EE and credit risk correlation: Evolution of the Basel regulation framework and its potential impact on EEM

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Executive Summary

In the last ten years, energy efficiency (EE) has gained in importance as a key way of mitigating climate change and its dramatic effects and reducing energy consumption and therefore dependence on fossil fuels. EE has therefore been in the EU 2030 goals, which define specific targets for EE, among others.

Continued efforts are however needed in order to meet these goals, especially against a background where 75% of the EU's building stock is considered as energy inefficient (ECBC, 2020) and buildings have been responsible for almost 40% of the EU final energy consumption (BPIE, 2015).

The Energy Efficient Mortgage Initiative (EEMI), and the present Project as part of the EEMI, are seeking to respond to the need for huge investment to meet the targets by designing an energy efficient mortgage 'ecosystem' to support the financing of the improvement of the EU's building stock. The underlying assumption of the Initiative is that EE has a positive impact on credit risk reduction, increasing the attractiveness of the investment for EU banks and mortgage lenders and delivering spill-over benefits for homeowners. To this end, the EEMI's EeMAP and EeDaPP projects conducted literature reviews and empirical analyses which demonstrate a significant positive correlation between building EE and credit risk reduction, supporting the development of EE mortgages.

However, EU banks and mortgage lenders are currently facing three major concerns that might affect directly their lending activity and by extension EE mortgages: 1) the implementation of the Basel III regulation; 2) the global pandemic crisis and the post- pandemic crisis adjustments; 3) the increased climate change vulnerabilities.

At the same time, however, the significant interest in EE investments and the creation of a standardized "energy efficient mortgage" label allowing to reduce implementation and administrative costs, as well as the strength of the covered bond instrument, might be beneficial to EE mortgages.

The present report aims to expand the EE and credit risk correlation discussion, through an overview of the prudential regulation relative to credit risk. The deliverable proposes an overview of the Basel accords (I, II and III), their evolution and an evaluation of their potential impacts on EE mortgages. The report also considers covered bonds and their potential as a driver for EE mortgages.

Despite a rather positive evolution of mortgages' related prudential regulation, the transposition of the new framework to EU EEM might induce greater challenges and efforts for EU banks. Indeed, the implementation of the output floor, leading to an increase of capital requirements, might affect the lending capacity of EU banks, but also might involve a transfer of risk towards shadow banking, or a transfer of the regulatory burden and its inherent costs on borrowers. In all cases, the viability of EU EEM can be endangered.

Furthermore, EE mortgages are characterized by relatively low LTV ratios and should therefore benefit from lower RW, as defined by the new regulation, but according to ECBC (2021), the revised advanced

IRB approach might have a contrary effect through an important increase of RW. Based on the correlation analysis relating EE and borrower's credit risk, Johnson and Bertalot (2022)[1] suggest that since EEM are correlated to reduced loan probability of default and loan-to-value ratios, these assets could benefit from lower RW and lower capital requirements. The reduced credit risk can concern both borrowers and lenders and its integration into the prudential framework can induce a virtuous cycle. However, this risk mitigation can be very case-specific and for the moment it has not been "appropriately captured by the prudential framework of individual institutions".

Concerning covered bonds, the new regulatory framework is rather favorable, but a major challenge resides not only in the harmonization among European covered bonds' markets, but mostly in the equivalence of all non-EEA issued bonds which will be essential for maintaining their safer characteristics, both, for holders and for issuing banks, but also for resilient EE mortgages.

The Report concludes that even though the revised Basel III accords and the pandemic and post-pandemic adjustments, as well as the current Ukrainian conflict, present potentially important challenges to the global economy and the development of EE mortgages, potential opportunities are also available.

[1] Johnson, J. and L. Bertalot. (2022). D4.2 Energy Efficient Mortgages: How to comply & align with the EU policy agenda. EMMIP project.

1. Introduction

During the last ten years, energy efficiency (EE) has gained a growing importance as one of the potential tools i) for mitigating greenhouse gas (GHG) emissions, and thus tempering climate change and its dramatic effects, ii) but also to reduce energy consumption and therefore the dependence towards fossil fuels.

Thus, EE has been integrated first in the EU 2020 goals and hereafter in the EU 2030 goals, both defining specific targets in terms of Greenhouse Gas (GHG) emissions, renewable energy use in power generation, and EE[2]. While, the first two EU 2020 targets have been reached, further efforts in terms of EE are expected, especially given that 75% of the EU's building stock is considered as energy inefficient (ECBC, 2020) and since buildings have been responsible for almost 40% of the EU final energy consumption (BPIE, 2015).

However, the EE investments in the buildings' sector are exposed to several difficulties related to: 1) the economic context; 2) the Basel accords' implementation and 3) the large heterogeneity of EE labels and their evaluation by EE mortgage lenders[3].

The current economic context presents several important challenges for all economic actors, through the cumulation of the unusual and specific to the Corona virus pandemic conditions, the post 2008 financial crisis and the implemented unconventional monetary policy interventions (quantitative easing) as well as the urgently growing importance of climate change and its potential impact on producing capacities, infrastructures, and housing.

The combination of these factors stresses the importance of the orientation of investment decisions, but also the risks and the limitations to which is exposed the international banking system and more specifically European banks. Indeed, country-specific characteristics involve differentiated effects of the 2008 crisis, but also of the Corona virus crisis and the exposure to climate change risk. Namely, while the subprime crisis has presented less violent consequences on average for EU countries (comparatively to the US), in terms of banks exposures, mortgage market effects, unemployment, small and medium enterprises (SME) bankruptcies, the Corona virus crisis has apparently affected more EU banks (Deutsche Bank, 2021), even though the general economic conditions have been maintained stable by virtue of the timely adopted sustaining measures.

Nevertheless, although EU banks were in a better condition when entering the pandemic (comparatively to previous crises), according to the EBA (2020), they face reduced profitability (due to a combination of low interest rates, important competition, and consequent non-performing loan (NPL) ratios), increased long term financing costs, and a greater dependence on Central Banks.

Even though, they have been authorized to apply the regulatory framework more flexibly in order to promote capital liquidity and reduce the effect of the pandemic[4], the latest Basel III accord might be

[2] The latest targets were defined such as: a 40% reduction of emissions comparatively to 1990 levels; an increased use of renewable energies (hydro, solar, wind) in electricity generation up to at least 32%; an improved energy efficiency of at least 32.5% compared to the projected levels of expected energy use by 2030.

[3] Solutions to these aspects have been developed under the Energy Efficient Mortgage Initiative (EEMI) and will not be included in this report.

[4] Use of countercyclical buffers, the possibility to use non-CET1 for meeting Pillar 2 requirements, or temporarily operate below Pillar 2 guidance (EBA, 2020).

less favorable to EU banks which have considerably invested in the development of costly internal ratings-based (IRB) models and involving greater capital requirements.

Indeed, the implementation of the output floor and thus the restricted use of IRB models might affect the EU economic system, more heavily relying on financing provided by banks (comparatively to Anglo-Saxon economies depending rather on capital markets and thus preferring the adoption of the rather generic and ready to use Standard Approach (SA)). As such, the prudential regulation might directly influence european banks' lending capacity and the development of EE mortgages.

Therefore, the present report attempts to identify the potential effects of the Basel I, II and III Accords on banking regulation on EE mortgages and on credit risk. For this purpose, it builds on the previously obtained findings on the correlation between EE and credit risk within the Energy Efficient Mortgage Action Plan (EeMAP) and Energy Efficient Data Protocol and Portal (EeDaPP) projects.

While the first initiative was dedicated to the foundation of a standardized "energy efficient mortgage", promoting the renovation of existing or the acquisition of energy efficient properties, the second one aimed to complement the previously obtained achievements by improving the availability of large-scale standardized EE assets datasets, namely through the creation of a standardized reporting template accessible via a centralized portal.

Thus, Section 2 is dedicated to present shortly the obtained empirical results and literature-based assessments within EeMAP and EeDaPP. Section 3 aims to encompass the evolution of the prudential regulation relative to credit risk, through an overview of the Basel accords (I, II and III), their evolution and an evaluation of their potential impacts on EE mortgages. A particular interest is dedicated to covered bonds, which is discussed within a specific subsection. Section 4 includes the concluding remarks.

2. Results of correlation analysis between EE and credit risk (EeMAP and EeDaPP projects)

The EeMAP and EeDaPP projects have been developed within the Energy Efficient Mortgage Initiative (EEMI). The latter was created since EE mortgage assets (EEMA) are considered as presenting several advantages for lending institutions, borrowers, and policymakers. Namely, they are believed to reduce the owners' payment disruption risk, but also to increase the property value, and in consequence to reduce the lending risk for banks and financial institutions.

Thus, EEMI was aiming to propose a private solution promoting energy efficiency investments in buildings, as well as to create a standardized EE mortgage label facilitating the acquisition of EE properties or easing the process of EE renovation. An additional purpose of the initiative was to evaluate the availability of EE mortgage assets data across EU members and gather large scale datasets for investigating the link between buildings' energy efficiency features, its market value, and the loan's probability of default (PD), loss-given-default (LGD) and loan-to value (LTV) ratio.

Furthermore, in light of the EU2030 EE targets, the Initiative explores the potential of complementary solutions in addressing EE issues besides the already existing national, mainly public, initiatives such

as public funds, tax incentives, subsidies, utility rebates and so forth. Moreover, among all market-based tools promoting buildings' EE (green loans, energy efficiency obligation schemes, EE funds) green and EE mortgages present several advantages.

First, they focus exclusively on buildings. Second, they propose a tangible general framework, applicable across EU members and beyond. Third, governmental and common expenditures are less likely to be engaged directly given the private character of such investments. Fourth, this type of solution corresponds clearly to the expressed interest and demand on behalf of society. Indeed, energy efficiency presents benefits not only in terms of reduced energy consumption (for heating, cooling, hot water) and as such in terms of increased available income, but also in terms of potentially reduced healthcare costs as well as an increased property value (sales and rent value).

Therefore, within both projects, several evaluations on these topics have been led at the European (national and regional) and international levels.

Namely, under the EeMAP project two major orientations have been discussed: 1) EE and PD correlation analyses for the Netherlands, Belgium, Italy, Germany, UK and literature review for the US; 2) EE and property value (PV) through a literature review covering EU, US, Japan, China and UK.[5]

The same two orientations have been also applied under the EeDaPP project: 1) EE and PD correlation analysis for Italy, portfolio analysis for Italy, Belgium and Portugal, and literature review for the US, EU, and rest of the world; 2) EE and property value (PV) through a literature review covering EU, US, Japan, China, Singapour and rest of the world[6].

The next two subsections will be dedicated to a brief overview of the obtained results and the inherent conclusions.

2.1. Summary of obtained results under EeMAP

2.1.1. Correlation results described by the literature

Under EeMAP both topics on the correlation between EE and the probability of default and the property value have been discussed. Given the recent character of the topic, the literature, at that point of time, was quite restricted but has been further discussed under EeDaPP in order to include all new developments.

[5] The major deliverables focusing on these aspects are: D5.1 (M. Billio et alii (2019)), D5.2 (T. Baccega et alii (2019)), D5.3 (T. Baccega et alii (2019)), D5.4 (D. Leboullenger et alii (2019)) and Pelizzon, L. and M. Riedel. (2017). Creating an Energy Efficient Mortgage for Europe: Review of the impact of energy efficiency on probability of default.

[6] The major deliverables focusing on these aspects are: D5.4 (M. Billio et alii (2019)), D5.5 (M. Billio et alii (2020)), D5.7 (Billio et alii (2020)).

Nevertheless, both messages remain quite constant, confirming the positive correlation between EE on property value and reducing the risk of the owners' default. Given the largest availability of data for the US, most study evaluate the performance of the ENERGY STAR label.

According to the relevant literature, the major channel of transmission of the EE benefits occurs through reduced energy consumption allowing an increase in terms of disposable income and thus reducing the risk of default (PD) for the borrower and the risk for the lender through a lower LGD[7] if the proportion of defaulting borrowers is reduced. Other potential channels of transmission affecting positively the disposable income, that are not evaluated yet by the literature, concern the potential reduction in terms of healthcare expenses and the capacity to generate further revenues through selling the surplus of residential solar electricity to the grid.

The following two tables summarize the major findings obtained by the literature and discussed under the EeMAP project.

Table 1. EeMAP Findings Literature review: correlation between EE and PD

Country	Study	Major findings
USA	Burt, Goldstein, and Leeds (2010)	House ratings represent an accurate approximation of the reduced annual energy costs translating into lower default risk.
USA	Kaza, Quercia, and Tian (2014)	ENERGY STAR- labelled properties (EE properties) are less exposed to defaults.
USA	An and Pivo (2015)	ENERGY STAR- rated commercial buildings present a 20 percent lower probability of default comparatively to non EE buildings.
USA	Wallace et al. (2017)	EE efforts (evaluated eighter trough site energy use intensity, or source energy use intensity, or the ENERGY STAR score) reduce significantly the default risk.
USA	Rauterkus, Thrall, and Hangen (2010)	The borrowers' repayment ability is also conditioned by other buildings' sustainability features: property's location, access to transportation facilities, affordability and etc.
USA	Pivo (2013)	The borrowers' repayment ability is also conditioned by other buildings' sustainability features: property's location, access to transportation facilities, affordability and etc.
UK	Guin and Korhonen (2018)	The borrowers of energy efficiency properties are less exposed to mortgage payment defaults.

Source: EeMAP project (2019)

Table 2. EeMAP Findings Literature review: correlation between EE and property value

Country	Study	Major findings
USA	Eichholtz, Kok, and Quigley (2010)	ENERGY STAR-rated commercial properties benefit from a 3% higher rental rate and a sale premium up to 16% higher.

7 As it will be discussed further increased property value also reduces the LGD, through a lower exposure of the lender.

USA	Bloom, Nobe, and Nobe (2011)	ENERGY STAR-rated properties benefit from higher sales prices comparatively to equivalent non- EE properties.
Netherlands	Brounen and Kok (2011)	EE labelled properties benefit from a 10% sale premium.and are sold within shorter time delays comparatively to equivalent non-EE properties.
Sweden (Stockholm)	Högberg (2013)	EE information is integrated into home buyers' decisions and more efficient properties benefit from a sale premium.
USA	Kahn and Kok (2014)	EE labelled properties (LEED, GreenPoint, ENERGY STAR) benefit from a 2.1% sale premium.
Northern Ireland	Davis et al. (2014)	EE characteristics are integrated into properties' sales prices in Belfast, Northern Ireland
Singapore	Deng and Wu (2014)	EE labelled properties benefit from a price premium of 4.7% in the residential resale sector
EU, USA, Australia, Japan, Singapore	Ankamah-Yeboah and Rehdanz (2014)	EE buildings benefit from a larger premium at the sales than in the rental market; The observed effects are larger for commercial buildings comparatively to residential buildings. The EU presents the highest price premiums followed by the US.
Japan	Yoshida and Sugiura (2015)	EE residential buildings in Tokyo benefit from a price premium
England	Fuerst et al. (2015)	EE ratings influence positively properties' sales prices.
Japan	Yoshida, Onishi, and Shimizu (2016)	Rent premiums are rather related to reduced power and water expenses instead of EE labels.
China	Zhang, Liu and Wu (2016)	EE labelled properties benefit from an average price premium of 6.9% comparatively to equivalent non-EE properties.
Netherlands	Chegut, Eichholtz, and Holtermans (2016)	EE labelled properties benefit from a sale premium of 2.0 to 6.3 percent comparatively to equivalent non-EE properties.
Spain	De Ayala, Galarraga, and Spadaro (2016)	EE labelled properties benefit from a price-premium between 5.4% and 9.8%
UK	LENDERS (2017)	The potential savings on energy bills will increase the disposable income and thus will affect their borrowing capacity and reduce the default risk.

Source: EeMAP project (2019)

2.1.1. Correlation results obtained for the cases of Belgium, Germany, Italy, Netherlands

The major challenge faced by most studies in the field of EE mortgages is related to data availability and exploitability. As described in Table 3, in the case of the EeMAP project, focusing exclusively on the residential sector, only two national datasets have presented all the necessary requirements to fulfill a proper analysis (Belgium and Netherlands).

Table 3. EeMAP Findings Summary Table

Country	Scope	Main Findings	Energy Performance Criteria	Data Source	Reference
Belgium	Residential	Negative correlation – mortgages on energy efficient properties are correlated with lower risk (measured by PD survival rates)	Loan eligibility for 2009-2011 Government retrofitting programme (dummy variable)	Proprietary bank data on loan type and origination date	EeMAP Technical Report D5.3
Germany	Residential	Inconclusive – the absence of default data in the sample prevents any analysis or hypothesis testing.	Municipality and year of introduction of the "Passiv House Standard"	Building's construction year and zip code information	EeMAP Technical Report D5.2
Italy	Residential	Inconclusive – It has not been possible to merge the building-level information one-to-one with the anonymised loan-level data for data privacy regulations issues	Government EE financing programme (dummy variable)	ENEA – Italian Energy Agency data and anonymized loan-level banking information	EeMAP Technical Report D5.3
Netherlands	Residential	Negative correlation – Mortgages on energy efficient properties are correlated with lower risk (measured by PD survival rates)	EPC ratings	RVO Energy Agency	EeMAP Technical Report D5.3

Source: EeMAP project (2019)

Both results conclude to a negative correlation suggesting that EE mortgages are related with a lower credit risk expressed through a lower PD. These results are in line with those obtained by the existing literature, presented in the previous section, studying mainly the cases of the UK and the US.

Two additional attempts have been made (for the cases of Germany and Italy), but unfortunately, several data related issues have not allowed to perform a complete evaluation.

2.2. Summary of obtained results under EeDaPP

2.2.1. Correlation results described by the literature

The work led under the EeDaPP project aimed to complete with more recent studies, the undergone research within the EeMAP framework. Thus, two major orientations have been chosen: one focusing on the correlation between EE and default risk and one on the correlation between EE property value. The following two tables summarize the major findings of the recent literature on these two topics and conclude to a rather positive correlation in terms of reduction of the probability of default and an increased value of the concerned property.

Table 4 includes the three major studies discussed under EeMAP (Guin and Korhonen (2018) and Kaza and al. (2014) and An and Pivo (2015)) assessing the negative correlation between EE and default risk as well as some more recent studies reaching the same conclusions.

Table 4. Studies evaluating the correlation between EE and probability of default (PD)

Country	Studies	Findings
USA	Kaza, Quercia, Tian (2014)	lower default risk
USA	An and Pivo (2015)	lower default risk
USA	An and Pivo (2020)	lower default risk
USA	Wallace, N., Issler, Mathew, Sun (2018)	lower default risk
USA/EU	Zancanella, Bertoldi, Boza-Kiss (2018)	lower default risk
World	Pelizzon And Riedel (2017)	lower default risk
UK	Guin and Korhonen (2018)	lower default risk
Netherlands	Billio, Costola, Pelizzon, Riedel (2020)	lower default risk
UK	Guin and Korhonen (2020)	lower default risk

Source: EeDaPP project (2020)

Table 5 presents an overview of the most recent studies focusing on the correlation between EE and property value. Most of the papers concern the UE and the US. Several other works describe the situation on the Asian market (Japan, Singapore, China) or at the world level.

Out of the 31 included studies, only 2 obtain rather inconclusive results concerning the positive correlation between EE and property value.

Table 5 – Studies evaluating the correlation between EE and property value (PV)

Region	Country	Studies	Findings
US	**US**	Eichholtz, Kok, and Quigley (2010)	higher property value
		Bloom, Nobe, and Nobe (2011)	higher property value
		Fuerst and McAllister (2011)	higher property value
		Aroul and Hansz (2011)	higher property value
		Dastrup and Zivin (2012)	higher property value
		Kahn and Kok (2014)	higher property value
		Bruegge, Carrion-Flores, Pope (2016)	higher property value
		Qiu, Wang and Wang (2017)	higher property value
		Szumilo and Fuerst (2017)	higher property value
EU	**Netherlands**	Brounen and Kok (2011)	higher property value
	Netherlands	Chegut, Eichholtz, and Holtermans (2016)	higher property value
	Netherlands	DNB (2019)	higher property value
	Sweden (Stockholm)	Högberg (2013)	higher property value
	Sweden	Wahlström (2016)	higher property value
	Germany	Cajias and Piazolo (2013)	higher property value

	Germany	Surmann, Brunauer, Bienert (2015)	No evidence, but important restrictiveness of the data sample
	UK	Fuerst, McAllister, Nanda, Wyatt (2015)	higher property value
	UK	UK Green Building Council, LENDERS project, Core report (2017)	higher property value
	Spain	De Ayala, Galarraga, and Spadaro (2016)	higher property value
	Italy	Mangialardo, Micelli, Saccani (2018)	higher property value
	Austria, Belgium, France, Ireland and the UK	Mudgal et. alii (DG Energy) (2013)	higher property value
	Austria, France, Germany, Italy, Norway, Poland, Romania and Spain	Pascuas, Paoletti and Lollini (2017)	EPCs considered unreliable or difficult to understand by real estate agents
	EU	Pascuas et alii (ZEBRA 2020) (2017)	higher property value
	EU	Brocklehurst (2017)	higher property value
	EU	Heijmans and Loncour (2019)	higher property value
ROW and world	**Singapore**	Deng and Wu (2014)	higher property value
	Japan	Yoshida and Sugiura (2015)	higher property value
	Japan	Yoshida, Onishi, and Shimizu (2016)	no effect
	China	Zhang, Liu, Wu and Zhang (2020)	higher property value
	World	Ankamah-Yeboah and Rehdanz (2014)	higher property value
	World	Zancanella, Bertoldi, Boza-Kiss (2018)	higher property value

Source: EeDaPP project (2020)

2.2.2. Correlation results obtained for the case of Italy

The econometric evaluation under the EeDaPP project faced several difficulties. Given the recent character of EE investments and the lack of legally binding constraints for each EU member state to meet the 2020 target, data availability is quite uneven and insufficient in terms of observations. Besides, the existing heterogeneity across the existing EE labels within the EU generates further complications for a tangible international comparison. Moreover, the EU's recent implementation of the General Data Protection Regulation (GDPR), slowed down the cooperation with pilot banks and the data collection process (a specific documentation was developed and implemented by CRIF and University Ca'Foscari of Venice in order to fulfil all the confidentiality requirements). At last, given the particularities of EE data and financial data, in some cases, matching issues can occur.

Within the project, three mortgage datasets covering the countries Belgium, Italy, and Portugal were considered. The Belgian and the Portuguese data was gathered from two national banks. The Italian data was provided by CRIF. Given the small size of the first two datasets and their inherent loan composition (samples characterized by relatively young loans and very few observed defaults), neither of the two portfolios could be used for a proper empirical analysis.

Thus, the econometric evaluation focused on the last Italian sample, given its more consequent size. It includes observations of 72,980 individual mortgage loans with mortgage origination years from 2012 to 2019.

According to the associated portfolio analysis, the percentage of more energy efficient mortgages has been increasing within the last decade, while less efficient properties are predominantly affected by a default. Indeed, in terms of EPC ratings, the larger share of the Italian mortgage market seems to concentrate on categories beyond the C rating level, which are also the most concerned by defaults. Within the considered sample, the largest share of mortgages is located in the regions of Lombardy and Emilia Romagna, and the regions of Abruzzo, Umbria, Veneto, Molise are those encompassing the largest shares of EE loans. The regions of Abruzzo, Sicilia, and Umbria present the highest degrees of non-EE defaults, while Calabria and Friuli Venezia Giulia have the highest degrees of EE defaults.

For the econometric evaluations, two major methodologies are applied: the Logit model and the Cox model. Both estimations highlight a negative correlation between EE and the owners' probability of default (PD), thus confirming that EE investments tend to improve owners'/borrowers' solvency. Additionally, the results indicate that the degree of energy efficiency also matters, i.e., more energy efficient buildings are associated with relatively lower risk of default. Once again, these findings highlight the role of energy efficiency in reducing the default probability of a borrower.

Despite important data availability constraints, the performed correlation analyses and the undergone literature reviews, under both projects, tend to demonstrate a positive effect of EE on credit risk reduction, through owners' probability of default (PD) reduction and increased property value. From a lender's perspective, this should involve reduced PD and loan to value (LTV) ratios. The relevance of these two indicators for the definition of the mortgages risk weights (RW) and the inherent capital requirements will be discussed in the next section.

3. General EU prudential framework and real estate financing

In order to understand at best the potential impacts of the Basel regulation on mortgages and EE mortgages, the first part of this section will be dedicated to the description of the major principles of the Basel regulation and their evolution, especially after the 2008 Subprime crisis.

3.1. The Basel framework

3.1.1. Creation of the Committee on Banking Regulations and Supervisory Practices

In consequence of important international currency disturbances, and the collapse of the Bretton Woods system, the central bank governors of G-10 (Belgium, Italy, France, Germany, Netherlands, Sweden, Japan, Canada, United Kingdom and United States) decided to establish in 1974 the Committee on Banking Regulations and Supervisory Practices. The latter was ultimately renamed Basel Committee on Banking Supervision (BCBS) which is holding four sessions annually organized by the Bank of International Settlements (BIS).

In the 1980s, banks' failures were particularly regular, as banks were lending at excessive levels and countries foreign indebtedness was also unsustainably increasing. This period, known in the U.S as the "savings and loan crisis", was characterized by a considerable potential bankruptcy risk for the major international banks given insufficient available capital.

Thus, the main target of the Basel Committee was the creation of a series of international standards for banking regulation in order to reduce credit risk and promote financial stability. The first aim of the Committee was to improve the international supervisory coverage. In this regard, several steps

have been launched to set the principles for sharing supervisory responsibility among national and foreign branches, and an improved cross-border transmission of prudential information concerning international banks. Based on the endorsement of supervisors from 140 countries, the report on "The supervision of cross-border banking" allowed an intensification of the relationship among supervisors in home and host countries.

The enlarged involvement of supervisors beyond the G-10 group has thus played a crucial role for the release of the Committee's Core principles for effective banking supervision, aspiring for a more effective supervision in all important financial hubs including those in emerging market economies.

The strengthening of the supervision coverage and procedures represented the first milestone in the international cooperation that led to the Basel Accords. Even though they are not legally enforceable, and must be adopted by national institutions, they have established several requirements and assessment methodologies reducing the banking system exposure to financial crises and amplifying its solvency capacity in times of financial instability. Thus, throughout all the Basel Accords, one of the essential topics concerns the banks' capital requirements and the used methodologies evaluating banks' credit risk.

3.1.2. Basel I: the Basel Capital Accord

The first Basel Accord, finalized in 1988 and implemented in 1992, aimed to reach a greater convergence in terms of minimum reserves requirements. Indeed, the large variety of national capital requirements was leading to a competitive inequality with potential repercussions on the financial stability of the international banking system. Namely, given the important interdependence and integration of financial markets, the potential default of a given international bank risks to impact severely several countries.

Thus, the first Basel agreement defined a separation between the Core Capital (Tier 1) and the Supplementary Capital of a bank (Tier 2). The first group includes all disclosed reserves and equities (representing the primary funding source of banks and at least 50% of their capital), while the second represents all other capital such as gains on investment assets, long- term debt (maturity greater than 5 years), undisclosed, revaluation and general loan/loss reserves.

A broad consensus was reached on the necessity of a weighted approach of the credit risk measurement and management. Thus, the Accord proposed a new framework classifying assets into four categories with respect to their risk weights:

- 0% for risk-free assets (such as: cash, treasury bonds from OECD countries)
- 20% for loans to other banks or securities with the highest
- 50% for residential mortgages
- 100% for corporate debt, sovereigns from non-OECD countries

International banks were advised to respect a minimum capital to risk-weighted assets ratio of 8% (Cooke's ratio). In order to reach these levels of cash reserves banks were encouraged to allocate a larger share of their capital to lower-risk investments and to favor sovereign debt and residential mortgages rather than corporate debt.

This framework was finally implemented not only in G-10 countries but also in all countries with international banks operating. Several amendments have allowed eighter for the inclusion of further precisions on the applied methodology or of additional factors for the calculation of capital adequacy, or for a better recognition of bilateral and multilateral netting effects.

The 1996 amendment targeted a further expansion of considered risks through the inclusion of market risk. The latter was incorporating all risks related to banks exposures to foreign exchange operations, and the trading of equities, debt securities, commodities, and options. Given the specific character of the amendment, securities regulators were also involved in its preparation. Moreover, for the first time, was authorized the use of internal models measuring banks' market risk capital requirements. The common adoption of internal value-at-risk models, even though subject to strict quantitative and qualitative standards represent one of the major topics discussed within Basel III accords.

3.1.3. Basel II: the revised capital framework

After the implementation of the minimal reserves requirements and the inclusion of market risk, the international banking system adopted the Basel II accords in 2004. It represented an extension of the previous accord through a deeper focus on three main pillars:

- **Pillar I- Regulatory Capital Charges:** given the large variety of risks that international banks face, the Accords proposed an extension of the definition of risk in the computation of the minimum capital requirements. The enlarged risk management framework, thus, included market and operational risks, to the already considered under Basel I (first version), credit risk. The latter corresponds to all risks arising from the banks' lending activity and encompasses recovery, default and counterparty risk (Bessis, 2015). Market risk is exogenous to the bank and refers to large market price movements related to interest rates, exchange rates, commodities, and equities. Operational risk is defined such as including all human factors, internal processes, and systems failures, as well as legal and regulatory risks (Basel Committee on Banking Supervision, 2006).

  Besides this enlargement of the risk definition, standardized measures of operational risk have been created. Also, a new approach on credit risk has been implemented trough a more precise separation of banks according to their exposure, a more specific targeting of risk assets and the use of less rigid evaluation methods (further details in Tables 6, 7 and 8). Furthermore, concerning credit exposure, particular attention has been dedicated to market values instead of book values, which ultimately revealed as one of the regulation drawbacks leading to the subprime crisis.

- **Pillar II- Supervisory mechanisms:** national regulators are authorized and encouraged to supervise the banks' internal risk control and capital assessment processes, through potentially requiring larger reserves facilities than the standardly defined under Basel I.

- **Pillar III- Market discipline through greater transparency:** the Accords required an enhanced disclosure of risk, in order to ease the supervision and the access to information. Transparency was considered as the necessary counterpart to a larger independence in the definition of the minimum capital requirements through the use of internal models.

As announced above, concerning credit risk, the new Accord implemented a separation among banks according to their activities and therefore to their exposure to risk. Table 6 summarizes the different regulation adopted in terms of risk measurement, capital calculation and differentiation in required capital between safer and riskier credits.

Table 6 Banks separation under Basel II

Types of banks	Credit risk measurement	Capital calculations	Differentiation in required capital between safer and riskier credits
Standardized	Fixed risk weights based on external ratings	Least sophisticated capital requirements	Least differentiation
Foundation IRB	Using formulas with internally determined inputs of PD and externally determined inputs by regulators (LGD, EAD and maturity).	More risk sensitive capital requirements	More differentiation
Advanced IRB ***(only with robust management system and data)***	Using formulas with internally determined inputs of PD, LGD, EAD and maturity	Most risk sensitive capital requirements	Most differentiation

Source: Latham & Watkins and Goldman Sachs (2009)

Further changes have been operated also within the banks' risk weighted assets. While Basel I accord were benefitting mainly to OECD countries and banks from OECD countries, under Basel II weights are assigned more strictly relatively to the ratings obtained by the concerned country or entity. Thus, countries, banks and companies with higher ratings are favored in comparison with the previous framework. Moreover, residential mortgages are considered as less risky. A brief overview of these aspects is presented in Table 7.

Table 7 Evolution of revised standardised approach to credit risk : Assets' weights evolution under Basel I and II

	Basel I	Basel II
Risk-free assets	• 0% for OECD risk-free assets (such as: cash, treasury bonds from OECD countries) • 100% for non-OECD countries	• 0% only for assets from countries with ratings AA- or above • evolution from 20% to 150% for entities with ranks from A to below B- • 100% for unrated entities
Loans to other banks	• 20% for loans to other banks (OECD countries, otherwise 100%) or securities with the highest credit rating	• 20% only for banks rated AA- or above • Evolution from 50% to 150% for banks with lower ratings • 100 or 50 % for unrated entities (according to national regulators' choice

Mortgages	• 50% for residential mortgages • 100% for commercial mortgages	• 35% for residential mortgages • 100% for commercial mortgages
Corporate debt	100%	Evolution from 20% to 150% according to the entities' ratings
Retail	100%	• 75% to individual and small business, diversified portfolio, max. aggregate exposure ≥ €1 million • 150% to 50% if default, depending on specific provisions against exposure
Equity	100%	100% (for corporates, banks and securities firms)
Specialized lending	100%	100%
Covered bonds	• 10 % in general • 20% (Italy, Portugal, UK, Sweden)	• same treatment as for banks • CRD rated bonds: 0% only for issuing banks with ratings AA- or above • evolution from 20% to 100% for entities with ranks from A to below B- • CRD unrated bonds: risk weight based on the one of the issuing bank

Source: Latham & Watkins and Goldman Sachs (2009) and UniCredit Research (2019)

Under the Capital Requirements Directive (CRD) (Directives 2006/48/EC and 2006/49/EC), covered bonds must be compliant with the UCITS-directive (Directive 2009/65 / CE) and have to fulfill several conditions regarding their collateral. Namely, are concerned: certain EU sovereign exposures, certain residential real estate exposures (up to 80% of value), certain commercial real estate exposures (up to 60% of value), certain loans secured by ships (up to 60% of value) and etc.

Another major change to the Basel I framework has been operated through the larger adoption of internal models evaluating market risk and operational risk. As summarized by table 8, the more rigid methodology applied under the previous regulation is replaced by a larger use of internal methodologies for the assessment of all three risks (Credit, Market and Operational).

This new approach allows to include some risk reducing techniques and thus provides more flexibility concerning the requested capital provisions, which unfortunately transformed into one of the weaknesses of the system.

Table 8 Risk computation methodologies under Basel I and II

Type of risk	Basel I	Basel II
Credit	Standard fixed approach according to the counterparty	• Standard approach (SA) based on external ratings. • Internal ratings (based on internal data and used upon authorization from the regulator)

Market	• Standard approach (SA) • Internal models (Value at risk models)	Unchanged
Operational		• Standard approach (SA) • Internal models

Source: ACPR (2017)

The adoption of these new rules required varying timescales (transition period from 2007 to 2010) and a strengthen cooperation between host and national supervisors, in order to allow to committee members and non-member countries to join the initiative.

Unfortunately, all these financial innovations and common efforts faced the unforeseen reality of the 2008 subprime crisis which revealed the underestimation of the interconnectivity among banks, the insufficient level of liquidity buffers and excessive leverage.

3.1.4. Basel III: the response to the subprime crisis and Basel IV

Indeed, the global financial crisis of 2008 revealed the weaknesses of the existing financial system and the limitations of the implemented regulation. Thus, the Basel III Accords were created to overcome insufficient and inefficient corporate governance and liquidity management practices, as well as inappropriate leverage capital structures and an inadaptation of the existing regulation to globalized financial flows.

These aspects have also been highlighted by Blundell-Wignall et al. (2018) which described not only the incapacity of the Basel II capital requirements to alleviate the effects of globalization (characterized by intense competition and interdependence), but furthermore have contributed to the expansion of leverage, through a growing use of off-balance sheet activity and derivatives.

Similar conclusions have been proposed also by the common report prepared by Latham & Watkins and Goldman Sachs (2009). They identified four major failings of the existing regulatory framework:

- The use of originate-to-distribute models too loosely regulated and controlled.
- The existence of certain too low risks weights (especially for off-balance sheet commitments).
- The use of trading book values for certain illiquid exposures, with market risk models unable to capture and fully evaluate the inherent risks.
- The insufficient and limited disclosure of off-balance sheet structured funding activities.

The observed dangerous combination of poor governance, limited risk management, and inappropriate incentive structures leading to important leverage exposure and insufficient liquidity buffers, thus, provided the necessary orientations for further improvements of the regulatory framework in order to avoid credit mispricing and its excessive growth.

The Basel III regulations were created in 2010, but their implementation is still postponed due to a long process of negotiations and the Covid-19 epidemic. They are expected to enter into force in 2022, according to the Bank of International Settlements (BIS). Given the long process of negotiations and the important level of amendments that have arisen, a large part of the industry defines the last

version of the agreement as Basel IV or finalized Basel III package[8]. Thus, in this section we will present mainly the most updated version of the accords.

In a nutshell, the new accords suggest the necessity for an increase of the capital reserve requirements for commercial banks, lower leverage ratios through a greater use of equity (instead of debt) and stricter liquidity ratio requirements. The proposed enhancements envision the possibility to adapt the compulsory reserves levels with regards to the economic context, with higher levels requested in times of credit expansion and conversely lower levels corresponding to reduced lending periods. Furthermore, the initiated under Basel II differentiation of banking institutions has been deepened through the categorization of banks based on their size and overall impact on the economy. Thus, larger banks with potential systemic effects on the global economy have been requested to keep larger reserves to guarantee the financial stability of the economy.

More specifically, as specified by BIS, in a first approach, the new framework aimed to improve and complete the previous three-pillars (capital requirements, supervisory mechanisms, and disclosure) through:

- the definition of stricter requirements on the quality and quantity of regulatory capital through a revision of the applied risk weights (RW) and a Minimum Ratio of total capital to RWAs of 10.50% instead of 8% under Basel I and II,
- the inclusion of global standards for counterparty credit risk and securitisation,
- the creation of a capital conservation (loss-absorbing) buffer (allowing to meet the minimum common equity requirement named the Common Equity Tier 1 (CET1) capital),
- the creation of a countercyclical capital buffer (restricting the participation of banks to credit booms and reducing their losses during credit busts through the adaptation of the reserves levels described above),
- a revised leverage ratio (limiting the bank's excessive exposure and accounting for off-balance sheet exposures regardless of risk weighting) and the creation of a corresponding compensating loss-absorbing buffer, in complement to the RW capital requirements,
- the definition of the Liquidity Coverage Ratio (LCR) (representing the liquidity necessary to guarantee the funding needs of the bank during 30 days of stress), thus it represents the ratio of high-quality liquid assets (HQLAs) sufficient to cover 100% of net cash outflows,
- the creation of the Net Stable Funding (NSF) Ratio (aiming to ensure a stable funding with regards to the assets and off-balance sheet activities of banks and thus compensating for any maturity mismatches),
- the creation of specific requirements for larger systemic banks and of a capital buffer aiming to compensate potential externalities,

[8] For purposes of a greater differentiation between the first and the finalized versions of the Basel III accords, we will choose to use the label "Basel IV" when we refer to the finalized package.

- strengthening of cross-border supervision relations.

In a second step, the Committee focused on the calculation methodology of capital requirements, with a specific framework dedicated to capital requirements for securitization, but also improving the credit risk assessment with the inclusion of derivatives transactions. An improvement of the market risk framework, as well as the review of the trading book capital requirements have also been discussed and disclosure procedures have been strengthened.

Furthermore, in 2017, new standards have been established for the calculation of capital requirements for credit risk (2.4.1), credit valuation adjustment risk and operational risk (2.4.2). Besides the revised leverage ratio and leverage ratio buffer for large systemic banks (2.4.3), the reforms include an output floor limitating the use of internal models for the computation of capital requirements and input floors (discussed in 2.4.1).

3.1.4.1. Capital requirements

Under the last version of the Basel III agreement, several changes have been implemented with regards to the computation of the capital provisions in order to encompass a larger set of situations and reach a greater granularity but also to include off-balance sheet exposures into the evaluation of credit risk.

As described in Table 9, most categories have been further detailed with greater requirements to be fulfilled. For mortgages and covered bonds, the framework is more complex and instead of fixed risk weights (RW), one can observe a variation of RW according to the LTV band of concern for mortgages and a stricter risk evaluation for covered bonds.

Table 9 Evolution of revised standardised approach to credit risk : Assets' weights evolution under Basel I, II and III

	Basel I	Basel II	Basel III
Risk-free assets	• 0% for OECD risk-free assets (such as: cash, treasury bonds from OECD countries) • 100% for non-OECD countries	• 0% only for assets from countries with ratings AA- or above • evolution from 20% to 150% for entities with ranks from A to below B- • 100% for unrated entities	Unchanged
Loans to other banks	• 20% for loans to other banks (OECD countries, otherwise 100%) or securities with the highest credit rating	• 20% only for banks rated AA- or above • Evolution from 50% to 150% for banks with lower ratings • 100 or 50 % for unrated entities (according to national regulators' choice	• 20% only for banks rated AA- or above, 30% for banks rated A- or above, evolution from 50% to 150% for banks with lower ratings • 20% for short term exposures for banks rated BBB- and above, 50% to 150% for lower ratings • 40/70/150 % for unrated entities (according to the concerned grade A/B/C relative to the level of exposure)
Mortgages	• 50% for residential mortgages • 100% for commercial mortgages	• 35% for residential mortgages • 100% for commercial mortgages	• Residential : according to LTV bands (20% for below 50% LTV, evolution from 25% to 70% for LTV above 50% and 100%

			• Commercial: Min (60%, RW of counterparty) for LTV ≤ 60% RW of counterparty for LTV > 60%
Corporate debt	100%	Evolution from 20% to 150% according to the entities' ratings	• Evolution from 20% to 150% according to the entities' ratings • 100% for unrated or 85% if corporate SME
Retail	100%	• 75% to individual and small business, diversified portfolio, max. aggregate exposure ≥ €1 million • 150% to 50% if default, depending on specific provisions against exposure	• 75% if Regulatory retail (non-revolvers) and revolvers • 45% if Transactors
Equity	100%	100% (for corporates, banks and securities firms)	• 150% for Subordinated debt and capital other than equities • 100% for Equity exposures to certain legislated programmes • 400% for Speculative unlisted equity • 250% for All other equity exposures
Specialized lending	100%	100%	Same as for corporate debt
Covered bonds	• 10 % in general • 20% (Italy, Portugal, UK, Sweden)	• same treatment as for banks • CRD rated bonds: 0% only for issuing banks with ratings AA- or above • evolution from 20% to 100% for entities with ranks from A to below B- • CRD unrated bonds: risk weight based on the one of the issuing bank	• Rated covered bonds: 10%/20%/50%/100% for respectively external issue-specific ratings AAA to AA–/A+ to BBB–/BB+ to B–/Below B– • Unrated covered bonds: 10%/15%/20%/25%/35%/50%/100% for respectively RW of issuing bank 20%/30%/40%/50%/75%/100%/150%

Source: Latham & Watkins and Goldman Sachs (2009), UniCredit Research (2019) and BIS (2017)

Furthermore, the accord has proposed several tools to harmonize the use of internal models. The aim was to reduce excessive variability of risk-weighted assets and to restore the credibility of the applied methodologies. Thus, output and input floors have been defined, as well as changes of Internal Ratings-based (IRB) approaches for several assets' classes have been implemented.

3.1.4.2. IRB approaches

As already explained, one of the major shortcomings of the previous regulation was related to the large use of inadapted internal models used for the calculation of regulatory capital requirements, including IRB approaches. As indicated in Table 8, two major methodological types have been implemented under Basel II: SA based on external ratings and IRB.

However, the large complexity of the used IRB approaches, the impossible comparability among banks and the lack of robustness for several asset classes have led to a reorganization. Thus, the evaluation of credit risk exposures of large and mid-size corporates, banks and other financial institutions and equities cannot be evaluated anymore through advanced IRB (A-IRB) approaches (Table 10).

Table 10 Revised scope of IRB approaches for asset classes

Portfolio/exposure	Basel II: available approaches	Basel III: available approaches
Large and mid-sized corporates (consolidated revenues > €500m)	A-IRB, F-IRB, SA	F-IRB, SA
Banks and other financial institutions	A-IRB, F-IRB, SA	F-IRB, SA
Equities	Various IRB approaches	SA
Specialised lending[3]	A-IRB, F-IRB, slotting, SA	A-IRB, F-IRB, slotting, SA

Source: BIS (2017)

These were allowing banks to estimate the inherent risk of assets that could not be modelized in a robust and prudent manner. They were used for the estimation of parameters such as: PD, LGD, exposure at default (EAD) and the maturity of an exposure.

According to the new regulation, aiming to reduce the variability of RWA, the foundation IRB (F-IRB) approach will be implemented since it applies fixed values to the LGD and EAD parameters. Furthermore, exposures to equities will be only evaluated through Standard Approaches.

Further improvements relative to the use of internal models concern the implementation of input floors, a more detailed specification of the estimation practices and the adaptation of the previously existing output floor.

3.1.4.3. Input floors

Input floors represent minimum values for bank estimated parameters used within the computation of RWA. These include the levels of PD for F-IRB and A-IRB approaches and LGD and EAD levels for A-IRB (Table 11).

Table 11 Minimum parameter values in the revised IRB framework (input floors)

	Probability of default (PD)	Loss-given-default (LGD)		Exposure at default (EAD)
		Unsecured	Secured	
Corporate	5 bp	25%	Varying by collateral type: • 0% financial • 10% receivables • 10% commercial or residential real estate • 15% other physical	EAD subject to a floor that is the sum of (i) the on-balance sheet exposures; and (ii) 50% of the off-balance sheet exposure using the applicable Credit Conversion Factor (CCF) in the standardised approach
Retail classes:				
Mortgages	5 bp	N/A	5%	
QRRE transactors	5 bp	50%	N/A	
QRRE revolvers	10 bp	50%	N/A	
Other retail	5 bp	30%	Varying by collateral type: • 0% financial • 10% receivables • 10% commercial or residential real estate • 15% other physical	

Source: BIS (2017)

Thus, according to the new regulation, the minimum level for mortgage PD should be 0.05% and the LGD levels for corporates with real estate collaterals should be at least 10%.

The introduction of such minimum values aims to ensure a minimum level of similarity and comparability in model parameters obtained through IRB approaches, but mainly to improve the robustness and risk sensitivity of IRB models.

Indeed, the lower the value of a parameter is, the greater will be the necessary number of observations for its relevant estimation. Thus, in case of a restricted number of observations, the underestimation risk is higher. Namely, one of the drawbacks of the previously used models concerns the insufficient number of historical default observations. For this reason, the newly proposed PD input floors for exposure classes are higher to the 0.03% input floors under Basel II (Capgemini 2020).

Since LGD modelling is based on poorer data quality, comparatively to PD evaluations, the risk of underestimation is even higher and thus the impact of input floors on IRB would be even greater.

3.1.4.4. Additional improvements

Further risk reduction techniques have also been considered such as:

1) LGD parameter reduction for unsecured exposures (40% instead of 45% for exposures to non-financial corporates);

2) LGD parameters reduction and collateral haircuts increase for non-financial collateral secured exposures.

Collateral haircuts represent the difference between the market value of an asset and the amount that can be used if the asset is used as a collateral. Thus, it corresponds to the percentage reduction in the asset's value if the latter is used as a collateral for a loan. Normally, the haircut is defined according to the lender's associated risk. Increased haircuts suggest a higher degree of risk and thus aim to limit the creditors losses. The same target is reached also through reduced LGD parameters.

3.1.4.5. Output floor

Under Basel III, the output floor has considerably evolved. While, under Basel II, the floor was calibrated such as representing 80% of the relevant Basel I reserve requirements, the Basel III revision is more complex. This change has been necessary since the previous implementation of the tool, across countries, was inconsistent but also because it was based on Basel I, which is no longer in application.

The new version defines a limitation on the bank's capacity to reduce their capital requirements comparatively to the standardized approaches. Thus, the use of internal models is allowed upon the following conditions: RWA of a bank must be calculated such as (i) representing at least 72.5% of the total RWA computed by using only the standard approach and such as (ii) they comply with the supervisory approval defined by the Basel capital framework. Therefore, a higher ratio would not involve any consequences, while a smaller one would require a compensation equal to the observed difference added to the internal model RWA.

During the negotiations, the French/German approach has opposed to the American. The U.S. insisted for a higher level which should avoid important discrepancies among banks' and regulators' risk assessments, while the European approach was considered as providing more flexibility to banks and a greater granularity.

3.1.4.6. Operational risk

Instead of the three previously existing standardized approaches and the advanced measurement approaches (AMA) used for the computation of operational risk capital provisions, the new regulation (BIS, 2017) proposes a single risk- sensitive standardized approach (the Standardized Measurement Approach (SMA)). The latter combines the evaluation of the income of the concerned bank and its historical losses. Thus, banks with higher incomes are believed to be more exposed to operational risk increases and those that have already experienced such type of losses are more prone to experience similar losses in the future.

3.1.4.7. Leverage Ratio framework

The leverage ratio, as indicated by BIS (2017), aims to limit the banks' exposure, in order to avoid a repetition of the previous crisis. The leverage ratio buffer targets Global Systemically Important Banks (G-SIBs) as their exposure might induce important externalities for the entire banking and economic systems.

The leverage ratio is obtained by dividing Tier 1 capital by the bank's total consolidated assets (on and off-balance sheet exposures) and it should reach a minimum level of 3%.

The related leverage ratio G-SIB buffer should be set at 50% of the riskweighted higher-loss absorbency requirements of a bank and it should be met with core capital (Tier 1: capital+ reserves). Similarly to the risk-weighted framework, it is divided into five levels, according to the capital distribution constraints that will be imposed on the concerned banks (Table 12).

Table 12 Capital conservation ratios relative to leverage ratio

CET1 risk-weighted ratio	Tier 1 leverage ratio	Minimum capital conservation ratios (expressed as a percentage of earnings)
4.5–5.375%	3–3.125%	100%
> 5.375–6.25%	> 3.125–3.25%	80%
> 6.25–7.125%	> 3.25–3.375%	60%
> 7.125–8%	> 3.375–3.50%	40%
> 8.0%	>3.50%	0%

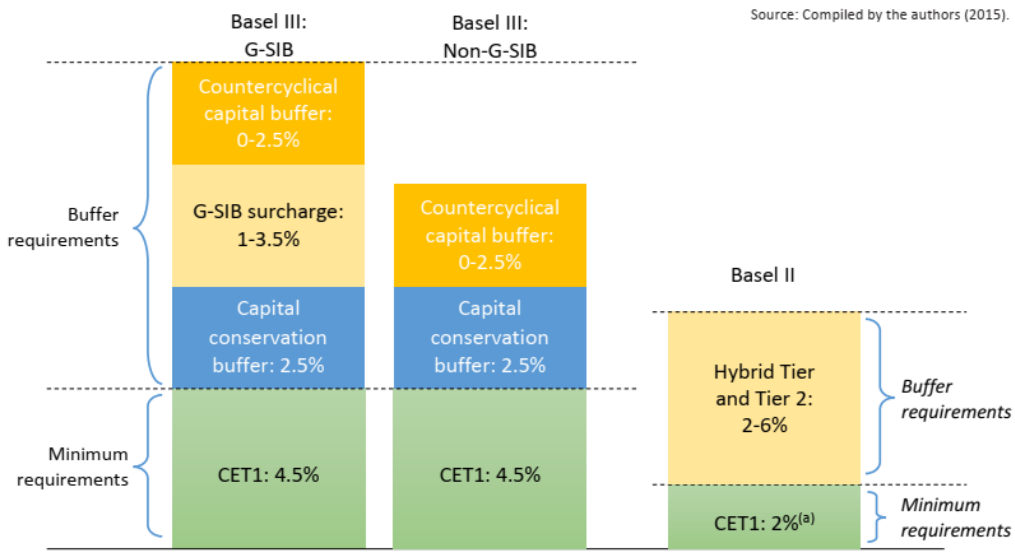
Source: BIS (2017)

The minimum capital conservation ratio that will be imposed on a G-SIB depend on its CET1 risk-weighted ratio and the Tier 1 leverage ratio. If a bank does not respect one of two ratios, it will be subject to the respective minimum capital requirements, if it does not respect both ratios, it will be subject to the higher of the two associated requirements.

The Common Equity Tier 1 capital has been introduced by Basel III and it corresponds to the minimum capital requirements. As represented in Graph 1, comparatively to Basel II the requirements have been increased from 2% to 4.5% and additional buffers have been included through the capital conservation

buffer (2.5%) and the countercyclical capital buffer (varying form 0-2.5%). G-SIB are even subject to an additional loss-absorbency requirement varying form 1-3.5%. Thus, comparatively to Basel II, the CET1 capital under Basel III has increased from 2 to 7%.

Graph 1 Comparison of CET1 capital requirements under Basel III and Basel II



Note: (a) Assuming that the predominant part of Tier 1 capital comprised CET1.

Source: Zeman et al. (2018)

3.1.4.8. CVA risk framework

Another important part of the Basel III reforms concerns the derivative instruments and the inherent risk of deteriorating creditworthiness of a counterparty. This risk, named credit valuation adjustment (CVA) risk has represented one of the major sources of losses during the subprime crisis. Thus, considerable efforts have been dedicated to the enhancement of the risk sensitivity of the CVA framework, to the strengthening of its robustness and to the improvement of its consistency.

These three targets are reached respectively through: 1) the incorporation of the exposure component of CVA; 2) the use of only standardized and basic approaches for its modelization and 3) the calibration of the modelling approaches such as to comply with market risk approaches since CVA risk is a form of market risk.

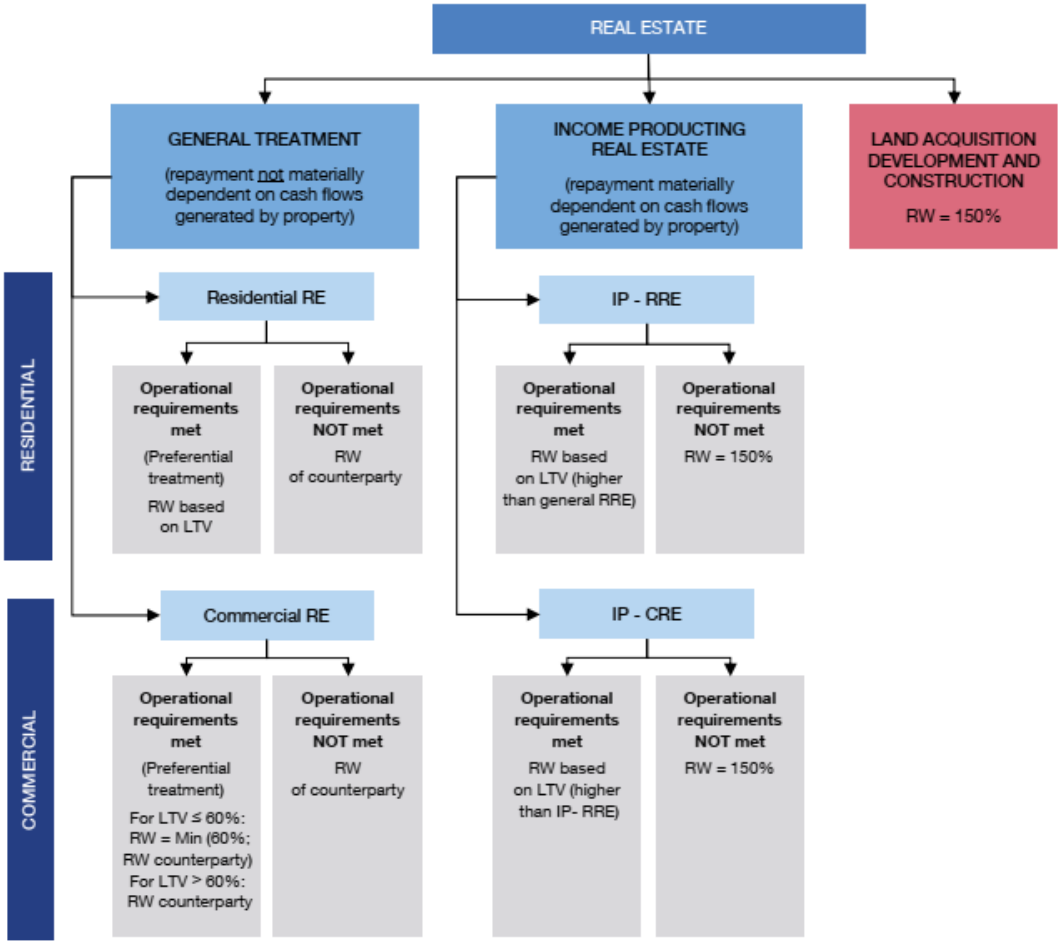
3.2 International banking regulation standards under Basel III and IV and real estate financing

3.1.5. Revised regulatory treatment for real estate exposures and its potential impact on the EE mortgage sector

As specified in the previous section, the new regulation proposes a more detailed approach on real estate exposures, enhancing thus the risk sensitivity of capital requirements. A large set of different approaches are adopted in order to cover different types of real estate loans, according to their final purpose (residential and commercial), the repayment method (income producing or not), whether

operational requirements are met or not or whether the loan is contracted for land acquisition (Graph 2).

Graph 2 Revised regulatory treatment for real estate exposures under Basel III



Source: Anguren et al. (2018)

Similarly to Basel II, the agreement includes a differentiated treatment according to the final use of the real estate (commercial or residential) in order to improve risk -sensitivity. Instead of the fixed RW for commercial (100%) and residential mortgages (35%) implemented under Basel II, Basel III proposes a greater granularity and RWs varying according to the LTV ratio of the concerned mortgages (Table 13).

Table 13 Mortgage risk weights under Basel III

Residential real estate exposures								
LTV bands	**Below 50%**	**50% to 60%**	**60% to 70%**	**70% to 80%**	**80% to 90%**	**90% to 100%**	**above 100%**	**Criteria not met**
General RRE								
Whole loan approach RW	20%	25%	30%		40%	50%	70%	RW of counterparty
Loan-splitting approach[2] RW	20%	RW of counterparty						RW of counterparty
Income-producing residential real estate (IPRRE)								
Whole loan approach RW	30%	35%	45%		60%	75%	105%	150%
Commercial real estate (CRE) exposures								
General CRE								
Whole loan approach	*LTV ≤ 60%*			*LTV > 60%*				*Criteria not met*
	Min (60%, RW of counterparty)			RW of counterparty				RW of counterparty
Loan-splitting approach[2]	*LTV ≤ 55%*			*LTV > 55%*				*Criteria not met*
	Min (60%, RW of counterparty)			RW of counterparty				RW of counterparty
Income-producing commercial real estate (IPCRE)								
Whole loan approach	*LTV ≤ 60%*		*60% < LTV ≤ 80%*			*LTV > 80%*		*Criteria not met*
	70%		90%			110%		150%
Land acquisition, development and construction (ADC) exposures								
Loan to company/SPV	150%							
Residential ADC loan	100%							

Source: BIS (2017)

As indicated by Anguren et al. (2018), commercial real estate is exposed to higher RWs, while residential real estate is benefitting from lower capital requirements.

From the standpoint of the EE mortgages, this provides a greater incentive for banks' preference for residential EE mortgages. According to the ECBC (2021), however, this will be detrimental to EE commercial real estate lending, and they recommend a more granular risk weight calibration. From an EE perspective, commercial real estate presents the advantage of scale economies in terms of lending and implementation procedures reaching larger energy consumption effects.

Furthermore, since the LTV ratio represents the borrowed amount compared to the total property value at the time of borrowing, this greater granularity seems to be particularly beneficial for exposures presenting low levels of LTV.

Namely, residential real estate loans with an LTV ratio below or equal to 80% are given a specific preferential treatment, since the associated RW is below the 35% level existing under Basel II. Therefore, such type of measure might be of particular interest for EE mortgages, presenting typically low LTV profiles.

Another particularity introduced by the new regulation concerns the "loan splitting approach" which is allowing banks to split a mortgage into a secured and unsecured exposure. For European banks, this possibility was already existing under the European Capital requirements regulation (CRR) (Anguren et al. (2018)). Indeed, for the EU, the Basel III framework started its introduction and implementation

in 2014, through the Capital Adequacy Ordinance (CRR) and the Capital Requirements Directive (CRD IV).

Nevertheless, through this approach, for LTV exposures below 55%, a part of the loan is secured by the property and is assigned a fixed risk weight (20% for residential real estate exposures 60% for commercial real estate exposures). The remaining part is treated as unsecured and is assigned the same risk weight as an unsecured exposure of the same obligor. As mentioned by Bundesbank (2018), the possibility for the implementation of such approach depends on the compliance of the commercial real estate lending loss rates with the hard tests ceilings. In such cases, national competent authorities may allow the application of the loan-splitting approach, for more flexibility.

Furthermore, with regards to the repayment method, the income producing real estates (both commercial and residential) are subject to higher RW.

Again, this highlights the preferential treatment dedicated to residential properties for personal use. However, compared to the Basel II framework, both residential and commercial real estates with low LTV levels are benefitting from a more favorable setting.

Concerning income producing properties, commercial real estate with low LTV ratios (below 80%) presents a greater advantage in comparison with the previous reform, while the effect for residential real estate is much more restricted. Only income producing residential properties with LTV ratios below 50% are exposed to lower capital requirements. This particularity may be of interest concerning the difficult trade-off on the financing of EE installations made by owners but benefitting to tenants. The new regulation might induce, thus, a contraction of this type of lending involving a stronger potential increase of EE properties' rents.

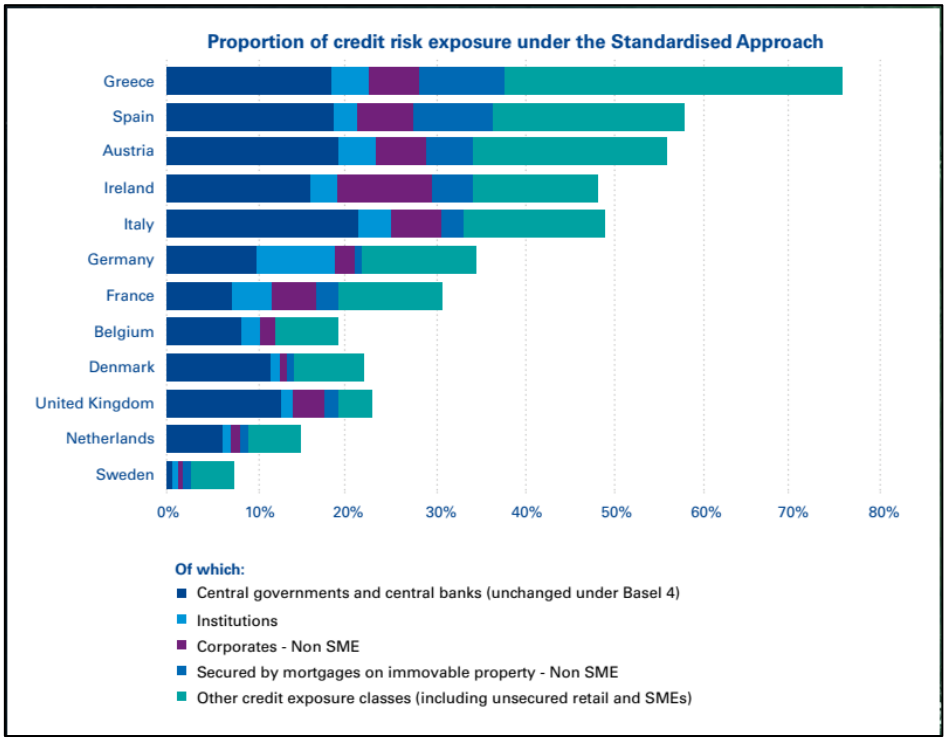
Nevertheless, with the exception of residential income producing properties, the transposition of the new regulation to EE mortgages suggests, at first sight, the implementation of more favorable conditions for development.

3.1.6. European transposition of the revised regulatory treatment for real estate exposures and its potential impact on the EE mortgage sector

Still, these potential direct effects on the real estate market and on EE mortgages must be considered in light of the indirect effects that the reform can induce as well as its transposition to the different national frameworks.

Namely, changes in capital requirements due to the new SA will depend on the characteristics of banks' credit portfolios (use of the SA for credit risk, types of credit exposures and quality of exposures in each asset class). As highlighted by KPMG (2018), the proportion of credit risk, and its composition among EU countries presents an important heterogeneity (Graph 3).

Graph 3 Credit risk exposures under the SA in European countries



Source: KPMG (2018)

The proportion of residential mortgage exposures is quite uneven, with a larger presence in Greece, Spain, Austria, Ireland, Italy and France. For these countries, the produced effects of the regulation might be stronger. Furthermore, the report highlights that the new regulation provides the opportunity for conservative lenders to significantly reduce their capital requirements by maintaining a low LTV portfolio, even though this might induce lower interest incomes. A similar consideration is addressed by McKinsey (2017) and by Feridun and Ozün (2020) arguing the necessity for banks to carefully evaluate the impact on their net interest incomes.

Given the low LTV ratios typical to EE mortgages, this potential lending concentration should not represent a threat. Furthermore, a more generalized incentive framework, such as the one launched by the EU institutions, combined to the already present significant interest for EE investments can lead to an increased demand for such types of products, thus compensating the lower marginal returns. Furthermore, the creation of a standardized "energy efficient mortgage" label can allow for a greater reduction of implementation and administrative costs.

Conversely, according to KPMG (2018), banks with high LTV portfolios will face however an increase in capital requirements. As stressed by the report, this kind of penalization of mortgages based on income producing real estate might be subject to national protests in those countries where this type of exposures have not presented a larger level of defaults. Namely, it is the case of NAS Invest[9] (2018)

[9] Real estate investment and asset management company operating in Germany, Luxembourg, Switzerland and Denmark

discussing the unfair treatment of the German commercial real estate market given its long-term stability and low loss ratios.

All these aspects demonstrate the need for further specification and eventually national flexibility to adapt the general regulation to national financial frameworks, especially for those countries presenting low risk profiles.

Similarly, Lussigny (2016) representing the Federation of French Banks, points the differences between the American and European banks in his argumentation on the necessity to consider these particularities in the implementation of the new regulation. Namely, European companies are more strongly related to banks for their financing than in the US (respectively 75/80% versus 20%), the accounting standards, the functioning of European mortgage loans (included on banks' balance sheets, while in the US they are transferred to Government sponsored entities such as Freddie Mac and Fannie Mae) and etc. involve more consequent impacts of the new reforms on EU banks. Similar considerations are also stressed by McKinsey (2017) and Reuters (2017), both indicating the greater exposure of EU banks and the latter stressing the necessity to consider the greater capacity of European banks on average to recover greater amounts from bad corporate loans and mortgages.

The differences between EU and US banks are also crystalizing through the confrontation between the use of IRB approach or SA. The implementation of the output floor, leading to a restricted use of IRB models and an increase of the capital requirements risks to penalize EU banks and their lending capacity (Copenhagen Economics, 2021). This will for certain affect negatively EE mortgages.

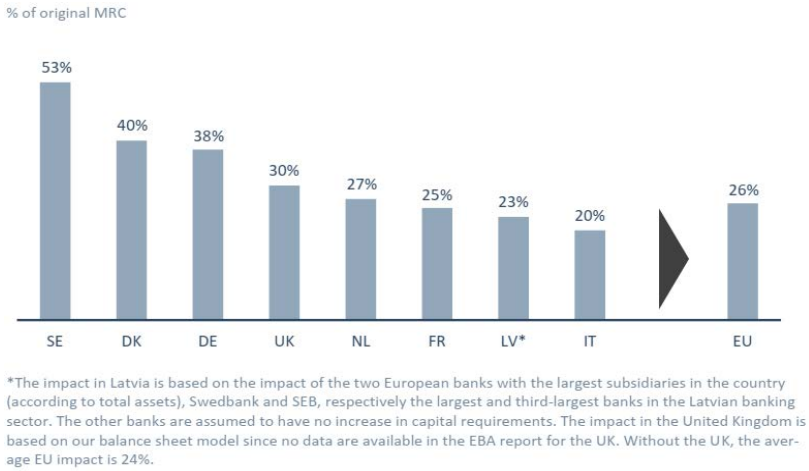
Nevertheless, the European heterogeneity needs also to be considered. Demary and Voigtländer (2020), from the German Economic Institute, stress the necessity to take into account national particularities, namely given the current design of EU mortgage markets. Countries like Spain, Greece, and Ireland present mortgage lending volume to house prices ratios corresponding to less restrictive lending and important house price bubbles. Concerning non-performing loans ratios, Greece, Cyprus, Bulgaria, Italy and Portugal present higher exposures to credit risk than the European average.

McKinsey (2017) also points the differentiated impact of the new CET1 ratios requirements on EU members. Sweden, Denmark, Belgium, the Netherlands, and Ireland seem to be more concerned, given that their banks' IRB models are characterized with low loss given default (LGD) estimates and thus will require greater regulatory capital efforts under the new regulation[10]. The same report also describes the heterogeneity among European countries in terms of sovereign exposures, Basel III capital deductions, operational risk SMA implementation.

Furthermore, Demary and Voigtländer (2020) recommend an urgent review of the reform. According to the authors, the transposition of the new rules, will involve an important increase in the capital requirements of the European countries (Graph 4), which might push banks needing important capital increases, towards risky financing, or a greater cooperation with credit funds leading to less transparency (the latter being less regulated and less supervised than banks), and a greater risk shift to the shadow banking sector.

[10] Concerning the Netherlands, the Dutch National Bank (DNB) (Malone, 2019) also affirms that the internal models for mortgage loans do not sufficiently reflect the increased systemic risk in the Dutch housing market.

Graph 4 Increase in minimum required capital (MRC) in EU countries



*The impact in Latvia is based on the impact of the two European banks with the largest subsidiaries in the country (according to total assets), Swedbank and SEB, respectively the largest and third-largest banks in the Latvian banking sector. The other banks are assumed to have no increase in capital requirements. The impact in the United Kingdom is based on our balance sheet model since no data are available in the EBA report for the UK. Without the UK, the average EU impact is 24%.

Source: Demary and Voigtländer (2020)

Moreover, according to the authors, if banks choose to resort to securitization and loan fund financing, comparably to the American approach, credit risk will be transferred towards special purpose vehicles instead of being included on banks' balance sheets. Thus, credit risk will be transferred to the less regulated shadow banking sector. Uluc and Wieladek (2017) also find evidence for a greater origination of riskier loans in consequence of an increase of capital requirements in the UK.

Increased capital requirements may lead to a transfer of risk towards shadow banking and thus can affect negatively, instead of improving, financial stability. Given the role played by mortgages in the subprime crisis, it is essential to avoid a historical repetition.

Another potential solution for raising capital, mentioned by Demary and Voigtländer (2020), concerns the decrease of RWAs, which will involve a reduced lending activity and increased costs for borrowers. Hoesli et al. (2020), also find evidence for a regulatory burden on the bank lending channel, based on a sample including France, Germany and the UK, for the period 2009-2015. They also conclude to a potential risk of a transfer of regulatory compliance costs to final borrowers. Uluc and Wieladek (2017) observe a decline in the individual loan size in the British mortgage market. Kristensen and Cotten (2019) confirm the same tendency for Norwegian savings banks transfering the burden to mortgage loan customers and favoring SME customers.

Increased capital requirements may lead to a reduced lending activity and a transfer of the regulatory burden and its inherent costs on borrowers. Accordingly to the national economic and financial prerogatives, mortgage loan customers might be affected as it is the case in Norway and in the UK.

In response to some of these aspects, the EBF (2019) proposes several enhancements to the reform. Namely, concerning the large heterogeneity among European countries and the need for further specification of the requirements, accordingly to the national risk exposures, the EBF suggests the lowering of European real estate risk weights, given the historically observed low loss rates and the important level of guarantees through the dual recourse of loans, along with the country specificities of each member state.

Also, the banking federation recommends that the calculation of the LTV ratio should be updated regularly especially for residential real estate mortgage portfolios given their long-term character. A similar point of view is defended by the ECBC (2021) considering the "valuation at origination as disproportionately penalizing" for the EU residential mortgage market. The Council advises for an accurate evaluation of LTV ratios based on the current value and the current debt.

Furthermore, the EBF report advises to not penalize the "best quality tranches of credit" corresponding to commercial real estate lending. The authors propose that each bank choses between the implementation of the loan splitting or the whole loan approach to all real estate assets for a certain period.

At last, the EBF advocates for a more "appropriate treatment of land Acquisition, Development and Construction (ADC) exposures" in order to not penalize the financing of new residential and commercial buildings. The ECBC (2021) expresses a similar standpoint and suggests the classification under the ADC, only in case of insufficient obligors' income and assets covering the loss risk (i.e. the loan payment is provided by the cash flow generated by the financed property). For all other cases exposures should be classified as SME, retail or corporate and the inherent risk weights should be defined according to the creditworthiness of the counterparties.

The ECBC report (2021) points an additional aspect that might negatively affect EE mortgages. According to them, the revised advanced IRB (compared to the current CRR) might involve an important increase of the risk weights relative to low LTV ratio residential and commercial real estate exposures. In such case, the expected positive effects of the new Basel regulation on EE mortgages, discussed in the previous section, might be rather reduced for the EU.

Besides the evolution of the risk weights associated to mortgages and covered bonds (Pillar I), the development of EE mortgages, is also subject to the implemented supervisory mechanisms (Pillar II).

Although, the regulatory framework defined under Basel III and IV has evolved considerably through the different consultations, the briefly described above chasms, point the necessity for further adjustments with regards to the European transposition. The monitoring of the potential regulatory enhancements will be essential for the evaluation of their impact on real estate markets and specifically on EE mortgages.

3.1.7. Covered bonds and EE

Another European particularity related to EE mortgages and credit risk concerns the relatively growing interest and involvement of covered bonds. The present section thus aims to briefly describe the development of this type of financial tool and its potential effect on EE mortgages.

3.1.7.1. Definition and distinction with subprime mortgage-backed securities

As defined by the European Covered Bond Council (ECBC), covered bonds represent "debt instruments secured by a cover pool of mortgage loans or public-sector debt to which investors have a preferential claim in the event of default". As such, they can be considered as a type of derivative instruments covered either by mortgage or public sector loans.

More specifically, covered bonds are issued by financial institutions regrouping bank loans (mortgages or public sector loans) which were sold to them for resale. The coupon bond payment is therefore covered by the mortgage or loan payment.

Thus, the covered bonds secured by mortgage loans present similarities with the subprime mortgage backed securities. However, the major difference between these two debt instruments resides in the presence of the covered bond loans on the books of the banks that have issued them, while the subprimes were mainly off-sheet operations escaping from any control. Thus, conversely, covered bonds present safer characteristics for holders and for issuing banks, since the bond holder is not exposed to unpayment risk, even if the issuing institution becomes insolvent. Nevertheless, covered bonds' safety is conditioned by the respect of strict requirements currently applied in the EU.

3.1.7.2. Evolution and characteristics

The covered bond industry originated 252 years ago with the creation of the "Silesian Landschaft model" by the Prussian King, Frederick the Great. As described by Wandschneider (2013), this system introduced the possibility for Prussian estates to finance long term projects benefitting to society through the issuance of covered bonds backed by mortgages. The functioning of these Pfandbriefe was founded on a cooperative basis characterized by joint liability and local administration, avoiding inefficiencies related to information asymmetries. The reliability of the system was strengthened by the mutual coverage among members.

Similar systems have been implemented, then, across Europe. For instance, the reconstruction of Copenhagen after the 1795 great fire relied on covered bonds (Realkreditobligationer). The French Obligations Foncières, created in 1852, established the major covered bonds characteristics, specific to this debt instrument even today.

As highlighted by the ECBC, this historical evolution has predefined the European predominance in the covered bonds market, evaluated at €2.6 trillion. Nevertheless, several other countries have also implemented similar systems (Australia, Canada, New Zealand, Singapore and South Korea) or are currently investigating or adopting covered bonds legislation (Brazil, Chile, India, Japan, Mexico, Morocco, Panama, Peru, South Africa and the United States).

According to the ECBC (2020), the interest towards this debt instrument has increased consecutively to the 2008 financial crisis, given its proven reliability, even for countries severely affected such as Spain and Italy. An additional incentive has been provided through the quantitative easing policies implemented in the US and the EU, as well as the ECB's Covered Bond Purchase Program[11]. The S&P report Global Covered Bond Insights (2019) further identifies the creation of a common EU legislative package as well as the growing interest for green and sustainable covered bonds as additional factors contributing for the development of the covered bonds market. According to the same report, in 2019, 60% of the issued covered bonds are concentrated in five major markets: Denmark, Germany, France, Spain, and Sweden.

Indeed, this predominance of the EU and the increasing share of mortgages (vs public sector loans) are also highlighted by the ECBC Fact Book (2020) (Graph 5).

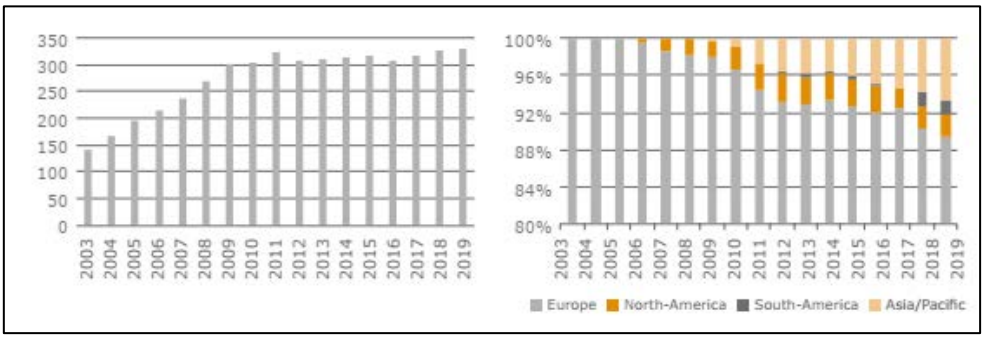
[11] Since 2014, the third purchasing program is ongoing (CBPP3). Two previous purchase programs (CBPP1 and CBPP2) have been launched in 2009 and 2011. Currently, a Pandemic Emergency Purchase program (PEPP) Is expected to be launched, consecutively to the Coronavirus pandemic.

Graph 5: Covered Bonds' issuance per type (left) and region (right), EUR bn

Source: ECBC (2020)

Besides the historical importance of the EU, due to more accommodative regulatory treatment (discussed further), since 2008, the ECBC (2020) has noticed an increasing participation of global issuers from 1% to 8% in ten years. In result, North American and Asian/Pacific markets present lately a growing importance (Graph 6).

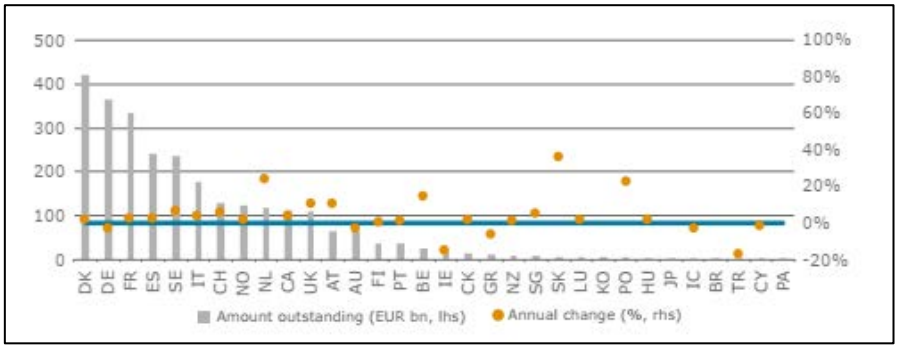
Graph 6: Number of issuers (left) and regional repartition, share (right)



Source: ECBC (2020)

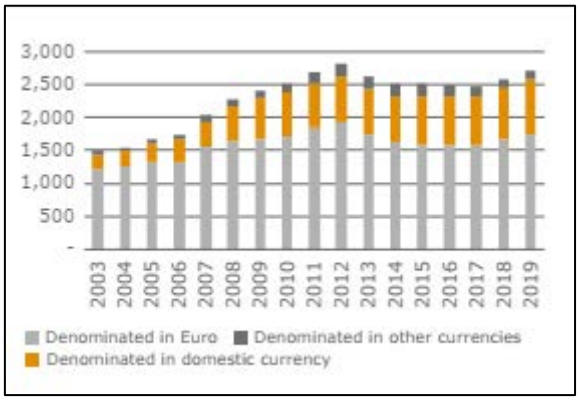
Nevertheless, as described by Graph 7, the larger share of covered bonds remains concentrated in six EU countries: Denmark, Germany, France, Spain, Sweden and Italy and denominated in euros (Graph 8).

Graph 7: Covered Bonds' country repartition[12]



Source: ECBC (2020)

Graph 8: Covered Bonds' currency repartition



Source: ECBC (2020)

3.1.7.3 Evolution of the regulation under Basel II, III, and IV. Potential impact on EE and challenges.

As mentioned above, the expansion of covered bonds in the EU is related to a more favorable regulatory framework. Indeed, the international regulatory treatment under Basel II was assimilating covered bonds risk exposure to the issuing bank risk exposure. Thus, this debt instrument was considered as senior unsecured bank bonds and was therefore possibly evaluated according to the same two options typical for banks' risk weighting (i.e. credit assessment of sovereigns or credit assessment of banks). As presented by Table 14, the regulation under Basel III before the final reformed version has maintained the same treatment for covered bonds. However, the reformed Basel III (Basel IV) framework is more in line with the European Capital requirements Regulation (CRR, 2013) which is less stringent.

[12] The annual change for Brazil, South Korea and Japan was exceeding 100%

Table 14: Evolution of the covered bonds regulation under Basel II, III and IV

External rating	AAA to AA-	A+ to A-	BBB+ to BBB-	BB+ to B-	Below B-
Basel II sovereign rating	20%	50%	100%	100%	150%
Basel II bank rating	20%	50%	50%	100%	150%
Basel III current	20%	50%	50%	100%	150%
Basel IV reformed	10%	20%	20%	50%	100%
CRR (current)	10%	20%	20%	50%	100%

Source: Unicredit Research (2019), ECBC (2020), BIS (2017)

Nevertheless, as mentioned by the Unicredit report "Overview of risk weights under Basel II, Basel III finalized and CRR" (2019), the covered bonds accepted under CRR have to fulfill several conditions[13] and should respect the UCITS- directive. Furthermore, a differentiation is operated between rated and unrated covered bonds. The risk weights of the first group are defined according to their ratings (Table 14), while those for the second group depend on the rating of the issuing bank (Table 15).

Table 15: Risk weight for unrated covered bonds

Risk weight issuing bank	20%	30%	40%	50%	75%	100%	150%
Basel IV	10%	15%	20%	25%	35%	50%	100%
CRR (current)	10%			20%		50%	100%

Source: ECBC (2020)

Under the finalized Basel III framework, "Covered bonds are defined as bonds issued by a bank or mortgage institution subject by law to special public supervision designed to protect bondholders" (ECBC, 2020).

- Thus, proceeds of bonds issuance should be invested such as they remain available for the whole period of bond validity, and they are able to cover all necessary reimbursement (principal and coupon) in case of issuers' failure.
- The eligible cover assets should include: public sector assets, residential and commercial mortgages subject to respectively an 80% and 60% LTV cut- off, and claims on banks (A- and above) eligible up to 15%.
- And, a nominal overcollateralization of 10% is required instead of the 5% statutory, contractual or voluntary collateralization under CRR.

Comparatively to CRR, the Basel IV recommendations are stricter in terms of repo eligibility criteria[14] and over-collateralization requirements but are aligned in terms of LTV ratio requirements. Nevertheless, the new regulation tends to be more favorable to cover bonds' development due to the

[13] Article 129 of Regulation (EU) No 575/2013 of the European Parliament and of the Council
[14] The ECB presents the "broadest repo eligibility criteria for covered bonds" (ECBC, 2020).

observed reduced risk-weighting. Accordingly, this should benefit to a further EE mortgages' expansion.

However, a major challenge for the development of covered bonds' markets and their sustainability might reside on their country-specific particularities. Indeed, one of the crucial tasks of CRR was to organize the harmonization among European covered bonds' markets. However, the consideration of all non-EEA issued bonds has been left for further discussions between the EU Commission, Parliament and Council, with a potential implementation two years after the Basel IV reforms entering into force in January 2020.

Thus, a strict third country equivalence and the respect of a harmonized and strict EU regulation on covered bonds will be essential for maintaining their safer characteristics, both, for holders and for issuing banks, but also essential for resilient EE mortgages.

4. EE and credit risk correlation: effects of Basel III framework on EEM

In a nutshell, while the most recent regulation seems to present more favorable conditions for EE mortgages (especially for residential properties and covered bonds), the transposition to the EU framework (characterized by the predominance of IRB models) and the implementation of the output floor, leading to an increase of capital requirements, might have the opposite effect.

Indeed, EE mortgages are characterized by relatively low LTV ratios and should therefore benefit from lower RW, but according to ECBC (2021), the revised advanced IRB approach might counteract through an important increase of RW, whilst output floor's implementation can penalize EU banks' lending capacity.

Furthermore, the rather disadvantageous requirements for EE commercial real estate lending (even though it presents a higher EE potential, combined to greater implementation scale economies), are even more demanding for income producing properties and for land acquisition and construction exposures. All this suggests a rather limited positive effect on EU EE mortgages.

As previously mentioned, the covered bonds' development can benefit from the new regulatory framework, but a major challenge resides not only in the harmonization among European covered bonds' markets, but mostly in the equivalence of all non-EEA issued bonds which will be essential for maintaining their safer characteristics, both, for holders and for issuing banks, but also for resilient EE mortgages.

From another standpoint, increased capital requirements, in an instable economic context, might have a twofold effect: i) a transfer of risk towards shadow banking, thus potentially affecting the financial stability; ii) a transfer of the regulatory burden and its inherent costs on borrowers (ex: UK, Norway). Evidently, in both cases, the viability of EU EEM can be endangered.

Thus, despite a rather positive evolution of mortgages' related prudential regulation, the transposition of the new framework to EU EEM might induce greater challenges and efforts for EU banks. However, based on the discussed correlation between EE and borrower's credit risk, Johnson and Bertalot

(2022)15 suggest that since EEM are correlated to reduced PD and LTV ratio, and thus to reduced credit risk, they could benefit from lower RW and lower capital requirements. According to the authors, such realignment of EEM's capital requirements, can unfold a virtuous circle benefitting to all stakeholders.

The argumentation of the authors is based also on the obtained findings by Billio et al. (2020) in their Dutch study and namely the fact that borrowers' credit information is enriched by EE information. Indeed, default rates are lower for borrowers with well-performing EE properties, even if they have lower disposable incomes. Thus, high EE ratings are not only beneficial to borrowers (through reduced credit risk), but also to lending institutions since they provide a deeper and more accurate understanding of the borrowers' capacity to reimburse and as such reduce the risk for the lender.

However, as highlighted by Johnson and Bertalot (2022), this risk mitigation can be very case-specific and for the moment it has not been "appropriately captured by the prudential framework of individual institutions".

5. Conclusion

The present report discusses the potential effects of the Basel accords on EE mortgages and credit risk. The literature reviews and the obtained empirical findings described within the EeMAP and EeDaPP projects demonstrate a significant negative correlation between building EE and credit risk through lower probability of default and the increased property value, supporting the development of EE mortgages.

Nevertheless, EU banks and mortgage lenders are currently facing three major concerns that might affect directly their lending activity (and by extension EE mortgages): 1) the implementation of the Basel III regulation; 2) the global pandemic crisis and the post- pandemic crisis adjustments; 3) the increased climate change vulnerabilities.

Even though the more recurrent occurrence of extreme weather events contributes to a growing consciousness of the necessity to dedicate investments to EE, the pandemic and post-pandemic crises as well the implementation of the Basel regulatory framework might hamper the development of EU EE mortgages.

Indeed, although a large part of European countries has adopted mortgage moratoria measures, in response to the pandemic and thus has avoided a considerable crash especially for more vulnerable households, the new mortgage lending has been temporarily interupted (EBA, 2020) and a slight contraction of the mortgage volumes has been observed. Nevertheless, according to the FSB Report (2021) the relatively current stable situation, might worsen in result of the phase-out of pandemic-related support and the potential ongoing increase of the default risk, involving a reduced lending capacity of already fragilized european banks.

Furthermore, the simultaneous economic recovery and rapidly increasing economic activity lead to transitory demand shocks and diverse shortages, involving an inflation increase. The recent developments in the Ukrainian conflict and the potential ongoing effects on the global economy would

[15] Johnson, J. and L. Bertalot. (2022). D4.2 Energy Efficient Mortgages: How to comply & align with the EU policy agenda. EeMMIP project.

also strenghten this trend in most EU members. In consequence, the economic system can be further fragilized through an associated increased default risk. Up to now, the ECB has not announced a potential intervention aiming at stabilizing the inflation rate, but if necessary, it might reconsider raising the interest rates, especially in the light of the effects of international interdependencies related to international trade and capital flows exposures that can hamper the current fragile stability (several disturbancies on energy raw material markets, potential risks also for food raw material markets, important provision risks related to zero-Covid policy applied in China).

In such case, fixed rate mortgages (predominant in Belgium, France, Germany and the Netherlands (Albertazzi et al., 2019)) might not be affected, but adjustable rate mortgages (typical to Austria, Greece, Italy, Portugal and Spain (Albertazzi et al., 2019)) risk to reinforce the vulnerability of the considered countries and their respective banking and economic systems, in case of increased defaults. From the lenders' perspective, the banks in the first group of countries would not be able to benefit from higher revenues.

Besides these hypothetical impacts of the pandemic, another strand of concerns that can potentially affect banking's lending activity is represented by the adoption of the revised Basel III framework. Indeed, even though residential and commercial mortgages with low LTV levels (particularly typical to EE mortgages) and covered bonds are benefitting from more favorable conditions in terms of risk weights, land Acquisition, Development and Construction exposures are particularly penalized.

Concerning EE mortgages this should suggest a rather positive on average configuration for the development of renovation mortgages, but in the case of the EU, the implementation of the output floor and the ongoing increased capital requirements levels for banks using IRB approaches might involve rather a contraction of the lending activity or the transfer of the regulatory burden and its inherent costs on borrowers (as it is the case in Norway and the UK). According to the ECBC (2021) low LTV ratio residential and commercial real estate exposures will be particularly affected, which suggest that, in such case, the expected positive effects of the new Basel regulation on EE mortgages, might be rather reduced for the EU.

However, from another standpoint, the significant interest for EE investments and the creation of a standardized "energy efficient mortgage" label allowing to reduce implementation and administrative costs, as well as the strength of the covered bond instrument might be beneficial to EE mortgages.

Also, several reports highlight the need for further specification and eventually national flexibility to adapt the general regulation to national financial frameworks, especially for those countries presenting low risk profiles. Moreover, they stress that increased capital requirements may lead to a transfer of risk towards shadow banking and thus can affect negatively, instead of improving, financial stability.

On the basis of all these considerations it is difficult to predict the evolution of EU EE mortgages. While the pandemic and post-pandemic adjustments as well as the revised Basel III accords and the Ukrainian conflict present important potential challenges, potential opportunities are also available.

6. Bibliography

Albertazzi, U., Fringuellotti, F. and S. Ongena (2019). Fixed rate versus adjustable rate mortgages: evidence from euro area banks. *ECB Working Paper Series* No 2322.

An, X. & Pivo, G. (2015). Default Risk of Securitized Commercial Mortgages: Do Sustainability Property Features Matter? *2015 RERI Research Conference proceedings*. http://www.reri.org/research/files/2014funded_An-and-Pivo.pdf

An, X. & Pivo, G. (2020). Green Buildings in Commercial Mortgage Backed Securities: The Effects of LEED and Energy Star Certification on Default Risk and Loan Terms. *Real Estate Economics. 10.1111/1540-6229.12228*. https://doi.org/10.1111/1540-6229.12228

Anguren, R., Castro, C. and D. Durán. (2018). Completion of Basel III post-Crisis reforms: overview and analysis of key features. *Banco de España Financial Stability Review*, Issue 34.

Ankamah-Yeboah, I. and K. Rehdanz. (2014). "Explaining the variation in the value of building energy efficiency certificates: A quantitative meta-analysis," *Kiel Working Papers* 1949, Kiel Institute for the World Economy (IfW).

Aroul, R. and J. A. Hansz. (2011). The Role of Dual-pane Windows and Improvement Age in Explaining Residential Property Values. *Journal of Sustainable Real Estate: 2011, Vol. 3, No. 1, p. 142-161*. https://doi.org/10.5555/jsre.3.1.k13602636061604q

Baccega, T., Bedin, A., Billio, M., Hristova, I. and M. Riedel (2019). D5.2 Technical report on the portfolio analysis of banks' loan portfolios. EeMAP project WP5.

Baccega, T., Bedin, A., Billio, M., Hristova, I. and M. Riedel (2019). D5.3 Technical Report on the Econometric Assessment and Results. EeMAP project WP5.

Bank for International Settlements. (2006). Core Principles for Effective Banking Supervision. Basel Committee on Banking Supervision.

Bank for International Settlements. (2017). High-level summary of Basel III reforms. Basel Committee on Banking Supervision.

Benetton, M., Eckley, P., Garbarino, N., Kirwin L. and G. Latsi (2017). Specialisation in mortgage risk under Basel II. *Bank of England Staff Working Paper* No. 639.

Bessis, J. (2015). *Risk Management in Banking* (4th ed.). Chichester: Wiley.

Billio, M., Costola, M., Pelizzon, L. & Riedel, M. (2021). Buildings' Energy Efficiency and the Probability of Mortgage Default: The Dutch Case. J Real Estate Finan Econ. https://doi.org/10.1007/s11146-021-09838-0

Billio, M., Costola, M., Hristova, I. And M. Riedel. (2020). D5.5 Final report on Econometric assessment and results. EeDaPP project WP5.

Billio, M., Costola, M., Hristova, I., Pelizzon, L. And M. Riedel. (2020). D5.7 Final report on correlation analysis between energy efficiency and risk. EeDaPP project WP5.

Billio, M., Costola, M., Hristova, I. And L. Pelizzon. (2019). D5.4 Technical report on portfolio analysis. EeDaPP project WP5.

Billio, M., Riedel, M., Bedin, A. and D. Leboullenger. (2019). D5.1 Technical report on the methodology design to carry out portfolio analysis. EeMAP project WP5.

Bloom, B., Nobe, M.C. and M.D. Nobe. (2011). Valuing Green Home Design: A study of ENERGY STAR Homes. JOSRE, Vol.3, No. 1, 109-126. www.costar.com/uploadedFiles/JOSRE/JournalPdfs/06.109_126.pdf.

Blundell-Wignall, A., Atkinson, P. and C. Roulet. (2018). Financial Innovation and Basel II. In book: *Globalisation and Finance at the Crossroads* (pp.41-85). 10.1007/978-3-319-72676-2_2.

BPIE. (2015). Investing in the European buildings infrastructure – An opportunity for the EU's new investment package. http://bpie.eu/wp-content/uploads/2015/11/Investing_in_Europe_s_buildings_infrastructure_BPIE_Discussion_Paper.pdf

Brocklehurst, F. (2017). What will you pay for an "A"? – a review the impact of building energy efficiency labelling on building value. *ECEEE Summer Study Proceedings*. http://proceedings.eceee.org/visabstrakt.php?event=7&doc=6-033-17.

Brounen, D. and Kok, N. (2011). On the economics of energy labels in the housing market, *Journal of Environmental Economics and Management*, 62, issue 2, p. 166-179, https://EconPapers.repec.org/RePEc:eee:jeeman:v:62:y:2011:i:2:p:166-179.

Bruegge, C., Carrión-Flores, C., J. C. Pope. (2016) Does the housing market value energy efficient homes? Evidence from the energy star program. *Regional Science and Urban Economics*, Volume 57, p. 63-76, ISSN 0166-0462. https://doi.org/10.1016/j.regsciurbeco.2015.12.001.

Cajias, M. and D. Piazolo. (2013). Green Performs Better: Energy Efficiency and Financial Return on Buildings. *Journal of Corporate Real Estate*, Vol. 15 No. 1, 2013, p. 53-72. https://ssrn.com/abstract=2362914

Chegut, A., Eichholtz, P. and R. Holtermans. (2016). Energy efficiency and economic value in affordable housing, *Energy Policy*, 97, issue C, p. 39-49. DOI: 10.1016/j.enpol.2016.06.043

Dastrup, S. R., Graff Zivin, J., Costa, D. and M. Kahn. (2012). Understanding the Solar Home price premium: Electricity generation and "Green" social status. *European Economic Review*, 56, issue 5, p. 961-973, https://EconPapers.repec.org/RePEc:eee:eecrev:v:56:y:2012:i:5:p:961-973.

De Ayala, A., Galarraga, I. and J. V. Spadaro. (2016). The price of energy efficiency in the Spanish housing market. *Energy Policy*, Volume 94, Pages 16-24, ISSN 0301-4215. https://doi.org/10.1016/j.enpol.2016.03.032 .

Demary, M. and M. Voigtländer. (2020). The impact of Basel IV on real estate financing*, IW-Policy Paper*, No. 18/2020, Institut der deutschen Wirtschaft (IW), Köln.

De Nederlandsche Bank. (2019). Energy efficiency is factored in well in the Dutch housing market. DNBulletin. https://www.dnb.nl/en/news/news-and-archive/DNBulletin2019/dnb385503.jsp

Deng, Y. and J. Wu. (2014). *Economic returns to residential green building investment: The developers' perspective. Regional Science and Urban Economics, Volume 47, Pages 35-44, ISSN 0166-0462.* https://doi.org/10.1016/j.regsciurbeco.2013.09.015 .

Deutsche Bundesbank (2018). Finalising Basel III. Deutsche Bundesbank Monthly Report January 2018

Eichholtz, P. Kok, N. and J. M. Quigley. *(*2010). Doing Well by Doing Good? Green Office Buildings. *American Economic Review, 100 (5): 2492-2509*. DOI: 10.1257/aer.100.5.2492

Eichholtz, P. Kok, N. and E. Yonder. (2012). Portfolio greenness and the financial performance of REITs, *Journal of International Money and Finance*, 31, issue 7, p. 1911-1929. DOI: 10.1016/j.jimonfin.2012.05.014

European Environment Agency. (2019). Trends and projections in Europe 2019, Tracking progress towards Europe's climate and energy targets.

European Banking Authority. (2020). The EU banking sector: first insights into the covid-19 impacts. Thematic note EBA/REP/2020/17.

European Banking Authority. (2020). Risk assessment of the european banking system. doi:10.2853/70473.

European Banking Authority. (2020). EBA report on the implementation of selected COVID-19 policies. EBA/REP/2020/19.

European Banking Authority. (2021). EBA report on the implementation of selected COVID-19 policies. EBA/REP/2021/02.

European Banking Federation. (2019). EBF summary on Basel IV in Europe. EBF_033787

European Mortgage Federation – European Covered Bond Council (EMF-ECBC). (2020). Paper on Implementing the Final Basel III Reforms in the EU.

European Mortgage Federation – European Covered Bond Council (EMF-ECBC). (2020). Position Paper Implementation of the Basel III Output Floor in the EU

European Mortgage Federation – European Covered Bond Council (EMF-ECBC). (2021). Measures taken in relation to mortgages as consequence of COVID-19 crisis.

European Mortgage Federation – European Covered Bond Council (EMF-ECBC). (2021). Final Position paper on Implementation of Basel III Framework into EU Legislation.

European Mortgage Federation – European Covered Bond Council (EMF-ECBC). (2021). European Covered Bond Fact Book 2020.

European Parliament, Council of the European Union. (2006). Directive 2006/48/EC relating to the taking up and pursuit of the business of credit institutions (recast).

European Parliament, Council of the European Union. (2006). Directive 2006/49/EC on the capital adequacy of investment firms and credit institutions (recast)

European Parliament, Council of the European Union. (2013). Regulation (EU) No 575/2013 on prudential requirements for credit institutions and investment firms and amending Regulation (EU) No 648/2012 Text with EEA relevance.

European Parliament, Council of the European Union. (2009). Directive 2009/65/EC on the coordination of laws, regulations and administrative provisions relating to undertakings for collective investment in transferable securities (UCITS) (recast) Text with EEA relevance)

Eurostat. (2020). Final energy consumption and distance to 2020 and 2030 targets, energy savings statistics. https://ec.europa.eu/eurostat/statistics-explained/index.php/Energy_saving_statistics#Final_energy_consumption_and_distance_to_2020_and_2030_targets

Feridun, M. and Özün, A. (2020). Basel IV implementation: a review of the case of the European Union. *Journal of Capital Markets Studies*, Vol. 4 No. 1, pp. 7-24. https://doi.org/10.1108/JCMS-04-2020-0006

Financial Stability Board. (2021). COVID-19 support measures: Extending, amending and ending.

Fuerst, F. and P. McAllister. (2011). The impact of Energy Performance Certificates on the rental and capital values of commercial property assets. *Energy Policy*, 39, issue 10, p. 6608-6614, https://EconPapers.repec.org/RePEc:eee:enepol:v:39:y:2011:i:10:p:6608-6614.

Fuerst, F., McAllister, P., Nanda, A. and P. Wyatt. (2015). Does energy efficiency matter to home-buyers? An investigation of EPC ratings and transaction prices in England, *Energy Economics*, Volume 48, Pages 145-156, ISSN 0140-9883. https://doi.org/10.1016/j.eneco.2014.12.012 .

Godard, R., and A. Harzi. (2018). Bâle IV : quels impacts pour les banques ? *PwC Lettre d'actualité réglementaire, Banque # 14.* ANALYSES ET PERSPECTIVES.

Guin, B. and P. Korhonen. (2018). Insulated from Risk? The Relationship between the Energy Efficiency of Properties and Mortgage Defaults. *Bank Underground* (blog), 16 octobre 2018.

Heijmans, N. and X. Loncour. (2019). Impact of the EPC on the property value. Working paper Concerted Action Energy Performance of Buildings (CA EPBD). https://epbd-ca.eu/wp-content/uploads/2019/06/12-CT3-Factsheet-EPC-impact-on-property-value.pdf

Hoesli, M., Milcheva, S. and A. Moss. (2020). Is Financial Regulation Good or Bad for Real Estate Companies? – An Event Study. *J Real Estate Finan Econ* 61, 369–407. https://doi.org/10.1007/s11146-017-9634-z

Hogberg, L. (2013). The impact of energy performance on single-family home selling prices in Sweden. *Journal of European Real Estate Research*. Vol. 6 No. 3, pp. 242-261. https://doi.org/10.1108/JERER-09-2012-0024

IEA. (2012). World Energy Outlook 2012. https://www.iea.org/publications/freepublications/publication/English.pdf

IPCC. (2007). Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Inter-governmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA., XXX pp.

Johnson, J. and L. Bertalot. (2022). D4.2 Energy Efficient Mortgages: How to comply & align with the EU policy agenda. EeMMIP project.

Kaza, N., R. Quercia, and C. Y. Tian. (2014). Home energy efficiency and mortgage risks. *Cityscape: A Journal of Policy Development and Research 16.* https://ssrn.com/abstract=2416949

Kahn, M. and N. Kok. (2014). The capitalization of green labels in the California housing market. *Regional Science and Urban Economics*, 47, issue C, p. 25-34, https://EconPapers.repec.org/RePEc:eee:regeco:v:47:y:2014:i:c:p:25-34.

KPMG. (2018). Basel 4: The way ahead. Credit Risk - Standardised approach, Bridging the gap to internal models.

Kristensen G. and S. Cotten (2019). Norwegian Banks' SME Discount Likely To Be Financed By Mortgage Customers. Nordic Credit Rating AS.

Leboullenger, D., Johnson, J., Toth, Z., Riedel, M., Bedin, A., Muecke, C. and M. Billio (2019). D5.4 Final report on the correlation. EeMAP project WP5.

Latham & Watkins and Goldman Sachs. (2009). Regulatory Capital Requirements for European Banks: Implications of changing markets and a new regulatory environment.

Lussigny, B. (2016). Proposed changes to BCBS prudential framework : a view from the EU industry. Matinale European Institute of Financial Regulation.

Mangialardo, Alessia, Micelli, Ezio and Saccani, Federica, (2018), Does Sustainability Affect Real Estate Market Values? Empirical Evidence from the Office Buildings Market in Milan (Italy), *Sustainability*, 11, issue 1, p. 1-14, https://www.mdpi.com/2071-1050/11/1/12/.

Mudgal, S., Lyons, L., Cohen, F., Lyons, R., & Fedrigo-Fazio, D. (2013). Energy performance certificates in buildings and their impact on transaction prices and rents in selected EU countries. Brussels, Belgium: Bio Intelligence Service. *Report European Commission (DG Energy).*

NAS Invest. (2018). Phantom Menace or Real Threat? Implications of Basel IV for Germany's Real Estate Industry. News & Press Releases.

Næss-Schmidt, S., Bjarke Jensen, J., Ehmann, H., Facino, M. and A. Lemberg. (2021).Economic Impact Of The Final Basel III Output Floor: How the output floor can be implemented and what it entails for the Swedish economy. Copenhagen Economics for Swedish Bankers' Association.

Næss-Schmidt, S., Bjarke Jensen, J., Ehmann, H., Christiansen, B. (2019). EU Implementation Of The Final Basel III Framework: Impact on the banking market and the real economy. Copenhagen Economics.

Pascuas, R. P., Paoletti, G. and F. Anagnostopoulos. (2017). Nearly Zero-Energy Building (nZEB) technology solutions, cost assessment and performance. *ZEBRA2020: NEARLY ZERO-ENERGY BUILDING STRATEGY 2020 Deliverable 5.1. ZEBRA2020* IEE/13/675/S12.675834 Project. https://www.zebra2020.eu/website/wp-content/uploads/2014/08/Zebra2020_Deliverable-5.1_Report.pdf.

Pascuas, R. P., Paoletti, G. and R., Lollini. (2017). Impact and reliability of EPCs in the real estate market. *Energy Procedia*, Volume 140, p. 102-114, ISSN 1876-6102. https://doi.org/10.1016/j.egypro.2017.11.127.

Pivo, Gary. (2014). The Effect of Sustainability Features on Mortgage Default Prediction and Risk in Multifamily Rental Housing. *Journal of Sustainable Real Estate* 5:149-170. http://aresjournals.org/doi/abs/10.5555/jsre.5.1.y68534852m41531n

Pelizzon, L. and M. Riedel. (2017). Creating an Energy Efficient Mortgage for Europe: Review of the impact of energy efficiency on probability of default. Frankfurt am Main, Germany: *EeMAP project: Research Center SAFE, Goethe University Frankfurt.*

Reuters. (2017). German financial watchdog says Basel IV will hit some German banks. *Reuters.* Retrieved from https://www.reuters.com/article/us-germany-regulation-idUSKBN14U2D5.

Sanderford, A.R., Overstreet, G.A., Beling, P.A. and K. Rajaratnam. (2015). Energy-efficient homes and mortgage risk: crossing the chasm at last?. *Environ Syst Decis* 35: 157. https://doi.org/10.1007/s10669-015-9535-8

S&P Global Ratings. (2019). Global Covered Bond Insights.

Schildbach, J. (2020). European banks suffer more than US peers in the corona crisis . *Deutsche Bank Research EU Monitor Global financial markets*.

Schneider, S., Schröck, G., Koch, S. and R. Schneider. (2017). Basel "IV": What's next for banks? Implications of intermediate results of new regulatory rules for European banks. McKinsey & Company Global Risk Practice.

Surmann, M., Brunauer, W. and Bienert, S. (2015). How does energy efficiency influence the Market Value of office buildings in Germany and does this effect increase over time?. *Journal of European Real Estate Research*, Vol. 8 No. 3, pp. 243-266. https://doi.org/10.1108/JERER-04-2015-0018

Szumilo, N. and F. Fuerst. (2017). Income risk in energy efficient office buildings. *Sustainable Cities and Society*, Volume 34, Pages 309-320, ISSN 2210-6707. https://doi.org/10.1016/j.scs.2017.06.024

Qiu, Y., Wang, Y.D. and J. Wang. (2017). Soak up the sun: Impact of solar energy systems on residential home values in Arizona. *Energy Economics*, Volume 66, p. 328-336, ISSN 0140-9883. https://doi.org/10.1016/j.eneco.2017.07.001.

UK Green Building Council, LENDERS project. (2017). Core report: Improving energy costs in mortgages, promoting energy efficiency in homes. http://www.ukgbc.org/sites/default/files/Lenders_Core_Report_1.pdf

Uluc, A. and T. Wieladek. (2017). Capital requirements, risk shifting and the mortgage market. *European Central Bank Working Paper Series* No 2061 / May 2017.

UniCredit Research. (2019). Regulatory & Accounting Briefing: Overview of risk weights under Basel II, Basel III finalized and CRR**.**

Visnovsky, F. (2017). Bâle 1, 2, 3 … de quoi s'agit-il ?. Séminaire national des professeurs de BTS Banque Conseiller de Clientèle. ACPR Banque de France.

Wahlström. M. H. (2016). Doing good but not that well? A dilemma for energy conserving homeowners. *Energy Economics*, Volume 60, Pages 197-205, ISSN 0140-9883. https://doi.org/10.1016/j.eneco.2016.09.025.

Wallace, N., P. Issler, P. A Mathew, K. Sun (2018). Impact of Energy Factors on Default Risk in Commercial Mortgages. *Report. Lawrence Berkeley National Laboratory, Energy Technologies Area.* https://buildings.lbl.gov/publications/impact-energy-factors-default-risk

Wandschneider, K. (2013). Lending to Lemons: Landschafts-Credit in 18th Century Prussia. *NBER Working Paper* No. w19159. DOI 10.3386/w19159

Yoshida, J., Sugiura, A. (2015). The Effects of Multiple Green Factors on Condominium Prices. *J Real Estate Finan Econ,* Volume 50, Issue 3, Pages 412–437. https://doi.org/10.1007/s11146-014-9462-3

Yoshida, J., Onishi, J. and C. Shimizu. (2016). Energy Efficiency and Green Building Markets in Japan in Coulson, Lipscomb and Wang (Eds.), *Energy Efficiency and the Future of Real Estate*. http://dx.doi.org/10.2139/ssrn.2844040

Zancanella, P., Bertoldi, P., Boza-Kiss, B. (2018). Energy efficiency, the value of buildings and the payment default risk. *Publications Office of the European Union*, Luxembourg, 2018, ISBN 978-92-79-97751-0.doi:10.2760/267367,JRC11321.
https://publications.jrc.ec.europa.eu/repository/handle/JRC113215

Zeman, Z., Kalmar P. and C. Lentner (2018). Evolution of post-crisis bank regulations and controlling tools: a systematic review from a historical aspect. *Banks and Bank Systems*, 13(2), 130-140. doi:10.21511/bbs.13(2).2018.11.

Zhang, L., Liu, H., and Wu, J. 2016. "The price premium for green-labelled housing: Evidence from China." *Urban Studies*. http://dx.doi.org/10.1177/0042098016668288

Zhang, L., Wu, J., Liu, H. and Zhang, X. (2020), The Value of Going Green in the Hotel Industry: Evidence from Beijing. *Real Estate Economics*, Volume 48, Pages 174-199. doi:10.1111/1540-6229.12225