any other key climate intervention. Retrofits require the upgrade of old buildings, involving the physical and operational upgrade of thermal conditions of buildings, leading to lower energy consumption.

In Portugal the scientific literature on this field of research is not abundant. In this framework, and to our knowledge, only in [15] some preliminary results are reported regarding the trade-off analysis of the main impacts due to the implementation of the same four specific energy efficiency retrofit measures herein tackled on the overall employment and GDP. A systemic methodology has been proposed by introducing a bottom-up approach in a previous version of a top-down Multiobjective Linear Programming (MOLP) I-O model with interval coefficients that allows the assessment of avoided energy consumption and CO_2 emissions associated with the retrofit measures. However, besides the fact that the previous methodological approach only considers the average trade-offs for a prospective year, ignoring the accumulated effects, further insights are also necessary for the study of employment generation, requiring the models' closure, namely by explicitly considering the induced effects. Therefore, this paper is aimed at computing besides the projected accumulated direct and indirect employment effects, the expected accumulated induced effects (Type II multipliers) corresponding to those originated by the re-spending of income resulting from both direct and indirect effects from 2009 (the base year of our study) until 2020. Finally, the possible negative impacts of these energy retrofit measures will also be analysed by considering the potential reduction of energy consumption and the corresponding backward and forward sectoral linkages on job generation.

3. Methodological framework

I-O matrices allow the representation of each sector's production process through a vector of structural coefficients that describes the relationship between the intermediate inputs consumed in the production process and the total output. The supply side is split into several processing industries that deliver their total output (production), for intermediate consumption or final demand. These relationships can be illustrated through the following equation:

$$x_i = \sum_{j=1}^{n} x_{ij} + y_i \qquad 3.1$$

where x_i is the output of sector i, x_{ij} is the input from sector i to sector j, and y_i is the total final demand for sector i.

The monetary values in the transactions matrices can then be converted into ratios called technical coefficients. This is done by dividing each cell of the domestic intermediate matrix by its column total (output at basic prices).

Considering the hypothesis of constant returns to scale, Eq. 3.1 becomes:

$$x_i = \sum_{j=1}^{n} a_{ij}\, x_j + y_i \qquad 3.2$$

in which the coefficients a_{ij} are the amount of input delivered by sector i to sector j per unit of sector's j output, known as technical coefficients (or direct coefficients).

The productive system at a national level can then be represented through the following basic I-O system of equations:

$$\mathrm{x} = \mathrm{Ax} + \mathrm{y} \qquad 3.3$$

where A is a matrix of technical coefficients, y is a vector of final demand, and x is a vector of the corresponding outputs.

In order to finally calculate the output multipliers, one needs to derive Leontief inverse matrices.

Eq. 3.3 can then be rearranged to:

$$\mathrm{x} = (\mathrm{I} - \mathrm{A})^{-1}\mathrm{y}, \qquad 3.4$$

where I is the identity matrix with convenient dimensions and $(\mathrm{I} - \mathrm{A})^{-1}$ is also known as the Leontief inverse. Each generic element, b_{ij}, of $(\mathrm{I} - \mathrm{A})^{-1}$ represents the total amount directly and indirectly needed of good or service i to deliver a unit of final demand of good or service j.

3.1. Employment multiplier concepts and basic assumptions

Usually in models that account for job creation, jobs are measured in terms of job-years or full time equivalency. In our study, a job is a metric that represents the amount of resources necessary to employ one person for forty hours per week for a full year (i.e. full time employment – FTE).

Although precise definitions vary, direct jobs herein considered refer to the jobs generated from a change in spending patterns resulting from an expenditure or effort taken in a retrofit project [16]. Thus, the direct job contribution of a retrofit measure in terms of employment can easily be obtained by considering the direct job coefficients (jobs per output) of each activity sector engaged in all the activities of that retrofit measure. Indirect jobs are generated in the supply chain and supporting industries of an industry that is directly impacted by an expenditure or effort [16]. Induced jobs are generated by the re-spending of income resulting from newly created direct and indirect jobs [16].

Since the employment to output ratio is given for each sector in an I-O table, the overall significance and contribution of an industry to total employment can also be calculated by assuming that the sectorial employment ratios are fixed.

Thus, the indirect contribution of an industry to either total output or employment is not simply observable unless the multiplier and flow-on effects are taken into account. Therefore, the type I employment multiplier may be interpreted as the impact on the overall employment if the final demand in sector j increases by one unit. The employment multiplier for sector j, E_j^m, is thus defined as follows:

$$E_j^m = \sum_{i=1}^{n} (e_i) b_{ij}, \qquad 3.5$$

where e_i denotes the number of persons with FTE per one Euro output for each sector i, b_{ij} is the i, j^{th} element of the closed Leontief inverse matrix and n is the number of sectors. These multipliers would represent the number of new jobs created expressed as total employment for every new employee to meet increased final demand of new output, but one may wish to relate the simple or total employment effect to an initial change in employment, not to final demand (and output) in monetary terms. In this situation the employment multiplier, E_j, is:

$$E_j = \sum_{i=1}^{n} \frac{(e_i) b_{ij}}{e_j} \quad 3.6$$

Finally, induced effects represent the response by all local industries caused by increased (decreased) expenditures of new household income and inter-industrial transfers generated (lost) from the direct and indirect effects of the change in final demand for a specific industry. Because the purpose of this type II employment multiplier is also to estimate the flows of money in and out of households and the effect of these transactions upon industries (i.e., the induced effect), it is necessary to 'endogenise the household sector'. This consists on treating households as an additional industry by adding an extra row and column into the direct requirements table for 'compensation of employees' and 'household expenditures' coefficients, respectively.

A short example of the application of this methodology in our study will be provided when grasping some illustrative results in section 5.

4. Implementation of the methodology in Portugal

The building sector represents about 40% [17] and 30% [18] of total energy consumption in the European Union and Portugal, respectively. Therefore, the reduction of energy consumption in the building sector is an important measure for reducing the CO_2 emissions and energy dependence [17]. According to the Energy Efficiency Plan (EEP) [19] the building sector offers the greatest energy saving potentials. The EEP is focussed on the instruments aimed at promoting the process of retrofit in public and private buildings and thus improving the energy performance of the components and appliances used in them.

In Portugal, the first regulation related to energy performance and thermal comfort of buildings was endorsed in 1990 and required that new buildings and great refurbishments of existing buildings implemented measures to improve building energy performance. In the sequence of the previous European Directive on the energy performance of buildings [20] that was addressed to the Member States, a package of new regulation was enforced in Portugal in 2006 and is currently binding. In the building sector, the Portuguese legislation includes regulations regarding the energy and indoor air quality performance in buildings through the National System of Energy Certification and Indoor Air Quality in Buildings (SCE) [21], according to the requirements and statements contained in the Regulation of Building Conditioning of Energy Systems (RSECE) [22], and according to the Regulation of the Characteristics of Thermal Behaviour of Buildings (RCCTE) [23]. This new legislation package is stricter than the previous one and is either applicable to the new or older buildings needing great rehabilitation interventions. Therefore, the major potential for energy efficiency improvements exists in buildings, which have been constructed before 1990, when the first thermal insulation regulation was enacted. These buildings represent 71% of the existing building stock and 20% of this percentage have been constructed before 1945.

In order to estimate the direct, indirect and induced employment effects associated with the implementation of energy efficiency retrofit investment in the Portuguese building sectors it was first necessary to use an I-O symmetrical product by product table for total flows. The I-O table herein used was also used in [24] and is given at current prices of 2008.

Our analysis is focussed on buildings from the residential, private services and public services sector, considering two different construction stages: buildings dating back to 1945 and buildings constructed within the range of 1946 to 1990. Four key categories have been identified as important to be integrated into a retrofit project: window frames, window glazes and roof and wall insulation.

The total investment costs associated with the implementation of the retrofit investments considered were first disaggregated to account for the economic sectors directly involved with each retrofit investment. Moreover, we assumed that the impact on employment regarding these interventions is expected to occur within the country.

Fig. 1 depicts the sectoral distribution of the investment for each of the interventions herein tackled, which was based on several experts' opinions

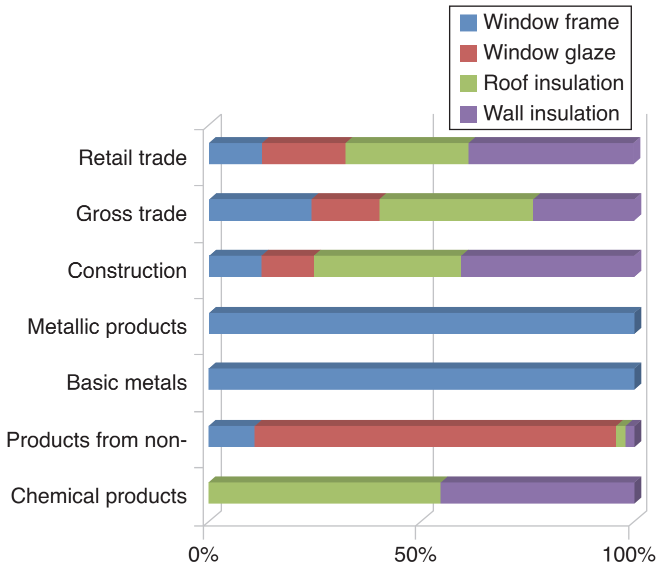

Figure 1: Sectoral distribution of each retrofit investment.

(academics and practitioners in the field of energy efficiency).

The unit investment costs (at basic prices) are given in Table 1 and were estimated for 2008 (the base year of our study) and were based on [25] and [26]

Table 1: Unit costs of each retrofit measure.

	Year of construction	
Retrofit measure (€/m²)	**< 1945**	**1946–1990**
Roof thermal insulation	18	13
Opaque facades	35	25
Double glazed windows	75	75
Window Frame	151	151

5. Illustrative results

The illustration of the methodology followed in section 4 will be performed for single glazed window replacement in single dwellings with four facades built before 1945, being analogous in the remaining retrofit investment options and therefore omitted. According to the building stock characterization provided in [27], the average window glazed area of this type of buildings is 17.2 m^2 and the useful floor area is about 225 m^2. Therefore, the total investment cost per building might be obtained through the costs provided in Table 1, corresponding to 1290 € and the total investment per useful floor space is 5.73 €.

The coefficients for job generation are then obtained by considering the information regarding the activity sectors directly engaged with this retrofit measure (see Table 2 and Table 3 below). The results obtained in Table 3 are observable in the second row of Table 4.

For an illustrative purpose we will only provide the sectoral distribution of the total estimated employment effects (direct, indirect and induced employment) for each energy efficient strategy in single dwellings with four facades, although this could be depicted for all types of buildings herein considered (see Fig. 2). If the option of single glazed window replacement is followed either with frames or not, the manufacturing industry contributes with the highest job generation potential, followed by construction. If the options of roof or wall insulation are privileged construction has the highest job generation potential followed by the manufacturing industry and services.

After analysing the total results of Table 4 it might be concluded that the buildings with highest job generation potential belong to private and public services,

Table 2: Data for computing job generation with single window glazing replacement in single dwellings with four facades built before 1945.

Activity Sectors	Investment Assignment	Window Glaze Investment (€/1000 m² useful floor space)	Direct Employment Coefficients (FTE jobs /10^6€)	Indirect Employment Coefficients	Induced Employment Coefficients
Chemical products	0%	0	3.6013	2.9391	6.5661
Products from non-metallic minerals	80%	4587	12.1864	1.8772	3.4555
Basic Metals	0%	0	3.9551	2.9546	6.2627
Metallic Products	0%	0	14.6715	1.5612	3.0656
Construction	15%	860	14.9514	1.9184	3.5698
Gross Trade	2%	115	14.4030	1.6539	3.4778
Retail Trade	3%	172	28.7788	1.2642	2.2322

Table 3: Direct, Indirect and Induced job generation for single window glazing replacement in single dwellings with four facades built before 1945 (FTE/ 1000 m^2 of useful floor space).

Activity Sectors	Direct Employment	Indirect Employment	Induced Employment
Chemical products	0.0000	0.00000	0.00000
Products from non-metallic minerals	0.0559	0.04903	0.08822
Basic Metals	0.0000	0.00000	0.00000
Metallic Products	0.0000	0.00000	0.00000
Construction	0.0129	0.01181	0.02123
Gross Trade	0.0017	0.00108	0.00301
Retail Trade	0.0049	0.00131	0.00479
TOTAL	**0.0754**	**0.0632**	**0.1173**

Table 4: Employment impacts for each building type and retrofit measure (FTE/ 1000 m^2 of useful floor space).

Building Function	Building Type	N° of Facades	Retrofit Investment	Direct Jobs	Indirect Jobs	Induced Jobs	Total
Residential	Single Dwelling (<1945)	4	Window Frame	0.1268	0.1056	0.2225	0.4550
			Window Glaze	**0.0754**	**0.0632**	**0.1173**	**0.2558**
			Facade Insulation	0.3472	0.3244	0.6241	1.2956
			Roof Insulation	0.0914	0.0903	0.1740	0.3557
		2	Window Frame	0.0737	0.0614	0.1294	0.2645
			Window Glaze	0.0438	0.0368	0.0682	0.1487
			Facade Insulation	0.2018	0.1886	0.3628	0.7533
			Roof Insulation	0.0914	0.0903	0.1740	0.3557
	Apartment Building, 3 floors (1946–1990)	4	Window Frame	0.1125	0.0937	0.1973	0.4034
			Window Glaze	0.0668	0.0561	0.1040	0.2268
			Facade Insulation	0.1721	0.1608	0.3093	0.6421
			Roof Insulation	0.0440	0.0435	0.0838	0.1712
		2	Window Frame	0.0664	0.0553	0.1164	0.2381
			Window Glaze	0.0394	0.0331	0.0614	0.1339
			Facade Insulation	0.1015	0.0949	0.1825	0.3790
			Roof Insulation	0.0440	0.0435	0.0838	0.1712
Private Services	Apartment Building, 3 floors (<1945)	4	Window Frame	0.9513	0.7922	1.6688	3.4124
			Window Glaze	0.5652	0.4742	0.8794	1.9188
			Facade Insulation	0.2264	0.2115	0.4070	0.8450
			Roof Insulation	0.0610	0.0602	0.1160	0.2371
	Apartment Building, 4 floors (1946–1990)	2	Window Frame	0.5310	0.4422	0.9314	1.9046
			Window Glaze	0.3154	0.2647	0.4908	1.0710
			Facade Insulation	0.0451	0.0422	0.0811	0.1684
			Roof Insulation	0.0330	0.0326	0.0628	0.1284
Public Services	Apartment Building, 3 floors (<1945)	4	Window Frame	0.3765	0.3136	0.6605	1.3506
			Window Glaze	0.2237	0.1877	0.3481	0.7595
			Facade Insulation	0.0896	0.0837	0.1611	0.3344
			Roof Insulation	0.0610	0.0602	0.1160	0.2371
Public Services	Apartment Building, 3 floors (1946–1990)	4	Window Frame	0.3765	0.3136	0.6605	1.3506
			Window Glaze	0.2237	0.1877	0.3481	0.7595
			Facade Insulation	0.0640	0.0598	0.1151	0.2389
			Roof Insulation	0.0440	0.0435	0.0838	0.1712

involving the replacement of single by double glazed windows and with or without frame replacement. This fact occurs due to the higher extension of the glazed area in this type of buildings. In the residential sector the highest job impacts are obtained with external thermal insulation of the opaque facade in dwellings with four facades built before 1945, when the construction materials had lower quality levels.

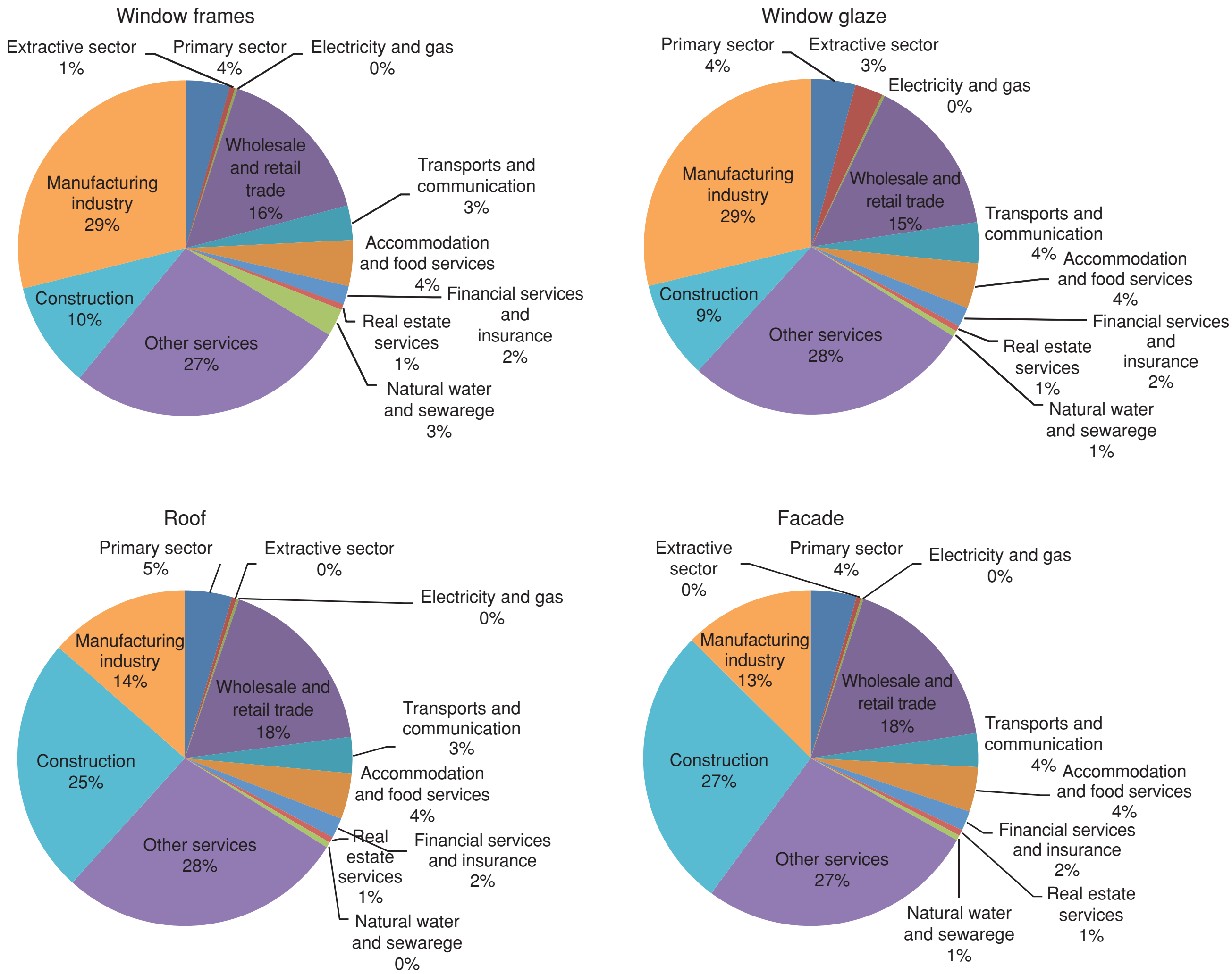

Figure 2: Sectoral distribution of the total estimated employment effects for a single dwelling with four facades (considering 1000 m^2 of useful floor space).

The prospective results for 2020 were obtained taking into account the necessary estimated retrofit investments per useful floor space according to the information provided in [26]. Fig. 3 illustrates the assignment per useful floor space of the retrofit measures that are expected to take place in the current building stock until 2020. The NEEAP incentives for the investment on the replacement of non-efficient glazed areas in the residential sector was herein considered, which accounts for 200 thousand dwellings until 2015. In addition, we have also considered the NEEAP incentives regarding thermal insulation (roof and facades), which considers 100 thousand dwellings to be refurbished until 2015. For the public and private service sectors we have considered that 39% of the total stock building area needs retrofit investment, where 3% of these are extremely damaged builds [26].

According to our assumptions, the useful floor space (in 1000 m^2) possibly subject to a retrofit intervention from 2009 until 2020 is given in Table 5, corresponding to an expected maximum average annual investment of 13 321 million Euros in the residential buildings, 12 630 million Euros in private service buildings and 2 200 million Euros in public service buildings.

The direct, indirect and induced employment totals (see Table 6) are then obtained by using the data provided in Table 4 and Table 5.

From the last column of Table 6 it might be concluded that the energy efficiency retrofit measures with a higher impact on total employment are those related to single

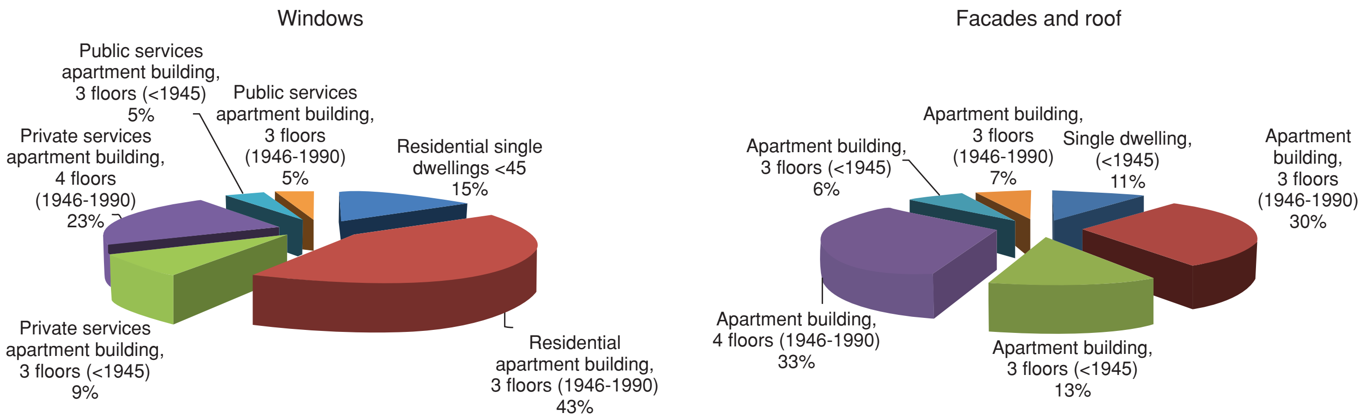

Figure 3: Assignment of retrofit investments according to the useful floor space.

Table 5: Accumulated useful floor area for each retrofit measure (1000 m^2).

Building Function	Building Type	Windows	Facades	Roof
Residential	Single dwellings (<1945)	1687500	843750	843750
Residential	Apartment Building, 3 floors (1946 – 1990)	4668750	2334375	2334375
Private services	Apartment Building, 3 floors (<1945)	1000000	1000000	1000000
Private services	Apartment Building, 4 floors (1946 – 1990)	2500000	2500000	2500000
Public services	Apartment Building, 3 floors (<1945)	500000	500000	500000
Public services	Apartment Building 3 floors (1946 – 1990)	500000	500000	500000

Table 6: Direct, indirect and induced job totals per each type of building and retrofit measure.

Building Function	Building Type	N° of Facades	Retrofit Investment	Direct Jobs (FTE)	Indirect Jobs (FTE)	Induced Jobs (FTE)	Total (FTE)
Residential	Single Dwelling (<1945)	4	Window Frame	214	178	375	768
			Window Glaze	127	107	198	432
			Facade Insulation	293	274	527	1093
			Roof Insulation	77	76	147	300
		2	Window Frame	124	104	218	446
			Window Glaze	74	62	115	251
			Facade Insulation	170	159	306	636
			Roof Insulation	77	76	147	300
	Apartment Building, 3 floors (1946–1990)	4	Window Frame	525	437	921	1883
			Window Glaze	312	262	485	1059
			Facade Insulation	402	375	722	1499
			Roof Insulation	103	101	196	400
		2	Window Frame	310	258	544	1111
			Window Glaze	184	154	286	625
			Facade Insulation	237	221	426	885
			Roof Insulation	103	101	196	400
Private Services	Apartment Building, 3 floors (<1945)	4	Window Frame	951	792	1669	3412
			Window Glaze	565	474	879	1919
			Facade Insulation	226	212	407	845
			Roof Insulation	61	60	116	237

Table 6: Direct, indirect and induced job totals per each type of building and retrofit measure (Continued).

Building Function	Building Type	N° of Facades	Retrofit Investment	Direct Jobs (FTE)	Indirect Jobs (FTE)	Induced Jobs (FTE)	Total (FTE)
	Apartment Building, 4 floors (1946–1990)	2	Window Frame	1327	1105	2329	4761
			Window Glaze	789	662	1227	2677
			Facade Insulation	113	105	203	421
			Roof Insulation	83	81	157	321
Public Services	Apartment Building, 3 floors (<1945)	4	Window Frame	188	157	330	675
			Window Glaze	112	94	174	380
			Facade Insulation	45	42	81	167
			Roof Insulation	30	30	58	119
Public Services	Apartment Building, 3 floors (1946–1990)	4	Window Frame	188	157	330	675
			Window Glaze	112	94	174	380
			Facade Insulation	32	30	58	119
			Roof Insulation	22	22	42	86

glazed window replacement with or without frame substitution, except for older single dwellings where facade insulation has a higher contribution. This fact might be the result of the poor quality of the materials construction used in these older types of buildings.

In order to obtain the possible negative impacts of energy efficiency savings on employment we have considered that the building heating and cooling systems are obtained from electric loads. This assumption does not comply with the recent building stock (particularly in the residential sector), but it is reasonable to assume that the building stock built before 1990 mainly uses electricity for space heating and cooling. The energy savings potential was computed through the consideration of the information provided in Table 7 which is based on [27].

Fig. 4 illustrates the total expected energy savings obtained for each retrofit measure taking into account the total heated area and the replacement of single by double glazed windows with and without frame replacement (upper side and lower side of Fig. 4). The corresponding electricity saved at basic prices of 2008 would be approximately of 472 millions of Euros (according to the data provided in the adjusted I-O matrix given in [24]).

Table 7: Energy reduction kWh/year/m^2.

	Roof	Window	Window+frame	Façade
Buildings <1945	65.00	30.50	43.30	156.30
Buildings 1946–1990	65.00	43.10	50.50	28.70

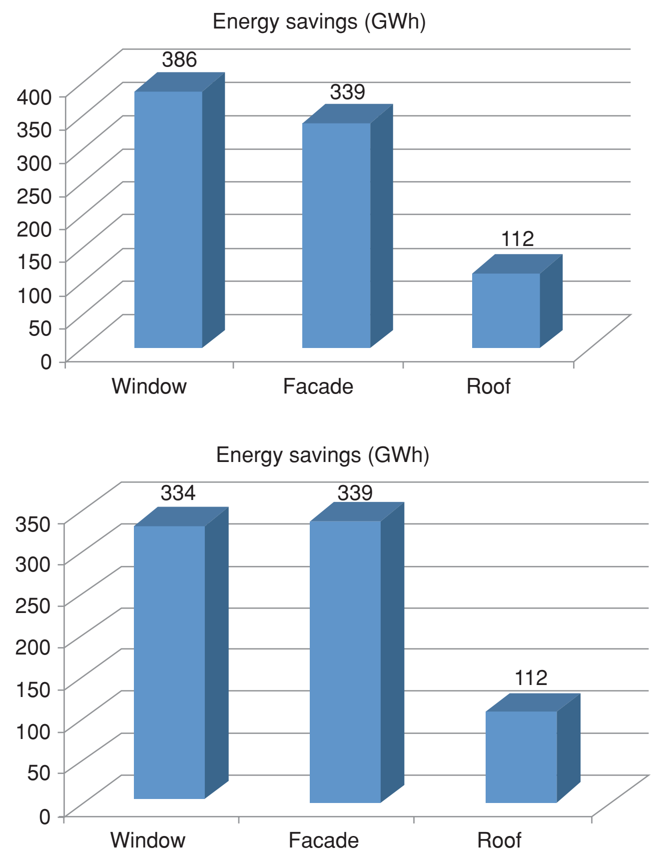

Figure 4: Expected energy savings in GWh per retrofit measure.

Based on the Portuguese Energy Balance [18] and on the I-O table derived in [24] we have also obtained the expected avoided imports of primary energy according to the electricity production mix of the base year for each retrofit measure, taking into account the total heated area and the replacement of single by double glazed windows with and without frame replacement (left hand side and right hand side of Fig. 5). It is worth noting that only the direct impacts regarding the expected electricity savings have been herein considered.

The computation of the avoided CO_2 emissions has been obtained by considering the average emission factor of 0.369 of t CO_2/MWh considered in [28], also taking into account the total heated area and the replacement of single by double glazed windows with and without frame replacement (left hand side and right hand side of Fig. 6). In this case only the direct impacts were accounted for.

The data depicted in Table 8 was achieved considering a best and worst scenario regarding single glazed window replacement. On the upper side it can be observed the expected job generation with the replacement of single by double glazed windows and frames. On the lower side of this table, the expected job generation only with the replacement of single by double glazed window is presented.

Table 8: Net job creation until 2020 considering windows with or without frame replacement.

	Job creation	Job destruction	Net Job creation
Direct jobs	5902	359	5543
Indirect Jobs	5155	2824	2331
Induced Jobs	10503	5426	5076
Total Jobs	21561	8609	12951
Average Jobs/year	1960	783	1177
Direct jobs	4348	337	4012
Indirect Jobs	3875	2647	1228
Induced Jobs	7326	5087	2239
Total Jobs	15550	8071	7479
Average Jobs/year	1414	734	680

After analysing Table 8 it is possible to conclude that the retrofit measures tackled in this study have a great potential in job generation creating much more jobs than

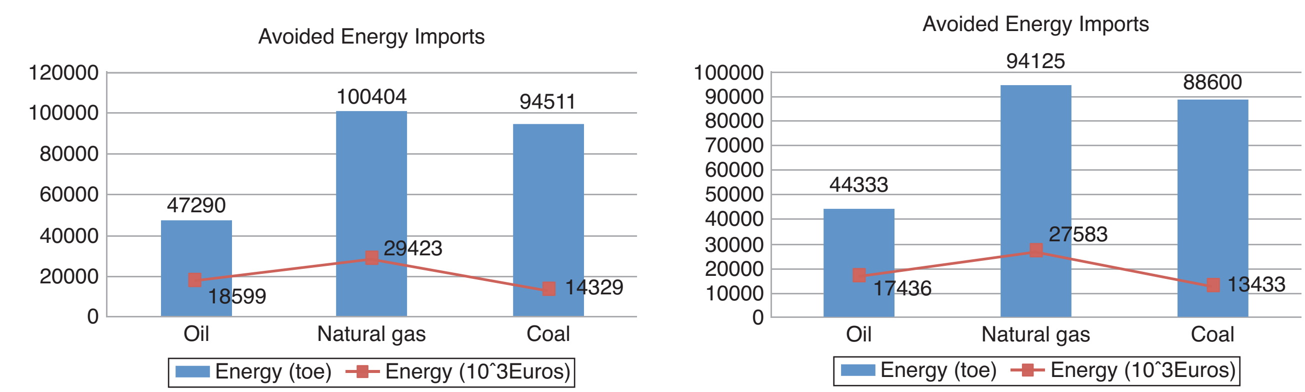

Figure 5: Avoided imports of primary energy in tonnes of oil equivalent (toe) and at purchaser prices (10^3 Euros).

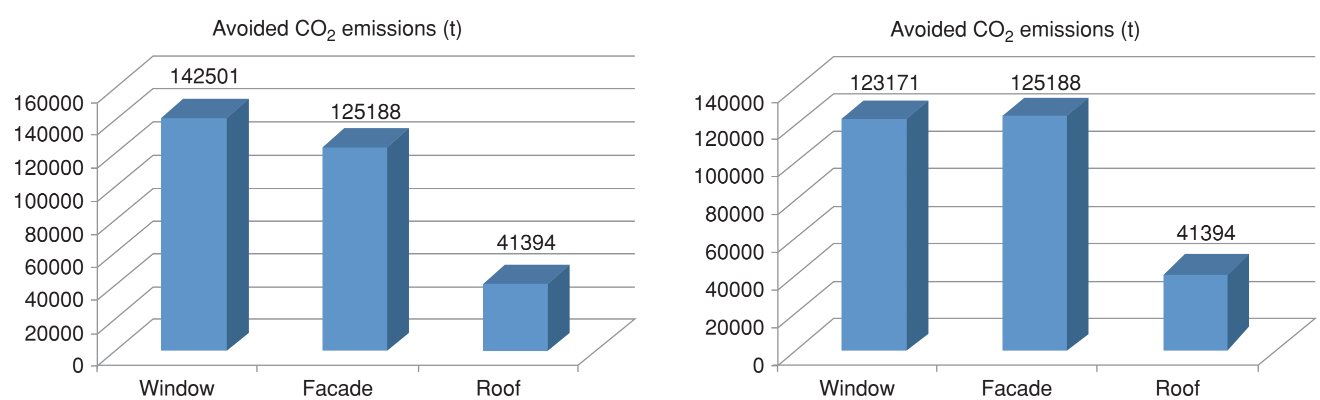

Figure 6: Avoided CO_2 emissions per retrofit measure in tonnes (t).

the expected destruction by the energy savings accomplished. Nevertheless, it is worth noting that the rebound effect was not handled in this study.

6. Conclusions

The main purpose of this study was to assess the impact of four specific energy efficiency retrofit measures on direct, indirect and induced jobs in several types of buildings, representing 71% of the building stock in Portugal. The measures chosen to perform the analysis involved the thermal insulation of roof and the opaque facades and the replacement of the existing glazed windows with more efficient ones. The difference of the results obtained by considering the replacement of frames in windows was slightly different regarding the opposite option. The first option allowed for lower levels of energy consumption and also higher levels of net job generation. This situation occurs because of the higher investment required for the implementation of this measure. Regarding the destruction of employment, both situations are identical although the first one generates slighter negative impacts. The target buildings belong to the residential, private services and public sectors and have been constructed before 1990, the year of the enactment of the first Portuguese regulation related to thermal performance of buildings.

This study also highlights that energy efficiency investments have advantages over a set of other climatic alternatives, namely the increase of energy security and higher social benefits, because the electricity bill can be reduced, higher comfort levels can be attained and also because of its positive net impact on employment generation, what is in accordance with current European, and namely Portuguese, energy policy.

Future work is currently under way in order to encompass other impacts of energy efficiency measures which allow providing a broader view of the employment effects of a global energy conservation plan for Portugal, combined with information on total energy savings directly and indirectly linked to this energy conservation plan; the corresponding effects on the Portuguese balance of payment as a consequence of that plan, eventual policy suggestions for its implementation and, finally, the estimation of the state budget effects, including positive effects of increased employment and increased incomes and reduced unemployment payments.

Acknowledgments

The authors would like to acknowledge FCT support under project grant PEst-C/EEI/UI0308/2011, the Energy for Sustainability Initiative of the University of Coimbra and the R&D Project EMSURE Energy and Mobility for Sustainable Regions (CENTRO 07 0224 FEDER 002004).

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