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The Need to Decarbonise Buildings: Reasons, Challenges and Objectives

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ABSTRACT

The article addresses the relevance of the real estate sector in climate change control through the decarbonisation of buildings. It presents a case study of an investment portfolio artificially constructed from randomly selected buildings in different Spanish cities and with different uses, evaluated in terms of their structural and energy characteristics. The CRREM tool is used to evaluate the decarbonisation horizon of the buildings between 2018 and 2050, their total emissions and their cost, in relation to the maximum allowed in the agreements signed by the EU in Paris (COP21). From this calculation, an assessment is provided of when buildings will become energetically stranded (energy obsolete) assets and the cost of carbon emitted above permitted levels. These calculations lend transparency to the investment decision-making process facing building owners in the EU over the next 30 years.

Key words: Stranding risk, Building decarbonisation, Real estate, Global warming, Spain, COP21, CRREM.

JEL Classification: Q51; Q52; Q54; Q56; Q58; R32; R38

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La Necesidad de Descarbonizar los Edificios: Razones, Retos, Objetivos

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RESUMEN

El artículo aborda la relevancia del sector inmobiliario en el proceso de control del cambio climático a través de la relevancia del proceso de descarbonización de los edificios. Plantea un caso de estudio de una cartera de inversión construida artificialmente a partir de edificios seleccionados aleatoriamente en distintas ciudades españolas y con distinto uso, los cuales se evalúan en cuanto a sus características estructurales y energéticas. Utilizando la herramienta de CRREM, se evalúa el horizonte de descarbonización de los edificios entre 2018 y 2050, el total de sus emisiones y su coste, comparado con el máximo que permiten los acuerdos firmados por la UE en Paris (COP21). A partir de este cálculo, se aporta una evaluación de la fecha en que los edificios se convertirán en activos obsoletos energéticamente, así como del coste del carbono emitido por encima de lo permitido. Estos cálculos aportan transparencia al proceso de toma de decisión de inversión al que se enfrentan los propietarios de edificios en la UE en los próximos treinta años.

Palabras clave: Descarbonización de edificios, Bienes inmobiliarios, Riesgo de obsolescencia energética, Cambio climático, España, COP21, CRREM.

Clasificación JEL: Q51; Q52; Q54; Q56; Q58; R32; R38

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1. Introduction. The relevance of decarbonisation in the real estate market

International commitments to reduce carbon emissions took an important step forward with the Paris Agreement (COP21) reached at the 21st Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) in 2015. As part of that agreement, signatory countries pledged to undertake the necessary measures to keep global warming below a 2ºC rise in temperature compared to pre-industrial levels. In successive pacts, the signatory countries lowered this global warming limit to 1.5ºC. The European Union (EU) signed these agreements in October 2016, initially along with 169 countries although the number of signatories subsequently rose to 197. By so doing, the countries accounting for a majority of CO2 emissions committed to implementing containment measures from 2020 with the entry into force of the Paris Agreement. The process may become even tougher since as the planet warms, the climate changes and with it the obligation to adapt all systems to ensure lower emissions.

The EU's adoption of the agreement required its application to all Member States from the moment it came into force. As such, the various European economies must transition to a social and economic system that eliminates excess carbon and greenhouse gas emissions. Given the current emissions levels, this process can be seen as a drastic intervention, entailing substantial change in the means and modes of production and way of life in European society.

The EU had previously (in 2009) started its policy of supporting efforts to curb global warming by producing binding legislation, known as the 2020 package, which included a series of initial climate and energy targets to be achieved by 2020: (1) 20% reduction in greenhouse gas emissions (from 1990 levels); (2) 20% of EU energy consumption to come from renewable sources; and (3) 20% improvement in energy efficiency. The 2020 package was based on the EU Emissions Trading Scheme (EU-ETS) together with other policy areas such as national emission reduction targets, national targets on renewable energy generation and the Energy Efficiency Plan and directives, including the 2010 recast of the Energy Performance of Buildings Directive (EPBD) (Hirsch et al., 2019). Within the former, this plan calculates, for each Member State, what are known as Effort Sharing Decisions (ESD)[1] on decarbonisation, in terms of reductions in CO2 or equivalent. The related targets range from -20% (from 2005 levels) for the wealthiest member states to +20% for the least wealthy, by 2020. Targets for 2030 range from 0% to -40% compared to 2005 levels of direct emissions.

In preparation for the COP21, the European Council published the '2030 Framework for Climate and Energy'[2] in which it establishes the three abovementioned objectives but sets more demanding reduction rates (40% reduction of greenhouse gases, 27% renewable energy generation as a share of total energy, and a 27% improvement in energy efficiency 27%) to be achieved by 2030. The 40% reduction was deemed necessary to achieve a maximum temperature rise of 2ºC. Subsequently, calculations and implementation showed that this effort was insufficient to ensure the maximum warming, and a further reduction of 55-65% was needed to achieve zero CO2 emissions by 2050 (EU(2012) Energy Roadmap 2050, Climact, 2018).

With the 'Energy Roadmap 2050' the EU defined the objectives of reducing emissions by up to 80-95% by 2050 and urged the development of different policies for the energy system to achieve the decarbonisation of economies while maintaining energy supply security and competitive prices. This objective was to be achieved by reductions of between -5.3% and -11.7% per year on top of the 2030 goals. Four decarbonisation scenarios in which to act and set targets were established: (1) High energy

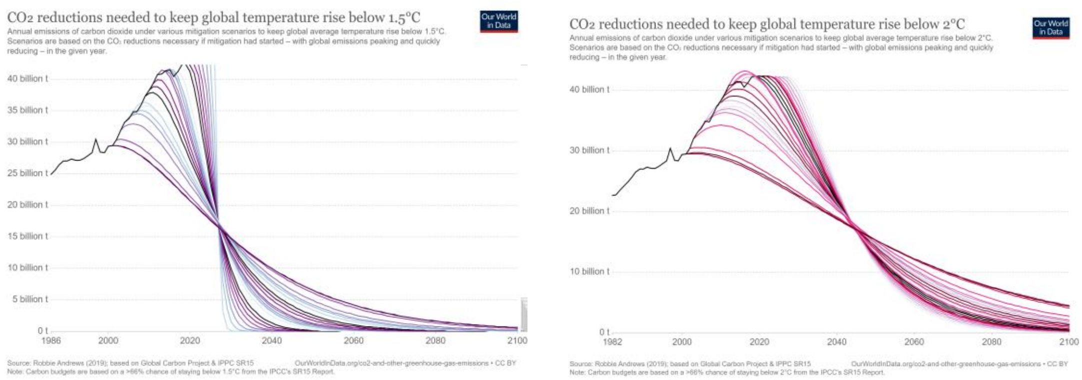
[1] On 14th May 2018, the European Commission adopted the new Effort Sharing Decision (ESD) to complement the EU-ETS system (the emission allowances market, which act as a support for emission surpluses of some Member States and reduction of others). The objective of ESD is to reduce emissions from the covered sectors by 10% by 2020 and by 30% by 2030, below 2005 levels. The ESD translates the commitments adopted in 2015 into binding annual greenhouse gas emission targets for each Member State for the periods 2013-2020 and 2021-2030, based on equity, cost-effectiveness and environmental integrity. The national targets are therefore based on the relative wealth of the Member States, as measured by gross domestic product (GDP) per capita.

[2] European Commission (2014).

efficiency (reducing energy demand by 41% by 2050); (2) increase in renewable energy sources (75% share of gross final energy consumption and 97% share of electricity consumption); (3) Nuclear energy (possible depending on levels of acceptance of nuclear generation, from low—non-nuclear—to levels that support this generation); and (4) application of carbon capture and storage (CCS) technology (which depends on the development of the technology and its commercial viability, but will be applied as a mandatory technology to methods that still emit). The EU argues that the four targets will reinforce each other and that the estimated emission reductions are possible. These agreements are implemented based on an estimate of the volume of emissions and the maximum that scientists calculate can be absorbed in the carbon cycle[3] without the temperature rising above the historical average. This concept is called the carbon budget and it is estimated that the global amount of carbon that could be naturally absorbed between 2019 and 2050 (and that economies could emit) without the temperature rise exceeding 1.5ºC is 669 GtCO2e (gigatons of CO2 equivalent) or 784 GtCO2e if the limit is set at 2ºC.[4] There is widespread agreement that if current emissions continue, this figure could be consumed as soon as 2034.[5]

The carbon volume must then be periodised to determine the maximum allowable emissions by country and sector in each year between the start of the containment measures and the final year. The result will determine the effort that each economy must make to achieve the goal of halting global warming. The 'frontier' of maximum emissions each year is known as the 'carbon pathway' and can be represented as a decreasing line from the starting point to the end date. Figure 1 visually depicts these pathways (coloured lines) using estimates from the Global Carbon Project, with estimates from Andrew (2019)[6] and two mitigation scenarios: 2ºC and 1.5ºC. Each line represents the maximum emissions (y-axis) in order to achieve zero emissions by the target year (2100 in this case).

Figure 1. Maximum emissions frontiers to meet COP21targets



Source: https://ourworldindata.org/uploads/2020/07/co2-mitigation-15c.svg, based on Robbie Andrew, online http://folk.uio.no/roberan/t/global_mitigation_curves.shtml

The risk of failing to control emissions is that global warming would continue until it reaches (and exceeds) a 4°C temperature increase, at which point the impact on nature is considered extreme (complete climate change, disappearance of species, sea level rise, etc.). The 4°C scenario will lead to a more drastic change in human lifestyles and, of course, economic losses. The UN Emissions Gap (UNEP) Report 2017 explains how denying the problem would lead to emissions above 65 GtCO2e per year and maintaining the current containment policy if applying more drastic measures would mean emissions of 52 GtCO2e per year. Applying measures to keep warming below 2ºC involves reducing emissions to 40 GtCO2e per year, while keeping warming below 1.5ºC means emitting less, 24 GtCO2e per year. The gap in emissions, as defined by UNEP, is the reduction target (Figure 2).

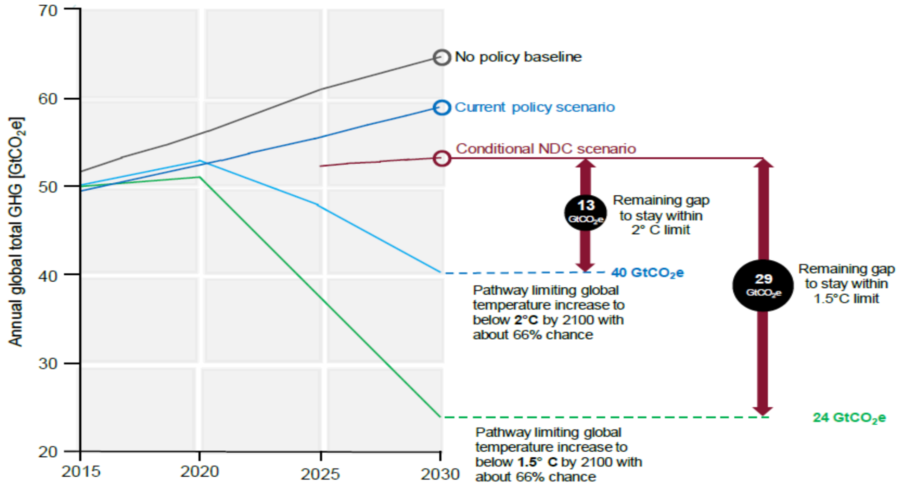
[3] https://www.youtube.com/watch?v=AL5Hjg30b_M

[4] The above figures are from the estimate of Rockström et al. (2017) cited in Hirsch et al. (2019), although other estimates for 2019 and 2020 can be found in https://www.carbonbrief.org/analysis-how-much-carbon-budget-is-left-to-limit-global-warming-to-1-5c

[5] CRREM estimation, Hirsch et al. (2019)

[6] The source is CO2 and Greenhouse Gas Emissions, Our World Emission Data. It is a specific web-figure.

Figure 2. Global CO2 emission reduction scenarios

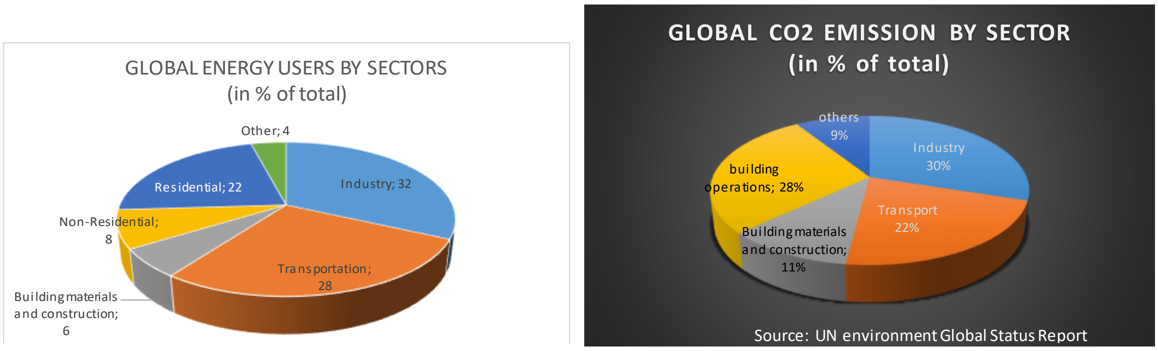


Source, UNEP, 2017

2. The role of the real estate market in the decarbonisation process

One of the sectors that will have to make the most significant efforts to decarbonise is real estate. Although this sector has not typically been disaggregated from the conventional sectoral classifications, part of the emissions associated with productive activities depend on the specific characteristics of the buildings, as are those associated with households. The fact that this sector plays a relevant role in emissions is shown by Figure 3.

Figure 3. The role of construction and real estate in terms of energy demand and CO2 emissions



Source, Global Alliance for Buildings and Construction

Source: UN environment Global Status Report

In essence, Figure 3 shows that in terms of energy demand, residential and non-residential (non-industrial) buildings account for 30% of total energy demand. If we add the construction processes and the production of materials (supply-side view), the total energy used by the sector represents 36% of the total demand. From the perspective of emissions (right-hand panel of Figure 3), buildings and everyday related operations account for 28% of the total CO_2 emitted into the atmosphere, with an additional 11% of emissions coming from the aforementioned supply-side activities. Therefore, this sector accounts for around 39% of the total emissions.

It has been shown that real estate and material production processes are very efficient at reducing emissions by improving energy efficiency in the use of materials.[7] This implies that prioritising

[7] The McKinsey report estimated the contribution of each sub-sector to global greenhouse emissions and the effects of intervention by 2030. In the ranking, improvements in real estate, such as insulation and energy retrofits, generated the greatest reduction in emissions and, therefore, negative CO2 reduction costs, in a sort of climate change economies of scale. McKinsey (2009), pp 7, available at https://www.mckinsey.com/~/media/mckinsey/dotcom/client_service/sustainability/cost%20curve%20pdfs/pathways_low carbon_economy_version2.ashx

investment in decarbonisation in real estate is emerging as a crucial tool to achieve climate change policy objectives.

The EU has identified this sector as one of the first targets in order to achieve the reduction. The EPBD, which sets out energy performance rules for new buildings and major renovations, has been transposed in all Member States through their 'building codes', known in Spain as the Technical Building Code (*Código Técnico de Edificación*). The regulation requires that from 2021 all new buildings must comply with the "nearly zero energy building" standard (2019 for new public buildings), where “nearly zero energy consumption” refers to the lowest possible energy consumption from coal-fired sources, encouraging supply with a high proportion of on-site production from renewable sources.

The EU ESD Directive (2003 and 2018) identifies the specific effort of existing and new buildings and calculates the necessary interventions to be made.

Moreover, some future projections show buildings as more than just a tool for emission reduction; they can be centres of transformation of the EU energy system by playing a changing role, going from being a place of consumption to real (clean) energy producers. With the use of specific technology and infrastructures, individual buildings can become producers and consumers, creating generation and consumption clusters inside the city, reducing the costs of delivering energy (CRREM, 2019) and starting the trend towards the decentralisation of energy production. Buildings can apply technologies such as Power-to-X, where buildings can be adapted for energy storage at times of high production and low demand.

Assessing the contribution of buildings to emissions is not straightforward, because there are no specific elements to break down individual contributions and because, as time goes by, the accepted decarbonisation environments may change, for institutional reasons and due to global warming (which increases the energy needs of each building). Buildings will adapt to higher temperatures to ensure a safe and comfortable environment for occupants with limited energy availability. Meanwhile, original building designs may not be appropriate for the new conditions, both because of their insufficient quality and because of their use. Consequently, part of the stock may no longer serve the purposes for which it was built or simply cannot be decarbonised as required by the regulations, generating premature obsolescence with the consequent loss of capital investment.

Energy obsolescence, which appears before economic obsolescence, occurs when non-adapted buildings are too expensive to operate, too expensive to retrofit, unable to reduce energy consumption and are left out of policy objectives. These buildings face early obsolescence and will become "obsolete assets". The risk of obsolescence will have a major impact on the asset value, the rental potential and the expected return on investment, generating capital losses that have not previously been foreseen. There is a growing demand in the real estate sector to identify and evaluate this risk in order to take appropriate investment decisions.

Energy obsolescence occurs when the building emits a larger-than-permitted proportion of the carbon budget, meaning building owners must ensure that they do not consume more than the carbon allowed before 2050 to avoid their buildings being fined or simply closed down, a likely scenario given current estimates of consumption. The current (EU) mandated rate for non-residential buildings is 91% total emissions reductions by 2050 in the 1.5ºC scenario and 78% at 2ºC (Hirsch et al., 2019:11).

2.1. The figures and the challenges of decarbonisation

According to most of the existing research, energy efficiency is low in buildings. There are at least two reasons for this. Firstly, the building stock is old in the EU, with much of it built back in the 1960s, and although it has been renovated in recent decades, especially in Spain, it has not been adapted to ensure low emissions. Secondly, the technical regulations introduced through the Technical Building Code affect new buildings and refurbishment. The 2007 crisis saw building in Spain (and in Europe) plunge to historic lows, so the impact of these regulations on the number of energy-adapted properties is marginal. In addition, there may be a lack of awareness of the need for energy renovation. A recent study by Christensen et al. (2018)[8] states that renovations are still mainly driven by cost-benefit analysis and do not seem to be related to reasons of sustainability.

Furthermore, it should be noted that most buildings are privately owned (businesses and homes), although there are also buildings that are publicly owned (administration) and that serve different uses (hospitals, schools...). The success of any programme aimed at fighting climate change depends on incentivising both public and private entities to make the necessary investments to increase energy efficiency. However, convincing households requires a market solution in which the costs do not exceed the assessment of the risk of obsolescence (stranding risk) or climate risks. This means investors need to understand the guidelines that determine whether the asset is at carbon risk and organise the investment process to assess its viability in terms of financial returns.

This article addresses how to calculate the carbon risk associated with buildings[9] in a case study setting, selecting a representative group of different types of buildings. In Spain (and in most European countries), there is not an accurate count of the total number of existing buildings since censuses almost exclusively cover residential use. In the Spanish case, the 2020 Cadastral Survey records 13.82 million built-up urban plots with a total of 38.95 million real estate properties. Assuming that each plot is a building, there is a large number of buildings to be energy efficiency assessed ($13.82*10^6$), which will require significant financial and technical effort.

Climate change regulations require efficient policies and decision-making based on a large amount of information-rich data. The features and age of the building stock, including minimum energy and carbon performance indicators, are crucial to accurately assess the total CO2 emissions, including those from construction, renovation and maintenance and use, as they are all part of the building's energy performance.

The methodology to be used to calculate the decarbonisation risk involves some fundamental milestones that must be defined at the country level as a specific characteristic of each country. The first is to estimate the carbon budget for the real estate sector and by subsector (within the country's carbon budget) to determine the intensity and timing of the action. The second is to evaluate the initial conditions of each Member State, such as climate, size of the housing stock, wealth or economic growth, establishing different requirements by climatic zones. The aggregate amounts have already been defined by the EU for each Member State, although not detailed by real estate subsectors.

Real estate assets have different emission patterns depending on their use, such as hotels or offices, due to their specific functional requirements. Thus, the risk of economic obsolescence and its temporal limits would be different and should be estimated separately.

3. Methodology

The stranding risk is calculated as the ratio between the CO2 emissions at any given time and the maximum emissions allowed for the real estate asset. (Eq. 1)

$$\mathrm{Robs}_{\mathrm{it}}^{\mathrm{e}} = \left(\frac{\mathrm{CO}_2^{\mathrm{e}}}{\mathrm{CO}_2^{\mathrm{m}}}\right)_{\mathrm{t}} \qquad (1)$$

where $CO_2^e i$ is the total emissions of the building (RE asset) *i* and $CO_2^e m$ is the maximum emissions allowed for it at time *t*.

Eq. (1) is a ratio that is evaluated today (initial period) but should be tracked in the future, so the two variables must be forecast from the current building information. The first variable refers to the evolution in energy consumption and carbon emissions of the building in its current state, which involves technical estimates based on the efficiency at the time of calculation. The second depends on the carbon budget assigned to the country and the specific sector, which in turn depends on variables independent of the building and related to energy efficiency requirements in each country and region,

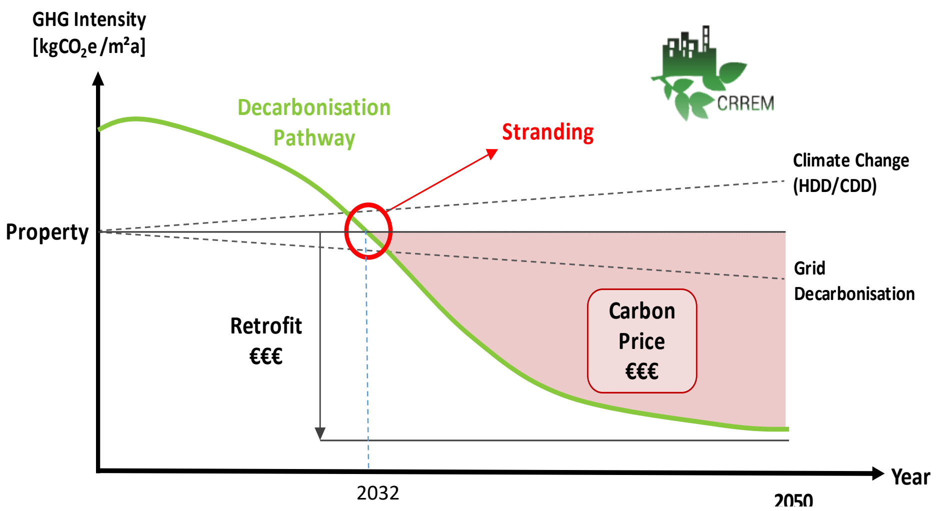
[8] Christensen et al. (2018).

[9] This tool was developed by a European research team as part of the CRREM project funded under the H2020 call and completed in 2021, in which the authors participated as the Spanish team. https://crrem.eu

as well as temperature-related issues (such as the evolution of climate change itself) and policy measures (such as the required acceleration in energy efficiency).

The idea is depicted in Figure 4. Initially, the maximum allowable emissions mark the decarbonisation pathway (similarly to Figure 1), with the limit of 2050 by which the maximum CO_2 emitted must be zero or close to zero. The property has a level of emissions measured at the time of inception, making it simple to assess its probability of becoming obsolete at each point in time. In the example shown in Figure 4, the property reaches its obsolescence starting point in the year 2032. The probability of obsolescence increases to unity up till that year and exceeds unity after that. That time also marks when it should start paying for the surplus carbon emitted. The property only has the option of investing in improving its energy efficiency when it approaches a probability of unity, reducing its volume of emissions to a new point. It then has a greater margin of time in which the probability of energy obsolescence will be less than unity.

Figure 4. Measure of the stranding risk likelihood



Source: CRREM, www.crrem.eu, Spanner and Wein, 2020

3.1. Calculation of maximum allowable emissions: pathways and descaling or decarbonisation pathway

The EU carbon budget for the real estate sector is calculated as an amount for the sector as a whole, by country. The CRREM project shared each carbon budget by sector in each country, based on existing information on energy use (CRREM, 2019, pp 56). The disparity in energy intensity by property type (Table 1) and the Global Real Estate Sustainability Benchmark (GRESB) estimates published in 2018 were used as a reference for allocating the budget to each real estate subsector.

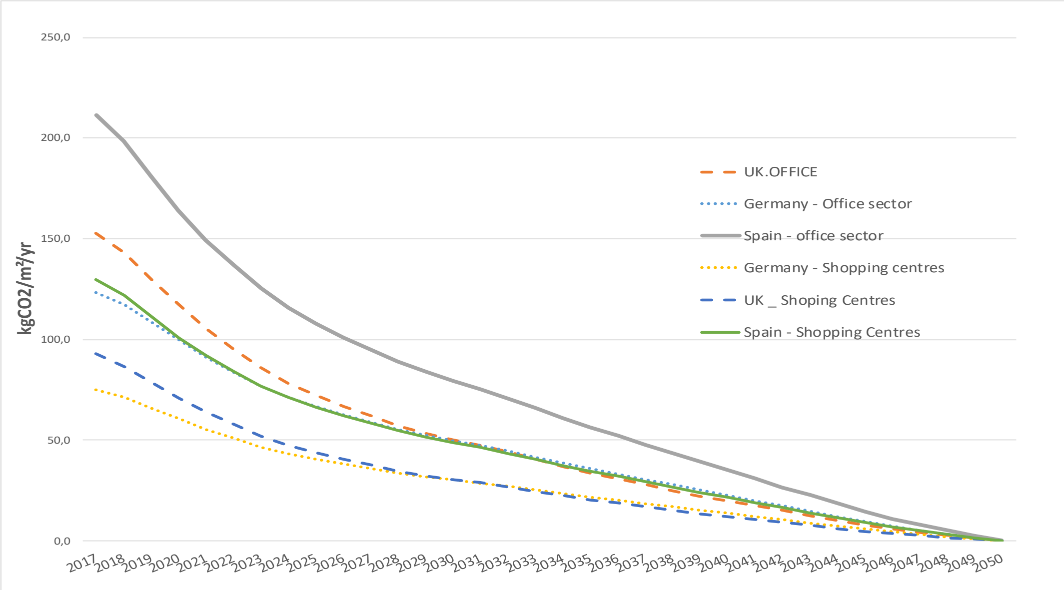
Table 1. Average energy intensities by property type

	kW h/m2
Office	154
Retail	148
Residential	136
Industrial	96
Hotels	195

Source: CRREM (2019, p. 64)

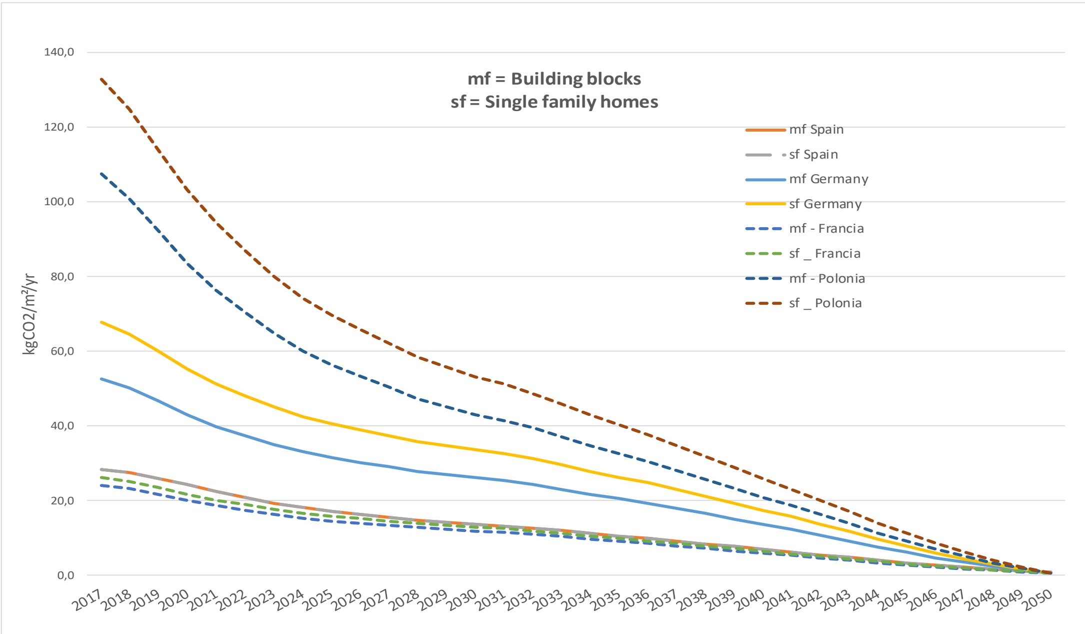
Decarbonisation pathways can be calculated using two methods: the convergence method and the contraction method. The former assumes a variable CO2 emission reduction intensity until the year of convergence. The contraction method assumes the same emissions reduction intensity (or quantity) ratio for all entities included in the analysis (Gignac and Matthews, 2015). The (future) maximum amount of emissions per m2 over the horizon 2050 were estimated by subsector using the convergence methodology. An example for offices and shopping centres is shown in Figures 5 and 6

Figure 5. Decarbonisation effort in offices and shopping centres. 1.5ºC limit



Source: Authors' elaboration using CRREM pathways.

Figure 6. Decarbonisation effort in housing sector. 1.5ºC limit



Source: Authors' elaboration using CRREM pathways.

3.2. Decarbonisation process and descaling emissions estimations

The condition for an asset not to fall into stranding risk (or risk of energy obsolescence) is represented by (2).

$$\sum_{2020}^{2050} A_y SI_y \leq C\ Budget_{2050} \tag{2}$$

Where A_y is the activity of the real estate sector measured by the number of square metres available, and SI is the emissions intensity of the sector, both in the year *y*.

To forecast emissions, the evolution of future built-up areas is computed (estimated using dynamic autoregressive modelling methods[10]).

The decarbonisation index for a specific subsector or property types (p_y) takes the form of a specialisation index, that is, the ratio of the differences in emissions intensity in year y and those that should exist at the end of the period (2050) divided by the same difference but relative to the base year (b)[11].

$$p_y = \frac{SI_y - SI_{2050}}{SI_b - SI_{2050}} \quad (3)$$

This index expresses the progress in the decarbonisation process of the analysed subsector or property type and is called the energy intensity (emissions) index.

Table 2 shows some of these calculations for the overall estimate of the EU and its real estate market.

Table 2. Mitigation in the real estate market of greenhouse gas emissions under the COP21 agreements. European Union

Maximum amount of global warming at the end of the century		1.5ºC				2ºC		
Global CO2 emissions 2019-2050 (in $GtCO_2$)		669				784		
CO2 emissions per capita until 2050 (according to carbon budget per capita)								
		2019	**2050**	**diff_%**		**2019**	**2050**	**diff_%**
tCO2 /per capita	Global	4.8	0.6	-87.5		4.8	1.4	-70.8
	EU	6.9	0.6	-91.3		6.8	1.4	-79.4
EU GHG (CO2e) emissions. All sectors:								
	$GtCO_2^e$	2019	2050	diff_%	$GtCO_2^e$	2019	2050	diff_%
Carbon Budget (GtCO2e) 2019-2050	72				78			
Emissions ($GtCO_2^e$)		4.3	0.38	-91.2		4.2	0.873	-79.2
Direct and Indirect emissions of **EU Commercial Real Estate Sector**								
Carbon Budget ($GtCO_2^e$) 2019-2050	24				24			
Emissions (GtCO2e)		1.2	0.144	-88		1.2	0.332	-72.3
EU Commercial Real estate sector carbon intensity pathway (based on emissions and projected development of floor area)								
Emissions by m2 ($kgCO_2^e$ /m2)		114	11	-90.4		112	25	-77.7

Source: based on CRREM (2019, p. 67)

As can be seen, the decarbonisation effort required is extreme, with reduction rates of more than 75%, indicating the need for a significant technological change to be made in the next 30 years.

[10] This estimate is part of the construction methodology of the CRREM tool and has not been published. It uses information on m2 of building for the 28 Member States and the different sectors, provided by Eurostat. Dynamic supply models by country and sector are estimated and annual production is predicted for 2050.

[11] For more details on the calculation, see CRREM, Hirsch et al. (2019, p. 59) ff.

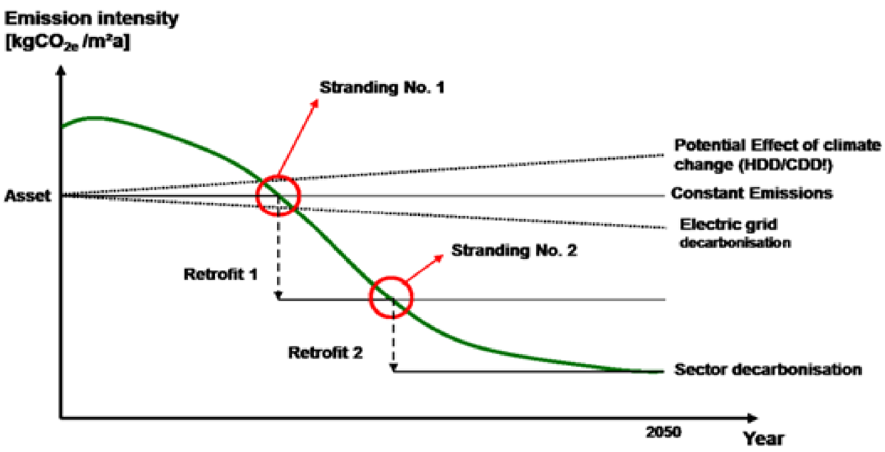
4. Implications of decarbonisation and relevance to the investment process

The implications of the abovementioned agreements are huge and mean that the building stock must undergo a process of major investment in decarbonisation. Given the scale of this need, investments should be timed to achieve the highest possible efficiency in capital expenditure and energy performance.

Figure 7 explains the energy evolution that a building (a generic use is shown here) in a city park should follow to comply with the agreed decarbonisation plan. The green line represents the total 'Carbon Budget' allowed for that building and is decreasing because, as it emits CO2, the outstanding amount of emissions in the carbon budget is reduced until it reaches zero in 2050 (when it cannot emit any more CO2). This line may also decrease more rapidly than expected as other non-efficient buildings enter the market or environmental policy requirements become more demanding. Let's assume that the analysed building is energy efficient at the starting point, 2020 (i.e., it emits less than it would at the beginning of the decarbonisation period) and emissions are expected to be maintained throughout the period (which could increase as the building ages or because of climate change). The point at which this emissions line crosses the annual decarbonisation pathway (circled in red) will be the point at which the building is in non-compliance. The building owners will be required to implement investment in energy renovation to reduce their emissions level (or pay the 'carbon price' in the form of taxes, fines, fees, etc...), which implies a mandatory investment.

It is possible that the effort made will not be sufficient (given that climate change may modify energy use and increase emissions, among other factors) and a new investment will be necessary in the remaining period until 2050, as indicated by 'retrofit 2' in Figure 7. Failure to invest will mean that buildings become a stranded asset (energy obsolete) and may be subject to compensatory policies; in commercial buildings, it may even be the case that they cannot be used. The losses from non-renovation may be greater than the investment, implying that investment plans should be designed long before the default becomes real.[12]

Figure 7. The need for investment in emissions reduction



Source: CRREM Project, https://crrem.eu/reports/report_1:X

This process, explained for one building, becomes much more complex if the entire stock and the heterogeneity of the buildings (condition, age, characteristics, use ....) are taken into account. Cities must thus play a key role in coordinating, implementing and managing the refurbishing process if they are to achieve the climate change objectives. Particularly relevant is the process related to the housing stock, where the calculations of economic profitability associated with land rental yield may not apply because users own their homes.

[12] Large European real estate management companies and investment funds are taking this process into account and are using the CRREM project estimates to assess their future building investment needs and associated returns. This is a current issue but has not yet been projected into the housing market.

5. Case studies

In this section, we calculate the timing of investments made using the calculation tool built by the CRREM project. Table 3 includes selected buildings to be analysed and illustrates a set of options that the investor may face. These buildings comprise a hotel, two residential buildings, a sports centre and three administrative-teaching buildings located in different Spanish cities.

Table 3. Case studies for the analysis. Characteristics

Type	City	Size (m^2)	Investment (Euros)	Reduction of energy consumption (%)
Hotel	Estepona	55,156	313,675	36
Housing block	Barcelona	3,372	159,800	20
Housing block	Barcelona	2,180	102,000	62
Sports building	Alicante	8,124	94,184	20
Administrative Building	Alicante	6,423	268,762	9
Administrative Building	Elche	1,041	54,534	2
Administrative Building	Elche	8,210	73,651	13
Administrative Building	Elda	3,459	106,400	15

Source: Authors' work

Two types of estimates are considered. The first assumes that each building is individually owned, so each owner can calculate the investment plan individually. The second assumes that they all belong to a single company or institution and are part of an investment portfolio. In such a case, the landlord can calculate them together and decide to offset emissions among assets.

In both cases, the CRREM calculation tool allows the analysis to be performed at the asset level and at the investment portfolio level to facilitate decision-making. The case studies are presented below.

At the asset level, the analysis is performed on an individual basis considering the global warming target of 1.5 or 2° C. At the investment portfolio level, the type of assets being evaluated (office building, housing...) should be identified and the existing investment mix established. From the basic information of the properties, the obsolescence diagram, the energy reduction path, the excess emissions per surface area, the energy costs and CO2 emissions of the property and the portfolio, among others, are calculated.[13]

5.1. Individual asset analysis: A hotel in Estepona, Spain.

As a case study, a hotel located in Estepona is taken as the first example. Basic data are shown in Table 3. Figure 8 shows when this asset will become stranded starting from the current situation and considering the two global warming targets of 1.5°C and 2°C: the year 2041 for the first target and seven years later, 2048, according to the second.

Knowing the stranding risk year means the landlord can act to prevent energy obsolescence burdens on the building.

Figure 9 illustrates the energy reduction path compared to the country-specific and property type-specific energy target stipulated for 2050. This Figure is a crucial indicator in terms of asset performance (together with the decarbonisation diagram seen in Figure 8) and measures the specific effort to be made by the property by calculating the emissions intensity index.

[13] A document explaining the calculation procedure step-by-step using the CRREM tool can be found in http://catedramodeloeconomico.ua.es/publicaciones/documentos-cortos/

Figure 8. Stranding risk diagram based on global warming target. Hotel

1.5°C 2°C

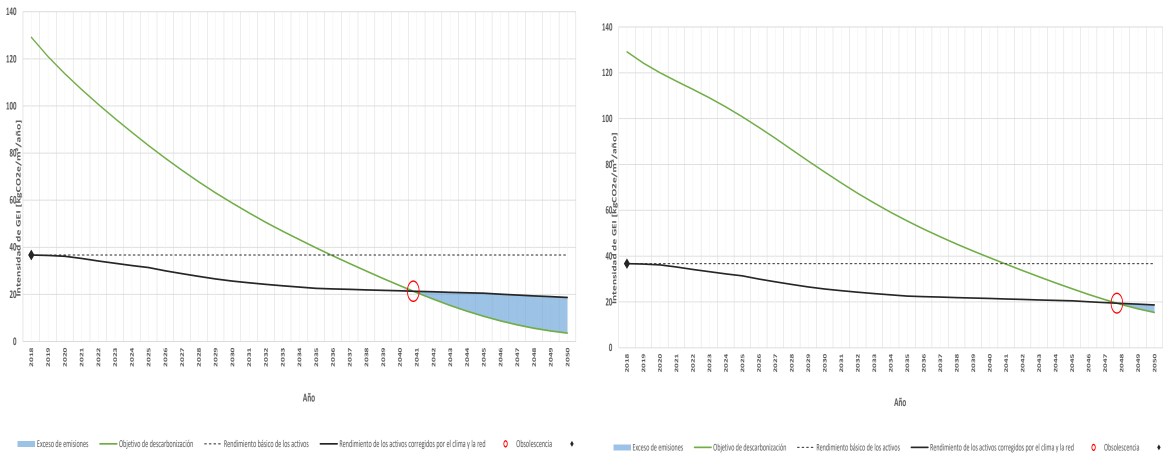
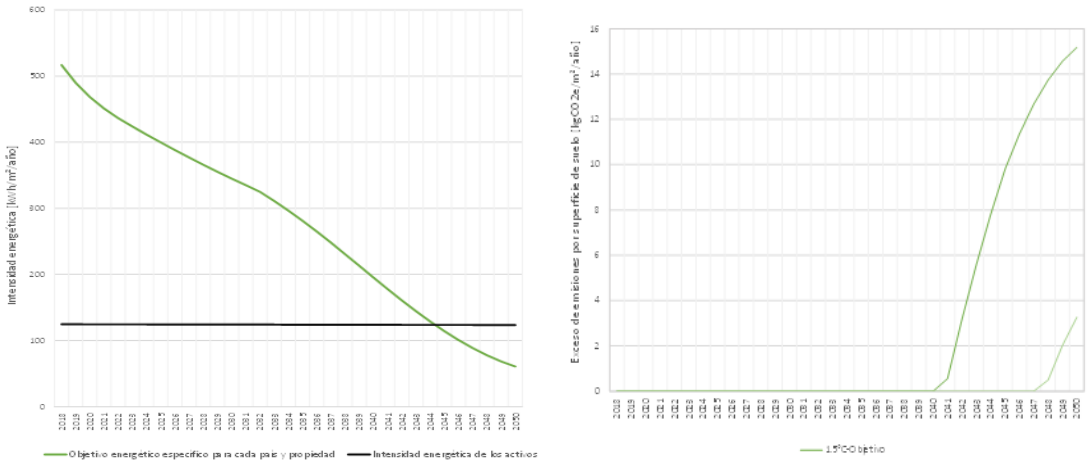


Figure 9. Energy intensity and excess emissions. Target 1.5°C. Hotel

Energy intensity index Excess emissions



According to the example and with the 1.5ºC target, the asset would become obsolete in 2041 (Figure 8), four years before it would reach the overall country/building targets (Figure 9). This indicates that although its energy intensity would meet the country/building reduction targets in 2041, its greenhouse gas emissions would be above average.

The right-hand panel of Figure 9 shows the excess emissions per m^2 from the year the hotel fails to meet the greenhouse gas emissions requirements and its quantification, as a cumulative total excess up to 2050 in kgCO2e, for the two scenarios (1.5°C and 2°C).

These indices make it possible to calculate the amount of energy consumed, emissions, and their costs, distinguishing between types of emissions based on energy and carbon price projections. By aggregating all valued consumption and emissions, the total annual costs for consumption and emissions can be calculated. Figure 10 depicts these calculations.

Based on the cost information calculated, it is possible to evaluate the annual costs of the hotel's greenhouse gas emissions. Figure 11 shows the period in which the property does not generate excess emissions (green zone) and therefore not only complies with regulations but also provides emissions savings. It also calculates the cost of carbon emitted from when it becomes a 'stranded asset' (red zone) and the amount of excess carbon emitted (and therefore the potential penalty). The costs of excess emissions are based on the carbon price per ton entered in the calculation as an assumption and could be adjusted any time to reflect the actual costs in the market. The costs/benefits are discounted at a default discount rate of 2%, which can also be adjusted.

Figure 10. Energy cost and carbon emissions with global warming of 1.5°C

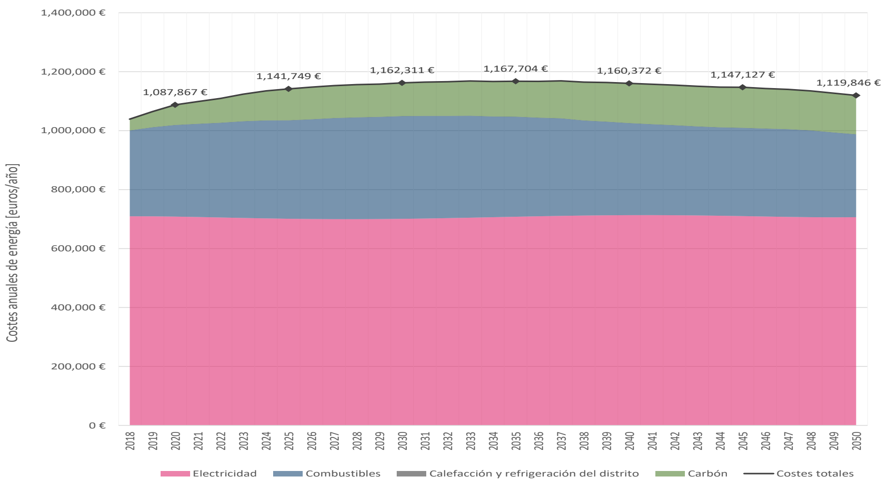
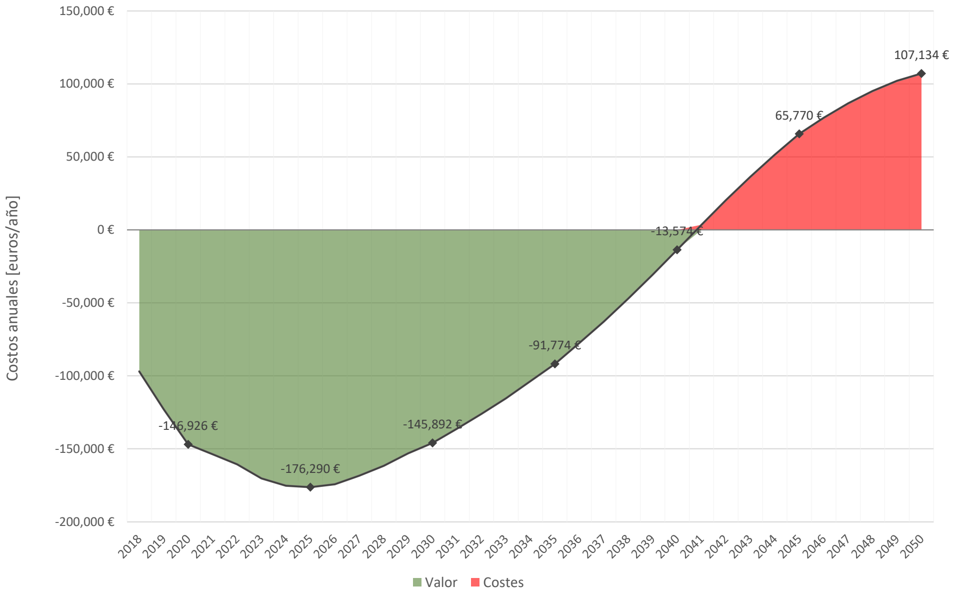


Figure11. Cost of the excess emissions with global warming of 1.5°C

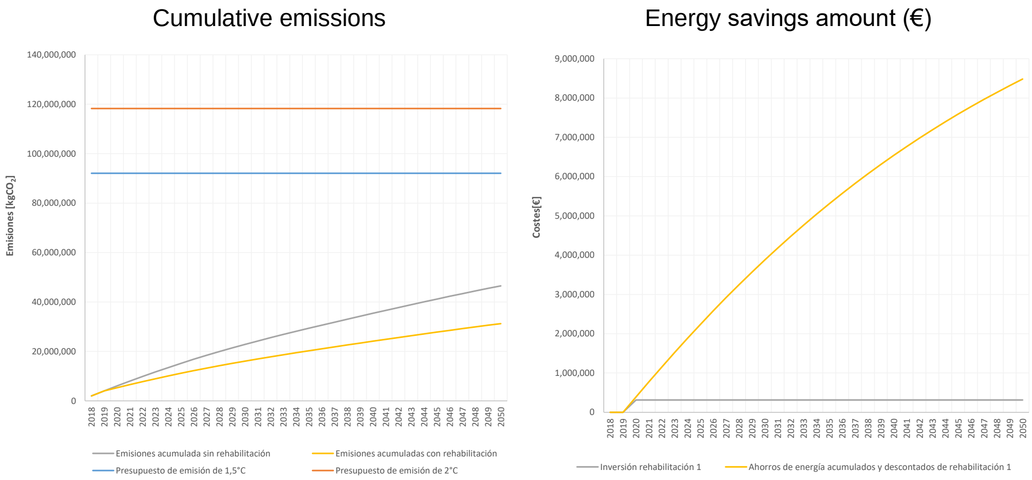


These results have major implications. Firstly, they allow an assessment of when a building can be classified as 'green' in the period of emissions reductions. Being classified as such would allow it to be used as collateral for a 'green' mortgage (e.g., to invest in energy renovation of that or another building). Secondly, it would also allow the building to participate in a potential retail version of an EU allowance-style emissions market, as this calculation assigns values to emission allowances that are not realised (negative emissions) and would allow trading among individual buildings (or portfolios) and could also serve as the basis for issuing 'green' emission assets.

It has been assumed that the building under analysis (hotel) carries out an intervention to improve its energy efficiency in 2020 with an investment of €313,675. Based on this information, the ecological payback from the retrofit measures taken has been calculated, both in terms of emissions and the cost savings in euros of the carbon not emitted. These two calculations are shown in the two panels of Figure 12.

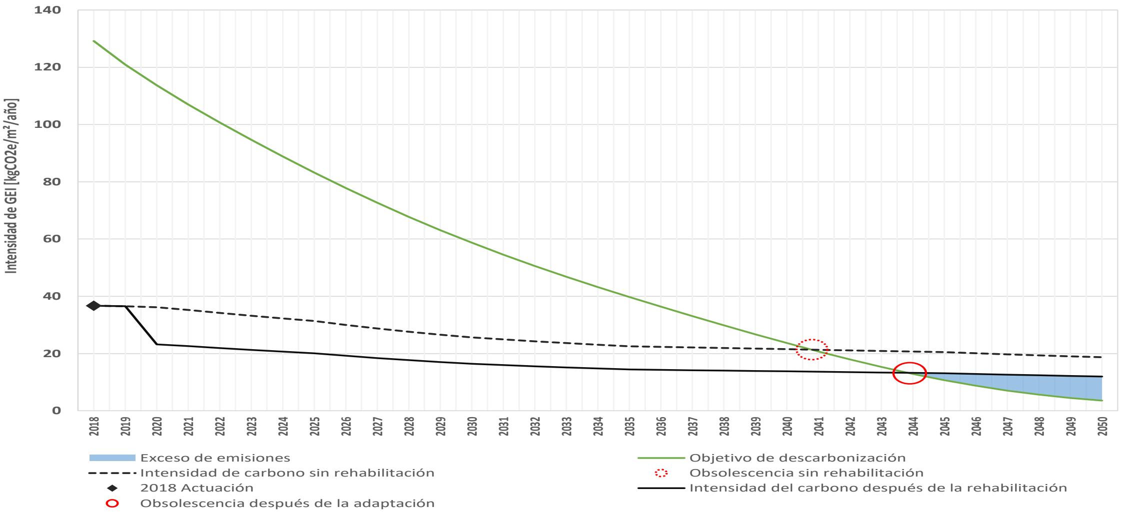
Figure 12 shows the cumulative emissions (kgCO2e) with and without retrofit measures; the difference between the two reflects the emissions savings achieved after retrofitting and the limits on the total carbon budget based on the two scenarios. The right-hand panel shows the cost of the retrofit investment and the cumulative amount of post-retrofit energy cost savings from the retrofit year and beyond.

Figure 12. Ecological recovery of retrofit measures. Hotel



Finally, Figure 13 shows the time gained by the building by delaying its energy obsolescence. Without intervention, its emissions intensity would have made it obsolete in 2041 (as discussed above and reflected in the dotted line in Figure 13). With intervention in 2020, the reduction in energy intensity (KWh/m2/year) resulting from the retrofit delays the point at which the asset becomes obsolete by 4 years (from 2041 to 2045).

Figure 13. Stranding risk diagram after the energy retrofit intervention. Hotel, target: 1.5°C



As can be seen, the estimation of the values derived from the interventions makes it possible to give precise information to the investor who wishes to continue managing the building. By pinpointing the default date, the investor can move forward with investment plans with a long lead time and calculate potential costs. Updated costs and value are the key elements for calculating the profitability of the potential renovation investment. They also make it possible to calculate whether the building may become a stranded asset because of its energy deficiency, prompting an evaluation of its possible demolition and/or reconstruction.

5.2. A building portfolio

The grouping of buildings in a portfolio can also be evaluated together. The advantage of portfolio analysis is that the energy efficiency of some buildings may offset the inefficiency of others so that energy cost-effectiveness decisions can be made within the portfolio rather than individually.

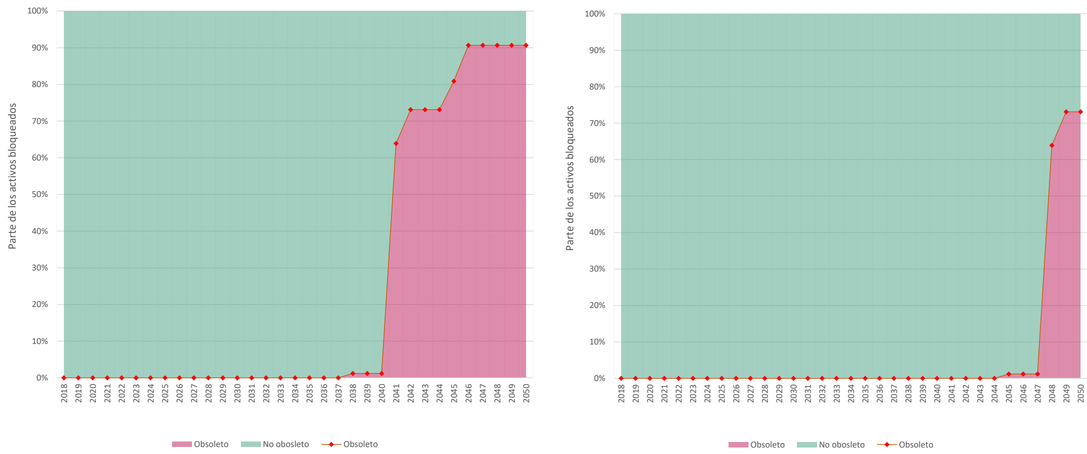
The grouping of buildings provides additional metrics for decision-making using the CRREM calculation tool. Moreover, the analysis can be performed for the entire portfolio, but including differential characteristics by country, property type, and individual entities, if applicable.

This section assumes that a company has a property portfolio consisting of the assets listed in Table 3. As seen in the hotel example, the assets start from a situation of reasonable energy efficiency. The assets are evaluated, and the results are grouped to obtain the portfolio totals. Despite the grouping, it is possible to identify which assets fall into energy obsolescence earlier and later than others, generating information that allows the investor to accrue the interventions.

Figure 14 shows the evolution of the relative proportions of obsolete and non-energy obsolete assets in the total portfolio. In this case, the calculation is made on the total area (m2) accounted for in the portfolio. The results indicate that in 2050, 90% of buildings would be stranded under the 1.5^{0}C target and 74% in the case of the 2^{0}C target. It is also possible to calculate by building and the exact moment of obsolescence.

Figure 14. Stranded assets, based on building area

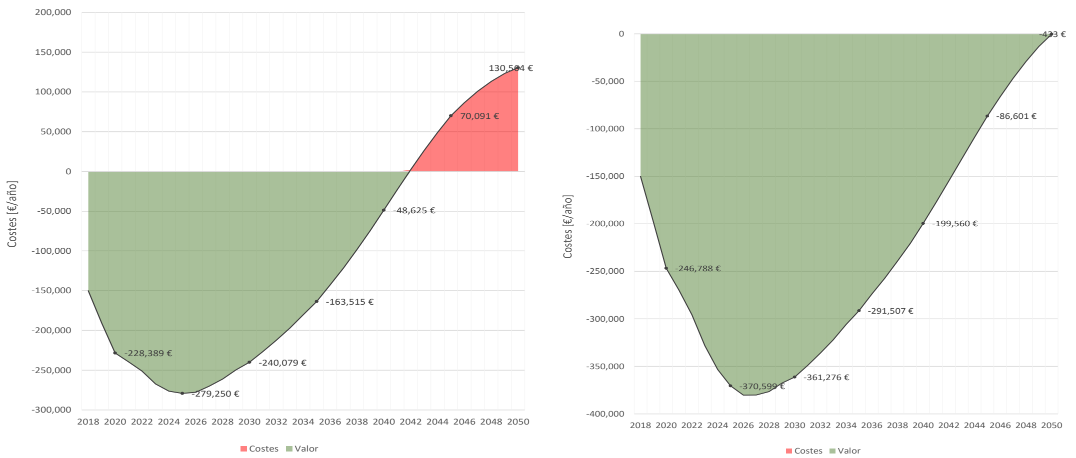
1.5°C 2°C



It is possible (by aggregation) to estimate the average emissions intensity of the entire portfolio with similar detail to those in Figures 8 and 13 above, which would determine the critical intervention years. Of greater interest would be the cost of excess emissions and the time they appear, in aggregate, for the portfolio. Figure 15 reflects the calculation made for the case study.

Figure 15. Costs of excess emissions in the portfolio. COP21 scenarios

1.5°C 2°C



As can be seen, the portfolio as a whole would incur greenhouse gas emission costs only in the case of a 1.5ºC limit on global warming and would face no costs in the case of a 2ºC limit.

6. Conclusions

This article discusses the relevance of undertaking energy retrofit investments in the EU building stock to ensure compliance with the environmental agreements aimed at mitigating global warming.

A review is presented of the EU Climate Change agreements and regulations, which must be transposed in the Member States, and the relevance of the real estate sector is highlighted. According to previous studies, buildings are the source of around 36%-40% of total emissions. As such, action taken to reduce this emitting capacity is fundamental to achieving the overall objective.

The article presents a case study in which the costs and benefits of energy retrofit measures are calculated, defining the risk of energy obsolescence at the building level and the real estate investment portfolio level.

The calculations and results presented here have used the calculation tool developed as part of the European project CRREM (Carbon Risk Real Estate Monitor, H2020), the methodology of which is explained in this article.

The analysis yields several indicators of major relevance for investment decision-making in retrofits. The first is when the building becomes energy obsolete before 2050, which would indicate when to invest. The second is the volume of excess emissions (in kgCO2e) and the amount in euros of the cost of excess emissions. These evaluations are an indicator of the costs facing the building due to its lack of energy efficiency, which may result in a drop in economic efficiency (by internalising such costs); unexpected additional burdens (due to the excess emissions resulting in taxes, fines, etc.); a lack of viability for the use of the building (becoming a 'stranded asset'); and its abandonment or demolition. The calculation also shows the periods in which the building saves emissions and values them. These calculations make it possible to quantify the emissions cost, allow the building to be classified as a 'green' asset and facilitate the development of a rating system that can serve to secure finance flows for the energy renovation itself.

The provision of estimates is key to reducing uncertainty in this sector and supporting investment decision-making; indeed, this has been the objective of the CRREM project and is expected to contribute to decarbonising the economy and mitigating climate change.

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