European Commission

EEFIG

ENERGY EFFICIENCY

FINANCIAL INSTITUTIONS GROUP

The quantitative relationship between energy efficiency improvements and lower probability of default of associated loans and increased value of the underlying assets

Final report on risk assessment

UN environment programme | finance initiative

EUROPEAN COMMISSION

Directorate-General for Energy
Directorate B: Just Transition, Consumers, Energy Efficiency & Innovation
Unit B.2 — Energy Efficiency

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REPORT ON RISK ASSESSMENT:

The Quantitative Relationship between Energy Efficiency Improvements and Lower Probability of Default of Associated Loans and the Increased Value of the Underlying Assets

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Manuscript completed in November 2021

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PDF	ISBN 978-92-76-51512-8	doi: 10.2833/532126	MJ-07-22-218-EN-N

Luxembourg: Publications Office of the European Union, 2022

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Acknowledgements

The Energy Efficiency Financial Institutions Group (EEFIG) was established as a specialist expert working group by the European Commission and United Nations Environment Programme Finance Initiative (UNEP FI), in late 2013, as a result of the dialogue between Directorate-General for Energy (DG Energy) and UNEP FI, as both institutions were engaging with financial institutions to determine how to overcome the well documented challenges inherent to obtaining long-term financing for energy efficiency.

EEFIG's work is the consensus group effort of over 500 members whose current professional experience falls into one of the following stakeholder groups:

- Public and private financial institutions (banks, investors, insurers etc.);
- Industry representatives and industry associations;
- Banking associations and investor groups;
- Energy efficiency industry experts;
- Energy efficiency services representatives;
- SME associations and expert representatives;
- Civil society experts representing diverse energy efficiency stakeholder groups;
- International Energy Agency (IEA);
- European Commission; and
- UNEP FI.

EEFIG is supported by a consortium led by COWI with commitments from the following partners: BPIE, Climate Strategy, d-fine, EEIP, EnergyPro, Fraunhofer ISI, ICCS-NTUA, and Viegand Maagøe. Peter Sweatman, chief executive of Climate Strategy is the rapporteur and co-founder of the EEFIG. In addition, the consortium is strengthened in capacity with commitments from the following individuals: Daire McCoy and Professor Nick Robins at the London School of Economics.

This report has been complied based upon the work of EEFIG WG8 whose full membership is listed below. We specifically thank Peter Sweatman (lead), Carsten Glenting, Markus Seifert, Dinne Hansen and Daire McCoy for their leadership of SR8's work, to Rasmus l'Anglois-Nordgren and Amalie Kafling Nørrelund for their dedication to the group resources and drafting support.

Legal Disclaimer

the accuracy of the data included in this report, nor do they accept responsibility for any use made by third parties thereof. This consensus view may not fully or entirely represent any single view of any member of the EEFIG working group on risk assessment.

Abbreviations

BPIE	Buildings Performance Institute Europe
BTL	Buy To Let
CRD	Capital requirements directive
CRR	Capital requirements regulation
DJSO	Dow Jones Sustainability Index
DNSH	Do No Significant Harm principle
EAD	Exposure at default
EBA	European Banking Authority
EC	European Commission
ECB	European Central Bank
ECBC	European Covered Bond Council
EDW	European Data Warehouse
EeDaPP	Energy efficiency Data Protocol and Portal
EEFIG	Energy Efficiency Financial Institutions Group
EeMAP	Energy Efficient Mortgages Action Plan
EEMI	Energy Efficiency Mortgage Initiative
EMF	European Mortgage Federation
ENEA	Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile
EPC	Energy Performance Certificates
ESG	Environmental, Social and Governance
EUGBS	European Green Bond Standard
FIAIP	Federation Italian Professional Real Estate Agents
GCD	Global Credit Data
ICAAP	Internal capital adequacy assessment process
IFC	International Finance Corporation
IFRS	International Financial Reporting Standard
IRB	Internal rating-based approach
JLL	Jones Lang LaSalle
LGD	Loss given default
NBS	Nationwide Building Society
NFRD	Non-Financial Reporting Directive
NZBA	Net-Zero Banking Alliance
PACTA	Paris Agreement Capital Transition Assessment
PGR	Proxy Green Ranking
RWA	Risk-weighted assets
SFDR	Sustainable Finance Disclosure Regulation
SFF	Sustainable Finance Framework
SFS	Sustainable Finance Strategy
SME	Small and medium-sized enterprise
SSM	Single Supervisory Mechanism
TCFD	Task Force on Climate-related Financial Disclosures
WG	Working group

Summary for Policymakers and Financial institutions

Summary for policymakers and financial institutions

In 2015, a GRESB real estate lending survey[1] reflected a reluctant attitude among financial institutions towards engaging in environmental, social and governance (ESG) issues in general, and in particular highlight that banks had less control over the assets they finance than their owners – and seeing no upside to promoting energy efficiency for them. This report addresses specifically this motivation by showing the links between credit performance and the energy performance of mortgage collateral.

Since 2015, the sentiment towards energy efficiency expressed by real estate lenders has changed, for four reasons: 1) Regulatory and stakeholder pressure on financial institutions to align their activities with the EU Taxonomy and to report it; 2) Growing evidence that mortgage loans collateralised by energy efficient properties are better credits; 3) That energy efficient properties are worth more than inefficient ones; and 4) The future risks of stranded properties that fall below potential future minimum energy performance standards.

Since EEFIG published its 2015 landmark report on the drivers for and barriers to energy efficiency finance and investments in buildings, SMEs and industry, the opinions and actions of its financial institution members have in fact changed dramatically.

In late 2018, the EU Commission, and its co-convener UNEP FI, launched an EEFIG working group to undertake a risk assessment and evaluate the evidence for a quantitative relationship between energy efficiency improvements and lower probability of default of associated loans and the increased value of the underlying assets. The working group recruited over 65 individual members and observers from across the EU Commission, asset managers, banks, central banks, regulators, sector experts and statisticians. Over two years, working group members contributed to and reviewed a reference library of evidence containing 120 documents, met eight times, launched national hubs and produced new statistical work covering over 800,000 mortgages in four European countries.

[1] The 2015 GRESB real-estate lending survey. Retrieved from: https://gresb.com/real-estate-lending-and-esg-observations-from-the-2015-gresb-debt-survey/, examples include "As a lender, we have less control over properties than do borrowers/asset owners. Furthermore, we realize no upside as a result of energy efficiency…Why should we consider environmental, social and governance (ESG) issues relative to our lending platform and processes?"

The conclusions and recommendations of this work are summarised here and are divided into sections which address the different work streams and target readers.

New evidence showing statistically relevant correlation between energy performance of building collateral and credit performance:

This WG uncovered and robustly assessed new evidence from a large sample of mortgages across several countries in Europe to **conclude that there is a statistically significant correlation between the energy performance of building collateral and mortgage credit performance**. This is also in line with the conclusions of a significant number of academic studies collected in the WG's knowledge base.

The two-year work period was insufficient to finalise additional studies expected from more countries and financial institutions. Going forward, it is encouraged that the findings are corroborated through additional work with other financial institutions' portfolios and in other EU Member States to further assess the causality of the relationship.

The primary analysis of this WG was conducted using the residential mortgage books of Nationwide Building Society (NBS) in the UK, Allianz in Germany and OP Financial Group in Finland. In total, the analysis was conducted on a sample of almost 800,000 residential mortgages across all three countries[2]. A forward-looking analysis was undertaken in each case controlling for different borrower credit scores, incomes, loan terms, loan-to-value ratios, along with a range of variables relating to the building and additional controls capturing municipality-level economic and the broader economic indicators. Energy performance data came from a combination of domestic energy performance certificates (EPCs) registers (where available) and proxy models based on energy demand or characteristics of the building.

It is worth highlighting the precise conclusions of the most thorough and numerous of the primary research studies from NBS:

- Customers that hold high and medium energy efficient properties are ~20% less likely to default than customers that hold low energy efficient properties, "all other things being equal";
- this relationship is stable and intuitive, after including control variables that might explain the relationship between EPC and default;

[2] While 82% of the mortgages assessed are from the UK. The WG notes that the technical work relates to a period when the UK formed a part of the EU28, and it was decided at the start of the work to continue using the technical frame for geographical boundaries determined when the group was launched.

- the coefficients are statistically significant with *p*-value < 0.01 meaning that the probability of the results being random is less than 1%; and

- the results are also robust to the inclusion of a battery of control variables and with a large sample of more than 600k properties.

These primary results are consistent with parallel work undertaken in Italy, Portugal and the Netherlands by members of the Energy Efficient Mortgages Platform. Under the Energy Efficient Data Protocol & Portal (EeDaPP) project econometric evaluations were undertaken using a Logit regression and Cox models. Using 73,000 Italian mortgages, EeDaPP 2020 results[3] showed a negative correlation between EE and the owners' probability of default, which also suggests that energy efficiency investments in mortgage collateral tend to improve owners'/borrowers' solvency. The EeDaPP results also indicate that the degree of energy efficiency also matters, i.e. owners of more energy efficient buildings are associated with relatively lower risk of default. Further studies were undertaken by Bank of England, in the Netherlands and Portugal that have similar conclusions.

The relevance for the people affected by energy poverty was underscored in Nationwide's analysis as they saw energy efficiency has a bigger impact at the lower end of the income distribution. This makes intuitive sense as when borrowers are more income constrained, lower energy costs are more material.

Review and assessment of research-body on the relationship of energy performance with an asset's market value:

Energy efficiency improvements are designed to reduce energy consumption and operational costs, but they can simultaneously improve a building's image, regulatory resilience, and comfort (improved temperature control, indoor air quality, and light as well as noise reductions). For the European Commission's Joint Research Centre (JRC) this provides the rationale for an increase in a building's value, and its improved marketability. In 2018, the JRC offered "a rule of thumb" pointing to an observed increase of 3-8% in the sale price of residential assets resulting from energy efficiency improvements, as well as an increase of around 3-5% in residential rents compared to similar properties. It also reported that this premium was over 10% in commercial real estate, all subject to country, region and building type.

The WG's review of the literature on green premium in real estate including studies from several European countries (NL, IE, DE, FR, PT, RO, UK) shows

[3] EeDaPP results announced in August 2020, and retrieved here: https://hypo.org/ecbc/press-release/energy-efficient-mortgages-initiative-eemi-eedapp-confirms-negative-correlation-between-energy-efficiency-and-risk/

that higher energy efficiency (indicated by EPC rating) increased the overall housing market prices and rental values. The body of WG research indicates that the most efficient properties can attract a market price premium of up to 10% in value, and approximately 5% for rentals, compared to equivalent least efficient or non-rated properties. Several studies also find less liquidity for the lowest rated buildings. The literature review which includes several recent studies (2019-2020) confirms the JRC 2018 findings of an observed increase of 3-8% in the sale price of residential assets resulting from energy efficiency improvements, as well as an increase of around 3-5% in residential rents compared to similar properties.

This is clearly highly location, typology and building specific, and yet aligns with WG members' expert opinion. The WG notes that the analysis in many of the existing studies is limited by the fact that energy efficiency may be correlated with unobserved quality variables such as the appearance or design of a property. More robust research designs using quasi-experimental methods, which control for selection bias, and the "repeat-sales" approach, which restricts analysis to samples consisting of at least two sales of the same dwelling at different points in time, get closer to the true causal estimate.

Finally, as the market starts to expect future mandatory minimum energy performance standards, and a stronger regulatory incentive for upgrade, this value differential is more likely to be spread around a mid-point of zero for the median performing building (EPC level D today) and that this mid-point will rise over time as European buildings are renovated and decarbonised by 2050.

For mortgage lenders, the probability of default (and ability to make interest and loan repayments) is the critical variable in capital allocations. Property value changes, while potentially impacting the amount recovered from a mortgage in default do not have such a significant impact on capital calculations – as mortgage default rates remain low, and losses given default are limited by average loan-to-value limits in lenders portfolios. Nevertheless, a write-down of the value of inefficient buildings (due to the introduction of mandatory minimum energy performance standards) would naturally be balanced with an appropriate increase in the value of efficient buildings – and this will also enhance the business case for renovation.

Recommendations to Policymakers:

Europe cannot afford to have the energy performance of each of its buildings be hard to access for owners and funders, complex to understand nor distant from real performance. The work of this EEFIG working group underlines the importance of a transparent register of EPCs in each Member State that is available to mortgage lenders in that country. Financial institutions as mortgage lenders and owners can also help rationalise this

market with the right set of incentives, information and obligations (carrots and sticks).

The EU regulatory framework should ensure that lenders identify, record and maintain current the energy performance of their buildings' collateral. Analysis similar to the EEFIG WG's statistical work can't be properly undertaken if borrower records cannot be augmented with buildings energy performance records. German, French, Spanish and Finnish members of EEFIG encountered these issues. Proxies are useful and have been demonstrated to approximate energy performance but are not as useful as real energy performance. Member States need to collect and make available EPCs to buildings stakeholders including lenders using the building as collateral. The contents and quality of EPCs also need to improve over time and increasingly move from approximate or design performance estimates to real energy performance. Actual energy performance should be updated to provide dynamic materiality and allow for more regular action on newly identified energy and climate risks over time (from static to dynamic assessment).

This EEFIG WG's work has focused on isolating and integrating energy efficiency as a risk factor into internal ratings based (IRB) models. IRBs models are the regulatory standard for assessing capital requirements in nearly all large banks in Europe. IRB models are optimised to measure credit risk, and new significant factors are not found frequently. Energy efficiency as a new factor in those models appears evidenced through the WG's work to improve risk differentiation, and thereby offer a way forward to integrate energy efficiency into a bank's credit policies and capital costs. A potential future revision of the EBA guidelines on PD and LGD estimation (EBA/GL/2017/16) could include a recommendation for banks to investigate energy efficiency as a risk factor during model development.

While IRB-banks can reorient credit risk calculation approaches (IRB-A) to accelerate the improvement of buildings' energy performance and risk management strategies, the benefits of capital released as a result of investing to improve collateral energy performance needs to be material to drive this outcome. The WG's work demonstrate the feasibility of including energy efficiency into IRB models based on historical data. Additionally, it can be reasonably expected that the effect of energy efficiency on credit risk will even increase during the transition towards climate neutrality.

Therefore, specific capital treatment to reflect the body of new evidence described in this report would support the business case for private sector financial institutions investing in energy efficiency, helping address the investment gap identified by the Commission in its EU Green Deal related communications. Naturally, this would have to involve the adjustments to the requirements for IRB approach, but also for the standardised approach, both of which are not fully independent.

In this context, the EBA's 2023 assessment of a dedicated prudential treatment of exposures related to assets and activities associated substantially with environmental and/or social objectives is an important instrument and should consider energy efficiency as a specific component.

In summary, the EEFIG WG's recommends the following to policymakers:

- The EU regulatory framework should require National governments collect EPC data and ensure easy access to EPCs to financial institutions. This includes improving data quality and a stronger connection to real usage also where EPCs have been available over several years.

- The EU regulatory framework should ensure that lenders identify, record and maintain current the energy performance of their buildings' collateral including the assessment of energy efficiency as a risk factor in their IRB PD and LGD models.

- Energy efficiency should be assessed as a specific component of the EBA's 2023 report on a dedicated prudential treatment of exposures related to assets and activities associated substantially with environmental and/or social objectives.

Recommendations to Financial Institutions:

In 2015, EEFIG identified a set of barriers to increasing energy efficiency investing including: high investment costs (as energy efficiency solutions are more capital intensive than less efficient solutions and often have longer pay-backs); high transaction costs - as energy efficiency investments are generally smaller than competing projects; and the limited availability of reliable information and real energy efficiency performance data is a growing issue for financial institutions.

The work of EEFIG's WG demonstrates more clearly than ever the benefits of attaching energy performance data to mortgage records to better manage credit risks and engage with customers to help them renovate properties to reduce transition risks and deliver the multiple benefits of energy efficiency including lower bills and a higher property value. All financial institutions are recommended to research how to include energy performance data and EPCs (or proxies for an interim period) for all buildings collateral in their customer data management systems.

The expansion of public engagement and Paris-aligned regulatory frameworks is sure to drive the engagement of more financial institutions to support the parallel development of new and tailored energy efficiency

financial products. Retail lenders should engage on energy performance with their registered mortgage customers and look to implement mortgage portfolio migration targets that improve the energy performance of portfolio collateral in line with national Paris-aligned decarbonisation pathways. This will require the development of new financial instruments supporting energy efficiency, and improving existing ones, and improvements should focus on reducing the cost of renovation finance and increasing the tenors of renovation funding to match the life of the energy efficient upgrades to be financed, levered (where available) by public grants or guarantees.

Energy efficiency investments are smaller than those relating to energy supply, and often they are more complex to assess. Developing finance lines and funds to finance energy efficiency and buildings upgrades requires the capacity to identify and evaluate these investments, internally or by sourcing the expertise. Financial institutions need to confirm that the investment to be financed improves energy efficiency, and is aligned with the EU Taxonomy, by ensuring that funded energy efficiency gains are measured and verified. The capacity of lenders and investors to carry out (or alternatively outsource) these technical tasks is a bottleneck that financial institution development can help address.

The transaction costs of developing an energy efficiency product and individual projects are high, for financial institutions and buildings owners. Technical evaluation, project execution and results monitoring are significant costs for these relatively small investment outlays. Standardisation of processes[4] and outsourcing to a trusted network of contractors vetted by the financial institution can facilitate project aggregation and reduce the transaction costs of energy efficiency finance and is necessary to develop securitisation for energy efficiency projects and for mortgage lender to upgrade their collateral portfolio’s energy performance.

Financial institutions can also help develop de-risking tools and deploy guarantees from Governments: (i) to mitigate credit risks related to financing energy efficiency especially for low-income households or to small and medium-sized enterprises or other companies with weak credit ratings; (ii) to reduce risks with innovative technologies or technologies in the early market penetration phase; and (iii) to adequately cover long term risks related to long tenor products.

In summary, The EEFIG WG's recommends the following to financial institutions:

[4] European (CEN CENELEC) and International (ISO) standards for energy performance reporting and climate risks assessment are examples of such standards.

- Financial institutions should tag loan collateral and underlying assets based on their energy performance;
- Financial institutions should where possible replicate the WG's statistical approaches to analyse their own portfolios to better manage credit risks and capital allocations;
- Mortgage lenders running IRB models should consider energy efficiency as a risk factor in them and optimise their approaches based upon the work of this WG and subsequent evidence;
- Financial institutions should develop dedicated products to support clients' energy renovation of buildings.

Limitations, Gaps and Recommendations for further work

The EEFIG WG highlights the new evidence being provided in this report, which can be built on and improved as follows:

- While we have demonstrated a statistically significant correlation between energy efficiency and credit risk in multiple geographies, additional work should continue to corroborate this relationship in additional EU Members States and to further assess the causality of the relationship.
- Further work is also encouraged to advance the understanding of correlations between energy efficiency and creditworthiness in the unsecured loan sector. EEFIG's ability to address the unsecured segment was severely diminished by the almost total lack of coherent and long-term data sets that were statistically comparable with energy performance information from its members. It is only through increased availability of standardised information on the energy performance of both residential and commercial assets and industrial and SME processes that our understanding of these relationships will be enriched.
- Further research into the size of the energy efficiency value premium for high performing buildings can be undertaken using quasi-experimental methods, which control for selection bias, and the "repeat-sales" approach, restricting analysis to samples consisting of at least two sales of the same dwelling at different points in time, get closer to the true causal estimate of energy efficiency value premium.

Clearly, EEFIG's energy efficiency correlation and statistical work is not over and there is space to deepen and expand these results both with more lenders and across more countries as more energy performance data becomes available and more lenders engage to decarbonise their balance

sheets in support of Paris alignment and in line with the EU Taxonomy. There are few financial institutions with the motivation and data to replicate these results and the EU Commission should consider EEFIG and/or Horizon Europe projects to deepen and repeat the work of across different regions and with different lenders. To refute the lender's reluctance to engage with energy efficiency as evidenced in the GRESB 2015 survey, lenders have to engage with their own data with own analysis to see the risks and take advantage of the benefits of better-quality analysis and risk management work.

Introduction

1 Introduction

This Report has been prepared in the context of the assignment "Launch and facilitate the implementation of a new EEFIG WG on Risk assessment: the quantitative relationship between energy efficiency improvements and lower probability of default of associated loans and the increased value of the underlying assets". Table 0-1 below provides a table of contents and overview of the structure of the report:

Table 0-1 Report structure and content overview

CHAPTER	CONTENT
Chapter 1 – Introduction	› Context on Green Finance and banks › Regulatory landscape › Questions framing the analysis › Assessment frame and methodology
Chapter 2 – Literature review and assessment of links between energy performance and asset value	› Identifying relevant knowledge › Conclusions on links between energy performance and asset value › Summary overview of relevant knowledge and initiatives
Chapter 3 – Statistical analysis of the correlation of credit risk with underlying asset energy performance	› Methods adopted by WG › Individual statistical studies › Methodological challenges and solutions
Chapter 4 - Conclusions and recommendations	› The conclusions of the WG on the relationships between energy efficiency improvements and lower probability of default of associated loans and increased value of the underlying assets › Recommendations
Appendix A, PowerPoint presentation of the main results, conclusions, and recommendations	› PowerPoint presentation of the main results, conclusions and recommendations
Appendix B, Further references	› Identifying relevant knowledge
Appendix C, National hub assessment Member State level	› Main drivers for energy efficiency in the financial sector › Main activities in each Member State › Lessons learned from the EEFIG WG discussions
Appendix D, Detailed PowerPoints from case studies	› Detailed PowerPoints from case studies
Appendix E, Overview of literature and documents	› Overview of literature and documents
Appendix F, Composition of the WG	› Composition of the WG
Appendix G, WG meetings package	› Agendas and minutes of meetings from all WG meetings

The opinions and positions expressed in this report are built on a consensus and relate to the evidence and findings of the EEFIG working group. As such they do not necessarily claim or represent the positions of each of the individual members of the organisations they represent. Rather, the report constitutes a consensus description of two years of collective work.

1.1 Context for green finance and financial institutions

Climate change and the resulting energy transition are disrupting and changing European energy markets, and this is impacting financial institutions – the sustainability performance of companies affects their clients as well as the viability of business models and corporate strategy in key sectors. This is compounded by financial institutions' financing of and investment in green assets which makes sustainability a core and material consideration for banks and investors.

As the European economy emerges from the covid-19 crisis, banks, investors and insurers are increasingly looking for new ways of engaging positively with their customers, enhance their reputation, increase their green assets and gain enhanced customer insight. Millennial customers are clients that increasingly require financial institutions to better define and demonstrate their positive impact on society at large. Cultural change towards sustainability in the financial industry is increasingly driven by the senior leadership of financial institutions – this readiness of senior financiers to engage with energy efficiency has also been a benefit to accelerate the technical work of EEFIG. Digitalisation is in parallel creating new opportunities for customer insight.

The EU's new sustainable finance strategy adopted by the Commission on 6th July 2021, together with a historic revised European Central Bank (ECB) strategy, provides a regulatory push for financial institutions to integrate sustainability far into their core business and improve the transparency and standards of their environmental, social and governance (ESG) reporting. It brings about the necessary acceleration of market standardisation, risk assessment and potentially a dedicated treatment of assets or activities substantially associated with environmental (and/or social) objectives and more sophisticated approaches to valuing energy efficient building's collateral. This has changed the approach of banks, investors and insurers, who now all see that sustainability matters to their bottom line. The two tracks of traditional energy policy-making and new approaches to directing the real economy via inclusion of ESG considerations in financial regulation are beginning to work in tandem.

Building foundational knowledge of link between financial and environmental performance

The alignment of bank lending with global goals for climate action and sustainable development has been held back by the lack of a robust quantitative understanding of the links between financial and environmental performance. Focusing on the key real estate sector, this WG joins the forces of research networks and teams undertaking statistical analysis of the relationships between the credit quality of unsecured loans, mortgages and the energy performance of underlying buildings collateral to uncover and provide statistical assessments of vital evidence that could significantly accelerate the greening of bank balance sheets.

Building on the 2019-20 results of EEFIG's work and years of experience in green tagging among leading European banks and EEFIG members, this working group (WG) brings together academic research, sector partnerships and leading banks. The aim is to merge loan and energy performance data, to form the basis for a knowledge network of analysis and outreach, and ultimately to influence both bank practice as well as better inform financial regulation and EU policymaking.

The WG members are individuals and organisations that share the view that green lending is not just vital for environmental sustainability, but also makes good economic sense for lenders in terms of risk management and market expansion. When the WG began, the statistical evidence required to test this hypothesis was distributed and emerging only. Overcoming this in the last two years has required the identification of the leading research groups to work with banks providing access to their loan books, and then to merge these with relevant environmental data points, or proxies, in order to provide careful and statistically robust analysis of potential relationships.

1.2 Regulatory landscape

The regulatory landscape is shaped by multiple initiatives of various authorities that create new legislation or amend existing legislation. Examples are the Deliberations of the European Commission on Capital Requirements Regulation (CRR3), as well the creation of new supervisory standards such as ECB's Guide to Climate and Environmental Risks.[5] Overall, legislative work on taxonomy, benchmarking, and disclosures is being pursued with high intensity (see Figure 0-2).

Much of the recent EU Commission work with financial institutions was released in a "Sustainable Finance Package" published and adopted on 6th July with three components:

[5] https://www.bankingsupervision.europa.eu/ecb/pub/pdf/ssm.202011finalguideonclimate-relatedandenvironmentalrisks~58213f6564.en.pdf

1 An updated Sustainable Finance Strategy (SFS) with six action areas, each with multiple components, to tackle climate change and four other EU environmental challenges;

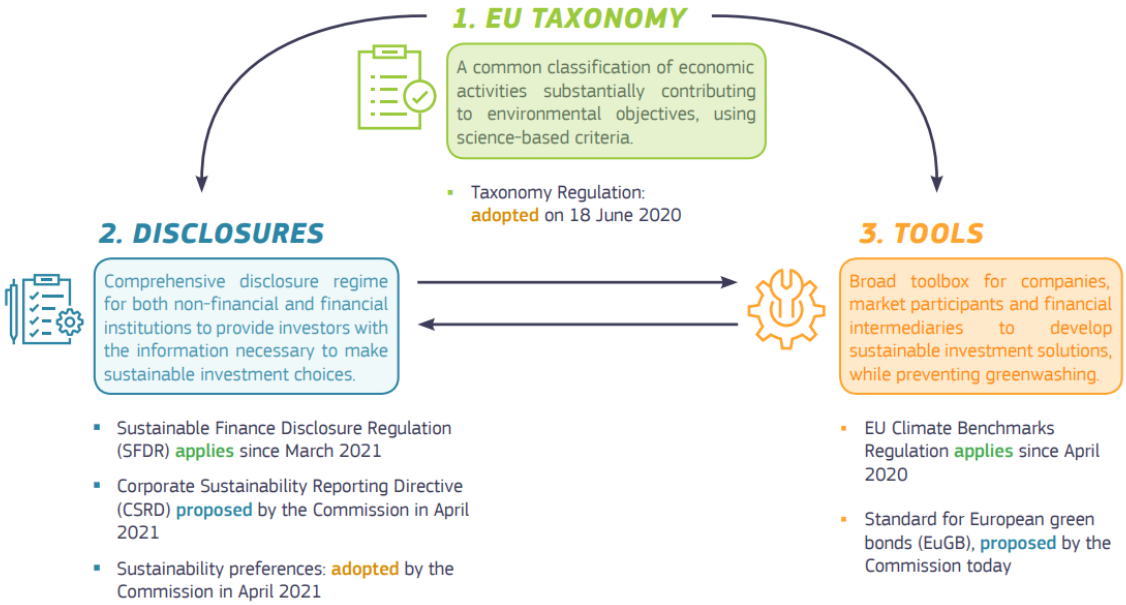
The European Green Bond Standard (EUGBS) proposal designed to harmonise voluntary standard for bonds financing sustainable investments; and

2 A Delegated Act containing the KPIs, thresholds and other information to be disclosed by financial and non-financial companies on how sustainable their activities are. This provides the details for compliance with Article 8 of the EU Taxonomy.

The Sustainable Finance Strategy (SFS)

The SFS is the strategy which develops the three pillars of the 2018 EU Sustainable Finance Framework (SFF): Mandatory disclosure of material non-financial matters (for big companies (the Non-Financial Reporting Directive (NFRD)) and funds (the Sustainable Finance Disclosure Regulation (SFDR)), Taxonomy standards - defining what sectors and thresholds matter, and tools to help comply (see Figure 0-1).

Figure 0-1 2018: The foundations of the EU Sustainable Finance Framework



Source: European Union (July 2021)[6]

[6] *European Union, 2021. Factsheet sustainable-finance-strategy,* (https://ec.europa.eu/info/sites/default/files/business_economy_euro/banking_and_finance/documents/210706-sustainable-finance-strategy-factsheet_en.pdf)

The SFS includes six sets of actions**,** each of which has six sub-components. The six sets of actions concern:

1 Extend the existing sustainable finance toolbox to facilitate access to transition finance;

2 Improve the inclusiveness of small and medium-sized enterprises (SMEs), and consumers, by giving them the right tools and incentives to access transition finance;

3 Enhance the resilience of the economic and financial system to sustainability risks;

4 Increase the contribution of the financial sector to sustainability;

5 Ensure the integrity of the EU financial system and monitor its orderly transition to sustainability;

6 Develop international sustainable finance initiatives and standards, and support EU partner countries.

A European Green Bond Standard (EUGBS)

EUGBS is a proposed Regulation[7] on a voluntary European Green Bond Standard for all issuers (private and Govts) to help financing sustainable investments. In 2020, green bonds represented 4% of total corporate bonds issued, but Europe has around a 40% share of the global green bond market.[8] Europe is thus well positioned to drive the development of global standards. Bonds are good instruments for financing the green transition. This is because institutional investors, who make investment decisions on behalf of individual members or shareholders, typically hold more bonds than equities, and because demand by far exceed current supply. EUGBS aims to set a 'gold standard' for green bonds to finance ambitious investments, while meeting tough sustainability requirements and protecting investors from greenwashing using the EU Taxonomy thresholds for green. EUGBS will be open to any issuer of green bonds, including issuers located outside of the EU. There are four key requirements under the proposed framework:

1 The funds raised by the bond should be allocated fully to projects aligned with the EU Taxonomy;

2 There must be full transparency on how bond proceeds are allocated through detailed reporting requirements;

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[7] EU COM(2021) 391 retrieved from: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021PC0391

[8] European Trade Union Institute. 2021. The European green bond standard: a good initiative hanging in the balance. July 6 2021. (https://www.etui.org/news/european-green-bond-standard-good-initiative-hanging-balance)

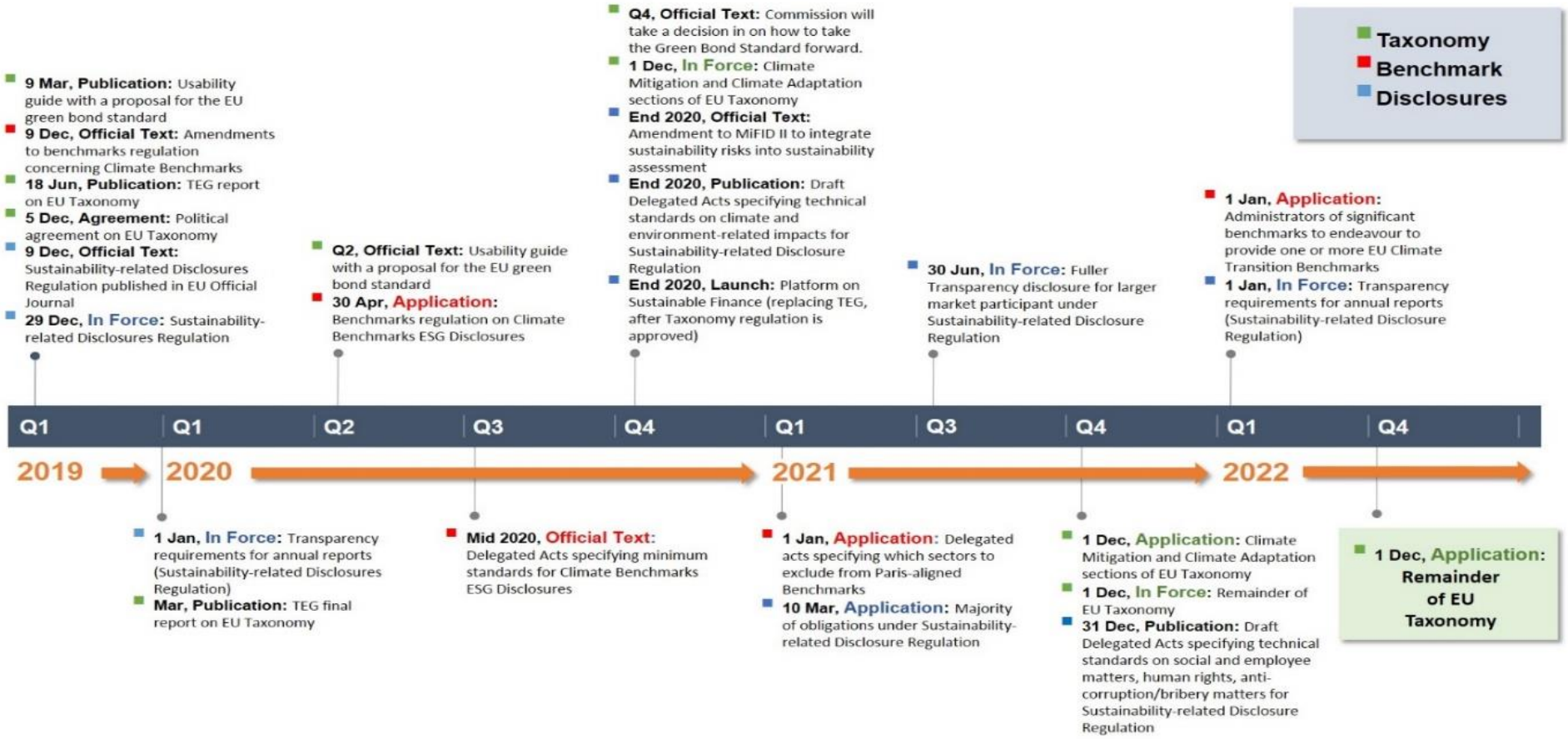
3 All EU green bonds must be checked by an external reviewer to ensure compliance with the Regulation and that funded projects are aligned with the Taxonomy. Specific, limited flexibility is foreseen here for sovereign issuers;

4 External reviewers providing services to issuers of EU green bonds must be registered with and supervised by the European Securities Markets Authority. This will ensure the quality and reliability of their services and reviews to protect investors and ensure market integrity. Specific, limited flexibility is foreseen here for sovereign issuers.

Delegated Acts under the EU Taxonomy Regulation

Article 8 of the Taxonomy Regulation requires financial and non-financial companies to provide information to investors about the environmental performance of their assets and economic activities. The Delegated Act(s) specify the contents, methodology and presentation of this information to be disclosed by large financial and non-financial companies on the share of their business, investments or lending activities that are aligned with the EU Taxonomy. The Climate Delegated act, formally adopted on 4 June 2021, provides "green" thresholds for business sectors covering over 90% of EU emissions, as well as lower limits where activities can be considered to be "Doing Significant Harm" (DSH) to an environmental objective. Large banks, asset managers, investment firms and insurance/reinsurance companies will have to disclose the share of environmentally sustainable economic activities in the total assets they finance or invest in from 2022.

Figure 0-2 Current timelines for taxonomy, benchmarking, and disclosures



Source: EU Action Plan Timeline of Relevant Dates, Sustainanalytics (2021)[9]

[9] Sustainanalytics, 2021: https://www.sustainalytics.com/esg-research/resource/investors-esg-blog/eu-sustainable-finance-action-plan-final-taxonomy-report-published-and-other-developments

European financial institutions are now adjusting their operational procedures and risk management to align with these new regulatory and reporting requirements and align their balance sheets and businesses with the Paris Agreement. While climate and environmental aspects have not traditionally been considered in the historical banking business model, they are being newly integrated into the existing regulatory frameworks of financial institutions. It became clear in the EEFIG WG discussions that climate and environmental risks do not constitute a separate risk type but are rather new and material factors that impact classical risk types like credit or market risk.

During the two years of this WG's activity, financial regulators and supervisory authorities have outlined and clarified their expectations in several ground-breaking papers:

- In November 2020, the European Banking Authority (EBA) launched their consultation on the incorporation of ESG risks into the governance, risk management and supervision of credit institutions and investment firms (EBA/DP/2020/03). The EBA explicitly mentioned energy efficiency of buildings as a driver of transition risks and recommends addressing the impact of energy efficiency of buildings on their valuations. The WG supported their members in contributing to this consultation. Further relevant EBA papers include:
  - EBA Consultation paper on draft technical standards on ESG P3 disclosures (March 2021) https://www.eba.europa.eu/eba-launches-public-consultation-draft-technical-standards-pillar-3-disclosures-esg-risks;
  - EBA EU-wide pilot exercise on climate risk: https://www.eba.europa.eu/eba-publishes-results-eu-wide-pilot-exercise-climate-risk

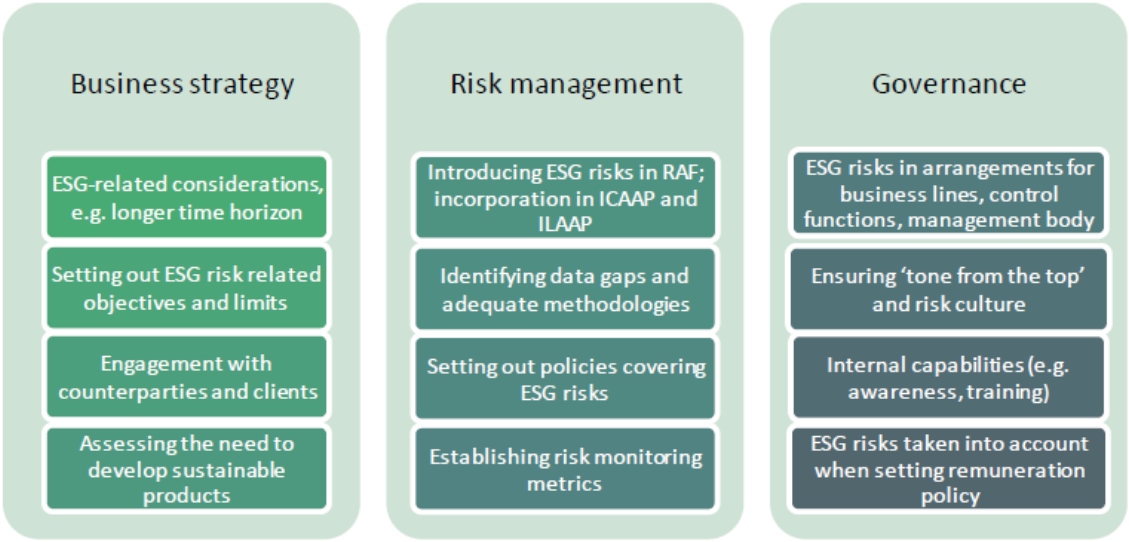
- In the same month (March 2021), the European Central Bank (ECB) followed up with their "Guide to Climate and Environmental Risks" which provided clear expectations towards ECB supervised banks, including that
  - Institutions are expected to give particular consideration to the physical locations and the energy efficiency of commercial and residential real estate (expectation 8.3),
  - institutions measure concentrations of assets with specific characteristics likely to be targeted by transition policies, for example the distribution of energy efficiency labels within residential and commercial real estate portfolios in the light of potential legislation (expectation 8.4), and
  - institutions may differentiate the loan prices for exposures according to their energy efficiency (expectation 8.5).

- Additionally, the ECB published their report on institutions' climate-related and environmental risk disclosures, and the ECB strategy, covering actions including:
  - Ensuring that disclosures are in line with EU policies as an eligibility requirement in collateral framework and asset purchases by designing adequate policies and conducting legal and operational preparations.
  - Incorporating climate change risks in credit ratings for collateral and asset purchases by assessing rating agencies' disclosures and understanding how they incorporate climate change risk in ratings, and developing minimum standards for internal credit ratings.
  - Incorporating climate change risks in the collateral framework by reviewing collateral valuation and risk control framework to ensure that climate change risks are reflected, and assessing financial innovation related to environmental sustainability.

- In March 2021, the EBA reported to the European Commission their advice on KPIs and methodology for the disclosure by credit institutions and investments firms under the NFRD on how and to what extend their activities qualify as environmentally sustainable according to the EU taxonomy regulation (EBA/Rep/2021/03). This report introduces the concept of a green asset ratio to summarise the alignment of bank exposures with the EU taxonomy.

- In June 2021, the EBA publishes its Report on management and supervision of ESG risks for credit institutions and investment firms (EBA/REP/2021/18) based on the feedback from the consultation conducted in November 2020. The recommendations of this report have been summarised as follows (Figure 0-3, reproduced from p. 13 of EBA's report):

Figure 0-3 Summary of recommendations set out in EBA's Report on management and supervision of ESG risks for credit institutions and investment firms.



Source: EBA/REP/2021/18

It is important to note that ESG requirements are supposed to be included into Basel pillar 2 risk management, i.e. the internal capital adequacy assessment process (ICAAP). In contrast to Basel pillar 1 under CRR, the ICAAP offers banks a higher degree of methodological choice, thus making internal risk management more specific to the business model of the bank.

- The ECB further pushed the agenda by sending a questionnaire on ESG related topics to banks supervised under the Single Supervisory Mechanism (SSM), i.e. under direct ECB supervision, in Q1 2021. This questionnaire triggered significant activities within the banks regarding the preparation and implementation of suitable methodologies for ESG risk management, including as one specific item the assessment of risks due to energy efficiency in real estate portfolios.

- In addition to the results published on the ECB internal climate stress test 2020,[10] the ECB announced to run a fully-fledged climate stress test for banks under the SSM in 2022.

A major milestone in terms of banking regulation and supervision will be the revisions proposed in the sixth Capital Requirements Directive and the third Capital Requirements Regulation (CRD6 / CRR3) deliberations, to be approved at the Commission level by the College of Commissioners. The WG strives to provide suitable input and analyses in this process, as pillar 1 capital requirements will definitely affect the capital costs of banks and thereby also the relative capital cost of their green and brown business areas.

[10] https://www.ecb.europa.eu/press/blog/date/2021/html/ecb.blog210318~3bbc68ffc5.en.html

1.3 Questions to frame the work

Given the wider policy and regulatory landscape, the imperative to better identify and quantify environmental risks, and overall data availability, the WG largely focused on energy efficiency in real estate assets. Specifically, we saw significant potential within the WG to specifically understand and analyse the quantitative relationship between energy efficiency improvements and lower probability of default of associated loans and the increased value of the underlying assets. The reason being that buildings are significant end-users of energy, and they are also one of the most significant asset classes on investor and bank balance sheets in Europe.

In addition to focus on the real estate sector, the WG has framed the analysis around the three high-level questions presented in Figure 0-4. These are also the questions that are of growing interest to banks, regulators and academics. All of these questions have been discussed in the WG, and in-depth quantitative analyses have been performed to address the first question.

Figure 0-4 Questions discussed by the WG

Source: EEFIG Working Groups, "Are green loans less risky?" (2021)[11]

All these aspects of the green finance agenda require robust evidence on the relationship between loan quality and environmental performance. With global real estate accounting for 60% of global wealth[12] and being the major component of many bank balance sheets in the form of mortgages and commercial real estate, leading banks are identifying green buildings and energy efficiency as the place to start their green transformation. Our theory of change has identified the absence of robust analytics as a significant barrier to scaling up green lending in the property sector.

[11] NBS, 2021: https://hypo.org/app/uploads/sites/3/2021/03/BAUHAUS-4_NationwideBuildingSociety.pdf

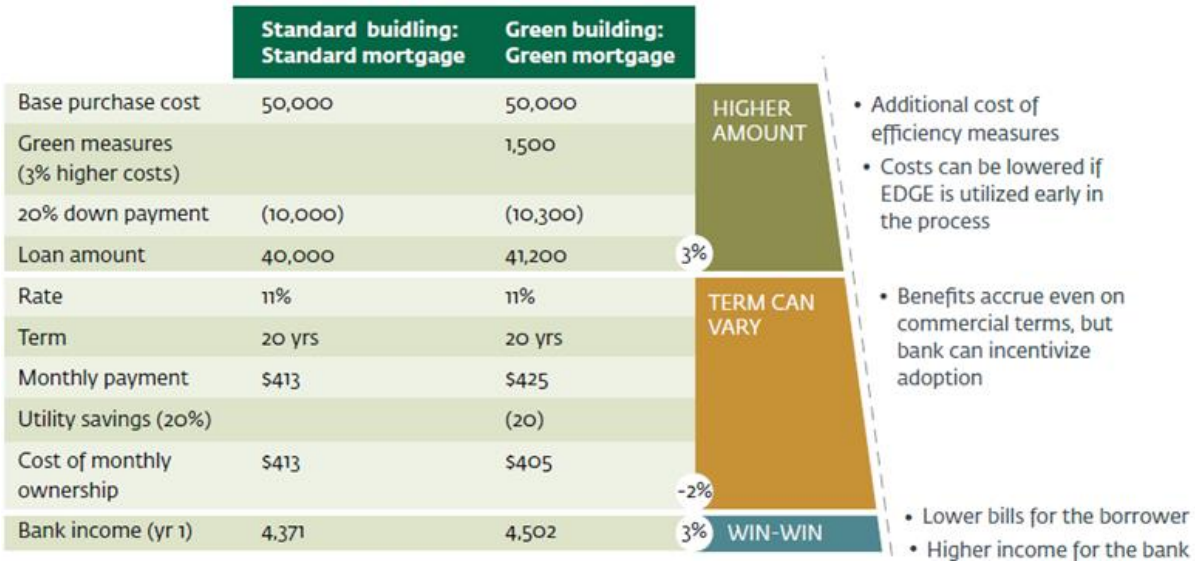
[12] Savills. 2016. Around The World In Dollars And Cents – 2016, Publication

1.4 Assessment frame and working method

Thesis

In principle and all else equal, borrowers living in houses with higher energy performance should have not only have greater thermal comfort, but also lower energy bills. Therefore, we might expect them to be a lower credit risk and produce fewer non-performing loans (and losses in case of default) due to their improved cash flows and debt servicing capacity (and a green premium in value terms). This is illustrated in Figure 0-5 in the case of green mortgages:

Figure 0-5 Stylised Green mortgage vs. standard mortgage



Source: IFC, 2019[13]

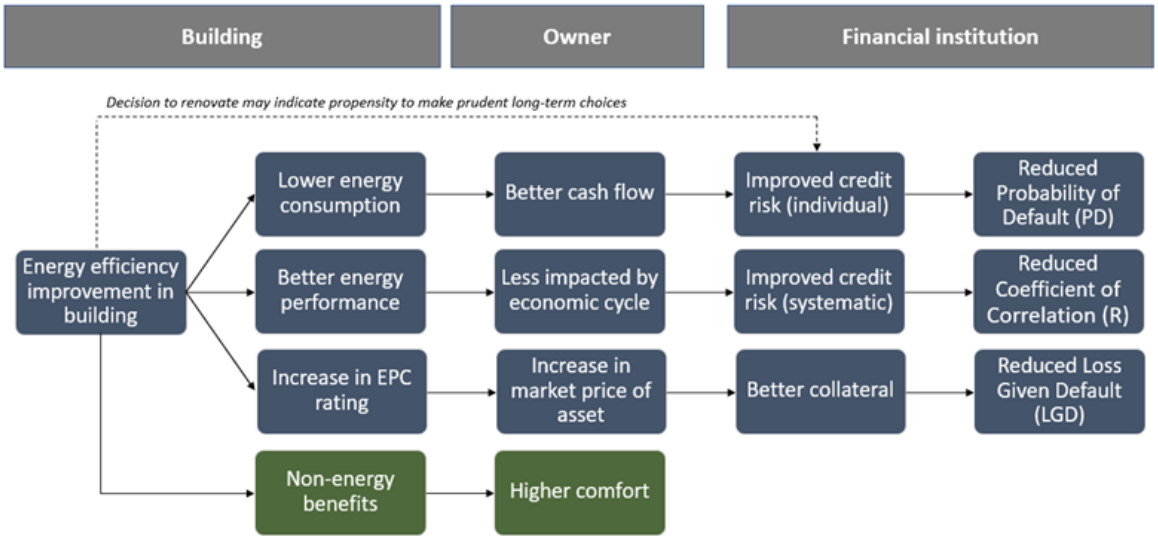
Methodology

Establishing a quantitative relationship (or correlation) between energy efficiency and lower credit risk can provide a central business case for lenders to focus on asset energy performance, work to improve this and originate more energy efficiency loans and mortgages. Given the fact that on average credit risk constitutes by far the most significant risk type for banks and hence credit risk plays a fundamental role in the derivation of banks' capital requirements, such a correlation provides leverage for banks to guide their business towards sustainability.

The possible underlying causal relationship between energy efficiency improvements, credit risk and asset value is complex. The chart below provides a simplified description of the causal relations and served as a point of departure for developing a common understanding in the WG.

[13] International Finance Corporation (IFC). 2019. "Green Buildings: Finance and Policy Blueprint for emerging markets." Retrieved January 6, 2020 (https://www.ifc.org/wps/wcm/connect/topics_ext_content/ifc_external_corporate_site/climate+business/resources/green+buildings+report)

Figure 0-6 Casual chain



Source: EEFIG Working Groups, "Are green loans less risky?" (2021)[14]

The analytical approach to be used by the WG was identified together research partners and the national hubs. It became clear that, in order to develop the quantitative relationships between energy efficiency improvements and lower credit risk of associated loans, we must understand and addresses the following key research questions:

- To what extent is asset energy performance correlated with credit risk (e.g. defaults and loan arrears)?
- How does this vary by observed factors such as asset owner income or employment/ business status and wider macroeconomic conditions?
- How does this vary within the different EU Member States?
- Is there evidence of a causal link between improved asset energy performance and improved credit risk?

In academic literature a range of modelling frameworks are documented such as survival analysis and hazard models, or maximum-likelihood models, including the multinomial logit, which seek to estimate e.g. the probability of default, conditional on the loan surviving to date as a function of observed characteristics. However, it should be noted that the financial institutions themselves are at the cutting-edge of methodological developments to analyse the quantitative relationship between risk factors and credit risk parameters – namely in the form of "rating systems". In setting up such systems the main goal is to find suitable risk factors which allow for risk differentiation between different investments and / or counterparties. While the probability of default (PD) provides an estimate of

[14] NBS, 2021: https://hypo.org/app/uploads/sites/3/2021/03/BAUHAUS-4_NationwideBuildingSociety.pdf

the likelihood that a financial borrower is not going to meet its financial obligation in time, the loss given default (LGD) provides an estimate of how much of the outstanding exposure will be lost to the lender in the event of default.

With the Basel II reforms financial institutions have been able to utilise such rating systems also for calculating their regulatory capital requirements — subject to regulatory approval — in form of risk-weighted assets (RWA). Corresponding approaches are known as internal ratings-based (IRB) approaches. For many banks the implementation of such IRB approaches has proved advantageous due to a resulting increased risk sensitivity and hence capital requirements that better reflect underlying risk. As such corresponding approaches are widely used across financial institutions and underlying methods are well established and understood and have been refined over many years.

The robustness of any analysis will also be greatly improved if the data is longitudinal rather than cross-sectional (i.e. having information on borrowers over time rather than a single snapshot at a given point in time, e.g. 5 years of data is considered a minimum for IRB-level evidence). This will also impact the choice of statistical method and approach. We also believe that given low default rates there maybe (subject to data) arrears and other pre-default signals such as rating migrations in the data which can be useful to investigate.

When trying to establish a universal statement on the relationship between energy efficiency risk factors and credit risk it was important for the WG to aim to include institutions who were able to perform analysis on various asset segmentations. One of the most important segmentation criteria is obviously the differentiation between those investments where creditworthiness depends on the (natural or legal) person and those where creditworthiness is predominantly driven by the cash-flows generated by the investment itself. Identifying this mechanism correctly is crucial for any analysis as well as policy prescription.

WG approach

Following an in-depth outreach process, the WG Secretariat received expressions of interest from 50 EEFIG member candidates wanting to join this WG. Out of those 38 candidates were selected based upon pre-agreed eligibility and balance criteria and invited to participate. They represent three types of EEFIG stakeholder:

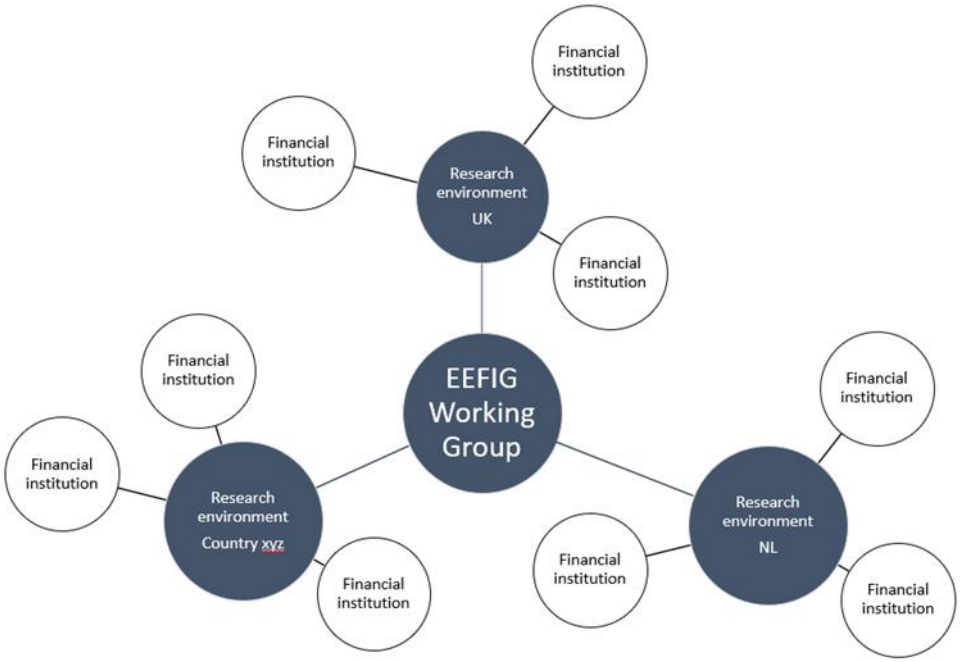
- Financial institutions (e.g. retail banks and asset managers) with access to data on defaults and arrears on assets with energy performance data available, and the aggregators of this financial data, such as Global Credit Data (GCD) or the European Data Warehouse (EDW);
- Research institutions and statisticians who can conduct or lead on the undertaking of research at national level on this (or other) data; and

- Representatives from regulatory bodies, technical bodies and policymakers.

Since that start of the WG, 30 additional observers were invited to present to and watch the WG's work. These include some of the unsuccessful candidates as well as WG guest regulatory speakers (including EBA, Bank of England and BaFin).

A key execution task for the WG was to identify and connect the various research organisations with "networks of banks" to move together and to accelerate the expansion of retail lending for energy-efficient homes and renovations through robust analysis, sector engagement and policy dialogue. Working together, the members of the WG identified relevant research papers and groups with the aim uncover, at the entity and asset-level, how to use green lending to improve the environmental performance of buildings. This exercise was designed as a hub-and-spoke approach, pooling relevant stakeholders into national groups, as illustrated in the chart below.

Figure 0-7 Hub-and-Spoke approach



A methods sub-group ran concurrently with the seven national hubs. Along with other activities, the methods sub-group set out to develop proxies, and robust statistical methods, for estimating the energy performance or energy consumption of buildings and thereby to provide a significant alternative for performing the required analysis of the relationship between energy efficiency and credit risk where Energy Performance Certificate (EPC) data is not available.

More specifically, the methods subgroup considered the following approaches for developing and applying proxy models for energy efficiency:

1 Benchmarking – compare measures of credit risk:

- At building attribute level – age, size, occupancy
- At industry sector level – compare sector level credit performance with sector level average energy consumption intensity

2 Using company accounts/current account data

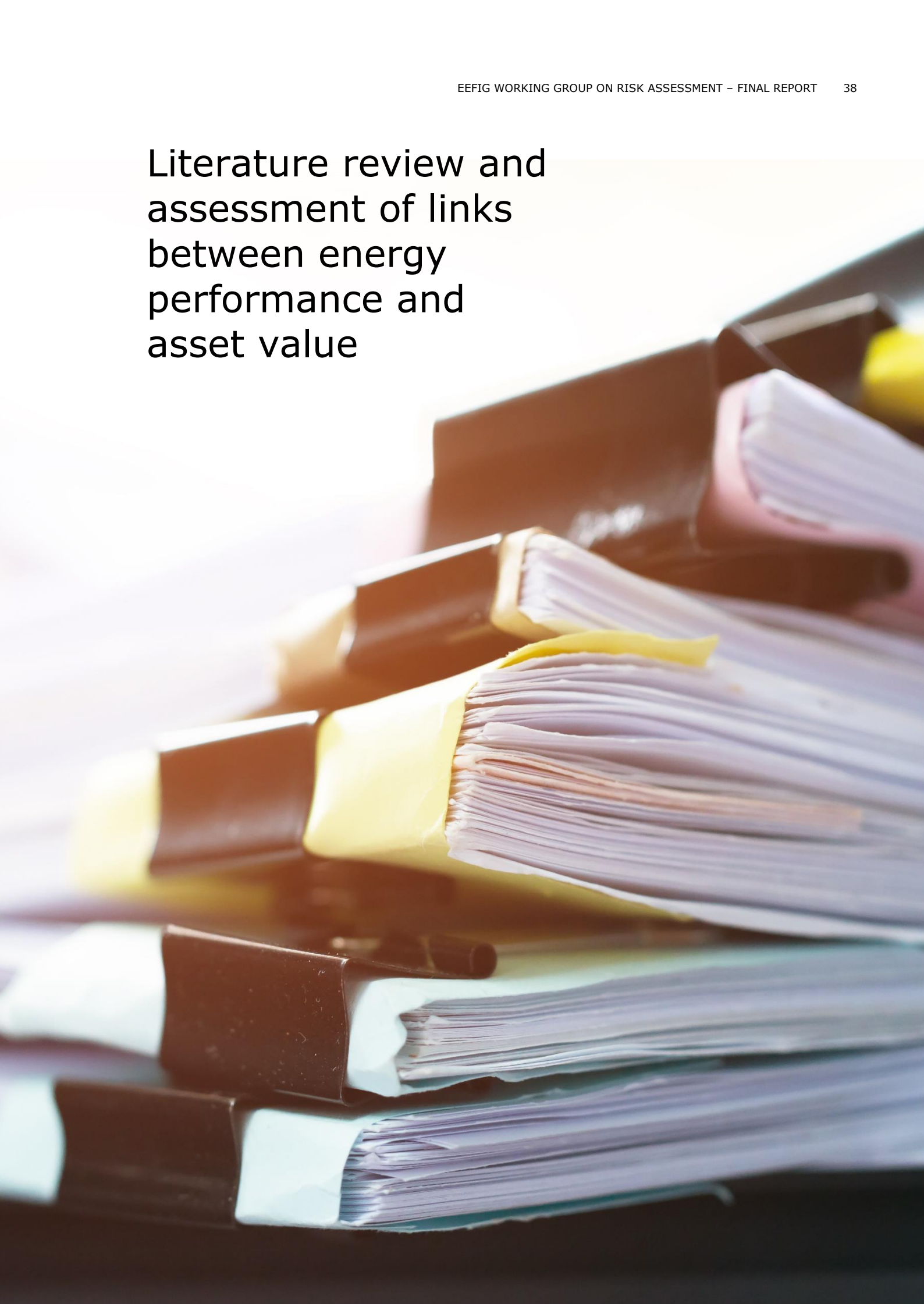
- Linking customer current account data with loan data - examining the relationship between energy costs and credit performance
- Link firm-level energy costs or investments in energy efficiency measures with credit performance.

The methods sub-group also developed proxies for energy consumption based on key determinants from the literature (size, occupancy etc.).

The timeline and key milestones for this EEFIG WG are shown in Appendix G[15].

[15] Note that part of Appendix G is attached as a separate file due to size

Literature review and assessment of links between energy performance and asset value



2 Literature review and assessment of links between energy performance and asset value

This chapter provides an overview of the most updated literature and reports identified by the WG and is backed with examples and evidence. This builds on existing EEFIG knowledge and many submissions that are documented in the WG interim reports, and it has benefitted from additional submissions from all WG members requested by the consortium in all relevant meetings and webinars. The current status of the knowledge base for the WG is a total of 82 documents provided by members and the research of consortium. A complete list of documents and classifying details is found in Appendix E. We assemble and comment on the evidence on the following:

- Evidence or analysis undertaken on the quantitative relationships between energy efficiency improvements and lower credit risk in associated loans. This has the potential to unlock benefits for borrowers, lenders and investors alike, thus mobilising additional investments in energy efficiency in Europe.

- Evidence or analysis undertaken on the quantitative relationships between energy efficiency improvements and the financial performance of assets. This includes asset values and rental income for residential and commercial properties. It is essential for assessing the opportunities that exist for borrowers and lenders alike

- Analyses or studies designed to assess a correlation between energy efficiency, sustainable components / ESG and credit risk. These may also help shape future banking regulatory considerations for energy efficient and related assets.

Section 2.1 presents the WG view on the current state of the literature, main findings and knowledge gaps for each of the three topics listed above. Following this overview, Section 2.2 presents a detailed overview of recent initiatives in this area. Appendix B provides details on methods used by the WG to identify and categorise knowledge, along with information on the shared WG knowledge library.

2.1 Current state of knowledge

The following section contains the working group's conclusions and assessment of the existing research relevant to the subject. It has been subdivided into a series of three succinct conclusions on each of the component parts than then provides a deeper dive describing some of the key papers reviewed from over 80 in the database.

2.1.1 Energy efficiency and credit risk

Since 2009 a number of studies have been conducted into the relationship between energy efficiency and credit risk. The focus has primarily been on residential mortgages, but some studies of commercial mortgages have also been undertaken. Organisations conducting analysis have included the Energy Efficiency Mortgage Initiative (EEMI), the Energy efficiency Data Protocol and Portal (EeDaPP), the European Mortgage Federation (EMF) and the European Covered Bond Council (ECBC), the Bank of England (BoE), the European Commission Joint Research Centre (JRC), the Sustainable Architecture for Finance in Europe (SAFE) and multiple academics across the EU and in the USA.

The WG would summarise the current state of knowledge as follows:

- Results largely suggest a negative relationship between energy efficiency and probability of default (PD);
- The degree of energy efficiency matters i.e., more energy efficient buildings are associated with relatively lower risk of default;
- Mortgages associated with high and medium energy efficiency properties are in the region of 20% less likely to default than those associated with low energy efficiency properties;
- While the evidence identifies a statistically significant correlation, more work needs to be done to identify causality, i.e. what is the exact mechanism driving the observed correlation?
- Methods have typically used Logistic regression and Survival Analysis but up to now have not attempted to integrate energy efficiency as a risk factor into an IRB model, the regulatory standard for assessing capital requirements in basically all large banks in Europe;
- Therefore, by taking an IRB approach, the new analysis presented by WG has taken a significant step-forward in the quantitative assessment of energy efficiency and credit risk;

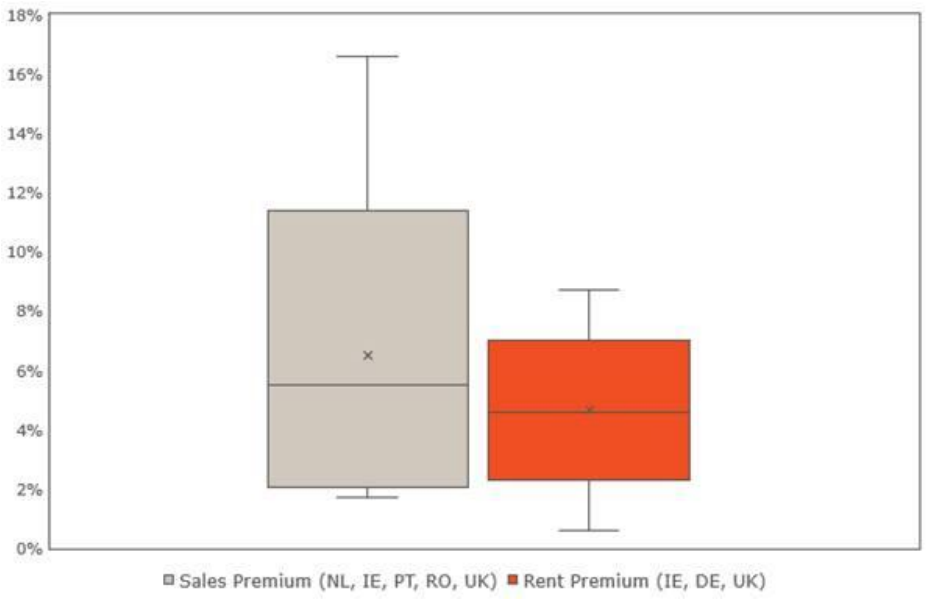
2.1.2 Energy efficiency and the financial performance of assets – the "green premium"

The literature on green premium in real estate is well developed and the WG has identified over 30 studies in the past decade or so. Studies have included analyses of capital and/or rental values and energy efficiency in the owner-occupied, private rented, social housing and commercial sectors. The majority of the evidence reviewed has been undertaken by academics. A couple of key review papers conducted by Maastricht University (as part of the EU-funded REVALUE project) and Wilkinson and Sayce (2020) review the academic literature and a number of EU and UK case studies. We collate all of this evidence below and add a number of additional pieces including recent analysis from WG member Nationwide Building Society, along with other work from Dodge Data & Analytics for the US Green Building Council and related work from PwC and the Hungarian Central Bank. The WG would summarise the current state of knowledge as follows:

- Most of the quantitative studies find that higher energy efficiency (as per EPCs or their international equivalents) has an upward influence on the overall housing market prices and rental values;
- In addition to a "green premium", evidence also exists of a "brown discount" for low energy efficiency buildings;
- However, the evidence is variable and effect sizes depend on the level of energy efficiency and other factors including geography and prevailing housing market conditions;
- The most efficient properties can attract a price premium of up to 10% for valuations and approximately 5% for rentals, compared to the least efficient or non-rated properties;
- Methods have typically used Hedonic regression models, often with a spatial component to control for geographically correlated unobserved factors;
- The analysis in a number of these studies is limited by the fact that energy efficiency may be correlated with unobserved quality variables such as the appearance or design of a property. More robust research designs include quasi-experimental methods such as Hyland et al. (2014) and methods which use the "repeat-sales" approach such as Fuerst el al. (2015) which restrict analysis to samples consisting of at least two sales of the same dwelling at different points in time, thereby getting closer to a causal estimate.

Specifically for Europe, the review of the literature on green premium in real estate included national studies from several countries (NL, IE, DE, FR, PT, RO, UK) which showed that higher energy efficiency (as per EPC rating) has an upward influence on the overall housing market prices and rental values. This is illustrated in the chart below.

Figure 0-8 Studies on green premium in real estate in Europe[16]



The studies hence indicate that the most efficient properties can attract a price premium of up to 10% for valuations and approximately 5% for rentals, compared to the least efficient or non-rated properties. Several studies furthermore find less liquidity for the lowest rated buildings.

The literature review which includes several more recent studies (2019-2020) hence confirms the JRC 2018 findings of an observed increase of 3-8% in the sale price of residential assets resulting from energy efficiency improvements, as well as an increase of around 3-5% in residential rents compared to similar properties.

2.1.3 Asset performance and Environmental, Social, and Governance (ESG) effects

In our efforts to comprehensively review all relevant material, the WG have also assessed the wider impacts of ESG effects on asset performance. While not strictly with the scope of SR08, this material provides informative context on factors related to energy performance, risk and asset values.

Studies include topics such as the impacts of overall ESG and climate-related environmental performance impacts on financial performance of corporate bonds, unsecured and infrastructure finance, the energy performance of commercial real-estate and ESG and credit risk. Due to the

[16] Sources: Estimates retrieved from Brounen (2011), Hyland et al. (2013), Fuerst et al. (2015), Chegut (2016), Aydin et al. (2020), Nationwide Building Society (2020), Evangelista et al. (2019), Taltavull et al. (2020), Cajias et al. (2016) and Fuerst et al. (2016; 2020)
The Y-axis is the percentage premium for EPC (A/B/C) over EPC (E/F). The Box charts show the range of estimates (lowest value, typical values, mean value and highest value).

diversity of topics reviewed here we do not attempt to summarise but rather present some highlights:

- Green use-of-proceeds project finance bank loans experienced a lower default rate than non-green project loans in infrastructure and power sectors (Moody's Investor Services, 2018);
- On average, commercial real estate's energy use decreased by 8 percent after obtaining the environmental building certification, with a significant variation in total reduction based on certification level, program and green label tenure (Eichholtz et al., 2019);
- Drawing from more than 2000 empirical studies, Friede et al. (2015) conclude that 90% of studies found a non-negative relation between ESG and corporate financial performance, with the large majority of studies reporting a positive ESG impact;
- A Barclay's research team assessment of the relationship between ESG and financial performance of corporate bonds finds that a positive tilt towards ESG factors results in a slow but steady improvement in bond performance, with the highest impact relating to Governance and the lowest to Social (Barclay's, 2017);
- Credit Benchmarks (2019) find over a half of the high ESG score companies are in category A, with only 7% are non-investment-grade. Most of low ESG score companies are in category BBB with 20% in non-investment-grade. There were no low ESG companies in the AAA category, and no B or C category among the high ESG companies;
- Finally, analysis by Jones Lang LaSalle (JLL) (2020) find that sustainable buildings in central London have a rental premium in range of 6% and 11%, and exhibit lower vacancy rates after both 12 and 24 months.

2.2 Summary of relevant knowledge and initiatives

This section provides a deeper dive into some of the key papers and reports which were identified, presented and discussed by EEFIG working group members in framing their conclusions.

2.2.1 Energy efficiency and credit risk

EeMAP and EeDaPP

EeMAP (Energy Efficient Mortgage Action Plan) is a market-led initiative focusing on design and delivery of an "energy efficient mortgage" to incentivise private capital into energy efficiency completed in February 2018. The initiative is run by Energy Efficiency Mortgage Initiative (EEMI), bringing together 47 key lending institutions, 17 national, European and International authorities and a multitude of other market stakeholders and

funded by the Horizon 2020. Under the initiative, a number of technical reports and support material for standardisation, launch and assessment of the energy efficiency mortgages were published.

The initiative notably produced a "Review of The Impact of Energy Efficiency on Probability of Default"[17] in October 2017, reviewing academic literature on this subject at that time. The report found that only three studies prior to 2017 attempted to measure the direct impact of energy efficiency on mortgage default risk and that all three of these studies were conducted using housing data in the United States (one looking at residential mortgage data and two investigating commercial buildings). It concluded that all three studies find evidence of a significant reduction in default risk associated with energy efficiency and that this effect is larger for more efficient homes and hence not only the energy efficiency label alone but also the degree of efficiency plays a substantial role.

The report was later elaborated on by "Final correlation between energy efficiency and default rate"[18], in 2019, presenting results of empirical and econometric studies on link between credit risk and energy performance of buildings that were used as collateral in both, commercial and residential mortgages. This report suggested that there is a link between the energy performance of buildings and credit default risk regardless of whether energy efficiency is captured via individual energy performance labels or proxies (e.g. property types and construction years). Several of the countries investigated indicated a negative correlation between energy performance and risk, meaning that, all else being equal and controlled for, energy efficient mortgages and loans appear to be less risky than their non-energy efficient counterparts.

Table 0-2 below summarises these main results, pointing to the negative correlation. However, it also identifies challenges of comparability, data access and limitations of methodologies based on a one-time observation of narrowly defined market data and segments.

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[17] EeMAP. 2017. "Creating an energy efficient mortgage for Europe. Review of The Impact of Energy Efficiency on Probability of Default." Retrieved January 6, 2020 (http://eemap.energyefficientmortgages.eu/wp-content/uploads/2018/04/EeMAP-Technical-Report-on-the-Impact-of-Energy-Efficiency-on-Probability-of-default.pdf.)

[18] EeMAP. 11. 6. 2019. "D5.4: Final correlation between energy efficiency and default rate". Retrieved January 6, 2020 (https://eemap.energyefficientmortgages.eu/wp-content/uploads/EeMAP_D5.4_EMF-ECBC.pdf)

Table 0-2 Results of studies on credit risk and energy performance (2019)

COUNTRY	SCOPE	CORRELATION	ENERGY PERFORMANCE CRITERIA	DATA SOURCE
BE	Residential	Negative– mortgages on energy efficiency properties correlated with lower risk	Loan eligibility for 2009-11 Government retrofitting program	Proprietary bank data on loan type and origination date
DE	Residential	Inconclusive due to absence of default data in the sample	Municipality and year of introduction of the "Passive House Standard"	Construction year and zip code information
IT	Residential	Inconclusive – not possible to merge building-level data with loan-level data due to data privacy issues	Government energy efficiency financing programme (dummy variable)	Italian Energy Agency data, anonymised loan-level information
NE	Residential	Negative– mortgages on energy efficiency properties correlated with lower risk	EPC ratings	RVO Energy Agency
UK	Residential	Negative– the share of borrowers in mortgage arrears is significantly lower for energy efficiency properties.	EPC rating (score divided in terciles1 for a "best in class" indicator)	EHL; DCLC
US	Residential, Commercial	Negative – ENERGY STAR-commercial buildings are 20% less likely to default than non-labelled counterparts.	Green building Certifications & labels (LEED, ENERGY STAR, BREEAM, HQE)	Loan level information, Energy Star and Credit score ratings

In March 2018, the EeDaPP (Energy efficiency Data Protocol and Portal) initiative was launched with the aim to design and deliver a market-led protocol to enable the recording of data relating to energy efficient mortgage assets and which will be made accessible via the design of a common data portal.

Following the above, in 2020, a final report was submitted by EeDaPP on "Correlation analysis between energy efficiency and risk"[19].**The report's econometric analysis demonstrates a negative correlation between energy efficiency and the owners' probability of default (PD), and confirms that energy efficiency investments improve owners'/borrowers' solvency**. Moreover, 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. These findings highlight the role of energy efficiency in reducing the default probability of a borrower.

Table 0-3 below summarises these main results from three mortgage datasets from Belgium, Italy and Portugal. The Belgian and the Portuguese data comes from two banks that are operating in the respective countries. The Italian data was provided by CRIF[20]. The econometric evaluation provided in the report focuses only on the specific case of Italy.

Table 0-3 Results of correlation between energy efficiency and risk (2020)

COUNTRY	CONCLUSION
IT	The proportion of more energy efficient mortgages has been increasing over the last decade, while less efficient properties show higher levels of default. In terms of EPC ratings, the most significant share of Italian mortgages are properties with EPCs above the C rating level, which are also those with higher defaults. The results indicate a negative and significant correlation between the two variables of interest: buildings' energy efficiency and the probability of mortgage default.
BE and PT	Given the relatively young loans in both portfolios and, consequently, very few defaults, those loans identified by EeMAP banks in the two countries are not usable to perform a correlation analysis, at this stage.

The European Mortgage Federation (EMF) and the European Covered Bond Council (ECBC) launched a pilot scheme in June 2018 to develop an "energy efficient mortgage"[21] with over 40 lending institutions, supporting organisations and an Advisory Council. The aim was to design and launch a

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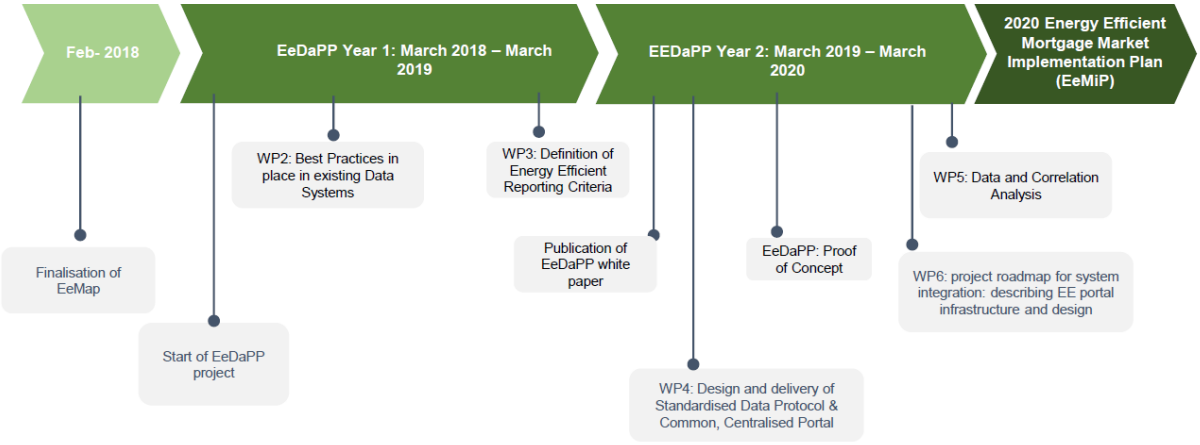
[19] *EeDaPP. 26.09.2020 "D5.7: Final report on correlation analysis between energy efficiency and risk". Retrieved September 6, 2020 (https://eemap.energyefficientmortgages.eu/wp-content/uploads/EeDaPP_D57_27Aug20.pdf)*

[20] *CRIF is a global company specializing in credit bureau and business information, outsourcing and processing services, and credit solutions established in 1988 in Bologna (Italy). More than 6,300 banks and financial institutions, 55,000 business clients and 310,000 consumers use CRIF services in 50 countries on a daily basis.*

[21] *An energy efficient mortgage is defined as "intended to finance the purchase/ construction and/or renovation of both residential and commercial buildings where there is evidence of: (1) energy performance which meets or exceeds relevant market best practice standards in line with current EU legislative requirements and/or (2) an improvement in energy performance of at least 30%". EEMI. 2019. "Definition of an energy efficient mortgage". Retrieved January 6, 2020. (http://eemap.energyefficientmortgages.eu/eem-definition/)*

specific product offering cheaper interest rates to people buying energy efficient homes or committing to implement energy saving measures, working along three main work streams: (i) Product e.g. a common Energy efficiency mort-gage definition was announced in 2018; (ii) Data i.e. EeDaPP; and (iii) Partnerships i.e. Advisory Council solutions and institutional support and development of EIB/EeMAP financing scheme. The key milestones delivered are summarised below:

Figure 0-9 Key milestones (EeDaPP)



Source: EeDaPP, 2019[22]

Green tagging and asset-level transparency

Initially published in December 2017, a report entitled "Mobilising Bank Finance For Energy Efficiency In Real Estate"[23] catalogues the progress of 10 European banks: ABN AMRO, BBVA, Berlin Hyp, HSBC, ING, Lloyds, SEB, Suedtiroler Volksbank, Triodos and UniCredit who came together to identify, analyse and promote green finance for housing and real estate through the direct attribution of environmental characteristics in their lending and debt capital markets operations. Climate Strategy and the UN Environment Inquiry into the Design of a Sustainable Financial System worked with UNEP FI and EMF-ECBC and these banks to better understand and document how Green Tagging could Drive Energy Efficiency Investments and scale up financing of energy-efficient housing and real estate.

Green tagging refers to a systematic process where banks identify the environmental attributes of their loans and underlying asset collateral as a tool for scaling up green finance. It allows for easier access to green bond markets, better tracking of green loan performance and provides

[22] *Energy Efficient Mortgage Initiative. 2019. "EeDaPP & EeMAP". Retrieved January 6, 2020 (https://www.efbs.org/wp-content/uploads/2019/10/Session2-4-Mahieu.pdf)*

[23] *Nick Robins and Peter Sweatman. December 2017. "Mobilising Bank Finance For Energy Efficiency In Real Estate." UNEP Inquiry and Climate Strategy & Partners. Retrieved January 6, 2020 (https://unepinquiry.org/publication/green-tagging-mobilising-bank-finance-for-energy-efficiency-in-real-estate/)*

transparency of climate risks and portfolio resilience. The growth in green tagging is driven by a number of factors:

3 Policy priority: The EU policy and agenda is a key driver in the form of the Capital Markets Union reform agenda and the implementation of Commissions Action Plan on Sustainable Finance, and more recently the Green Deal places a strong emphasis on energy efficiency in buildings is the area where there is the greatest in-vestment gap to deliver Europe's climate goals.

4 Financial innovation: Banks are designing a new range of green finance products in terms of lending and in debt capital markets and securitisation.

5 Market disclosure: Initiatives such as the FSB's Task Force on Climate-related Financial Disclosures (TCFD) are prompting banks to become more focused on quantitative reporting on green finance. In addition, the EU-wide classification system for sustainable investments now provides a reference taxonomy for green activities.

6 Financial regulation: The EC's review of the European Supervisory Authorities concluded that the ESAs should now "promote sustainable finance, while ensuring financial stability". Sustainability derived from the EU taxonomy will become a core part of the new securitisation framework and is likely to be taken forward by national regulators in France, Italy, Netherlands, Sweden and the UK.

Within this work the ten banks underlined the following two final conclusions:

- There is a strong case for connecting green tagging with links between sustainability factors and prudential regulation as inherent risks of non-green assets is not yet a leading driver for banks to implement green tagging;
- Financial institutions want to continue to investigate correlations between financial performances in mortgage portfolios with energy performance.

Partially as a result of this innovative study, EEFIG launched a specific WG to study and follow the progress of tagging in the context of the development of the EU's sustainable finance taxonomy. This WG published a final report in August 2020 which concluded the following:

- Account for actual rather than calculated energy consumption in existing buildings (The EU Smart Readiness Indicator can help to bring added value on the real energy consumption of residential buildings)
- For renovation of existing buildings, and new buildings, an absolute energy metric in KWh/sq.m/y was preferred over carbon (and aligned with national legislation) but should be complemented with a relative

reduction requirement (e.g. 30% - 50% depending on the country or type of building)

- The majority of respondents did not agree with the proposed EU taxonomy thresholds of 50% primary energy savings for renovation of existing buildings but do agree with the thresholds for new builds
- For construction of new buildings, respondents broadly support the use of NZEBs as a basis
- EPCs are a necessary basis for measuring performance of existing buildings despite problems with them. The calculated results of EPCs should be complemented by actual energy consumption data.

During the course of the project the Taxonomy evolved following input from the WG and of course many other stakeholders. Specifically, metrics changed to a percentage of Primary Energy Demand resulting from NZEB requirements from an EPC classification. Similarly, the metric for acquisition and ownership of existing buildings was changed to a requirement to be in the top 15% of the local existing stock in terms of Primary Energy Demand, as opposed to an EPC of B. On the matter of tagging, the EEFIG WG SR01 also concluded:

- Tagging is primarily driven by the need for asset level data – to then obtain portfolio wide information
- Corporate loans are more frequently tagged, followed by residential and then commercial real estate – FIs focus on transactions with the largest ticket sizes first
- EPCs are a useful tool for understanding energy performance, even though energy consumption data is still considered necessary; tagging is usually focussed on jurisdictions with excellent data availability.
- Green tagging is still a manual process and the process is considered very labour intensive by the FIs.

Bank of England UK correlation study

"Does energy efficiency predict mortgage performance?"[24] is the title of a January 2020 analysis by researchers at the Bank of England, Benjamin Guin and Pertttu Korhonen, who assessed the energy efficiency of a property as a potential predictor of mortgage risk.

The study matched loan performance data of residential mortgages in the UK (as of end 2017) with the EPCs of the underlying real estate and the income of the borrower at the time of origination, within a final sample of over 1.8 million observations.

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[24] *Benjamin Guin and Perttu Korhonen. January 2020. "Staff Working Paper No. 852. Does energy efficiency predict mortgage performance?". Retrieved April 7, 2020 (https://www.bankofengland.co.uk/-/media/boe/files/working-paper/2020/does-energy-efficiency-predict-mortgage-performance.pdf)*

The study suggests that mortgages on energy-efficient properties are less frequently in arrears and that the energy efficiency of a property is a relevant predictor of mortgage payment arrears. In general, about 0.93% of residential mortgages on energy-efficient properties are in arrears as compared to 1.14% on energy-inefficient properties (i.e. 0.21% difference – see Figure 0-10 below). The relation remains statistically significant within 99% confidence interval independently of borrowers' income at origination, type of property and year of origination. Therefore, the study suggests the energy efficiency of a property is a relevant predictor of mortgage payment arrears.

Figure 0-10 Share of mortgage in payment arrears by energy efficiency of the property

Energy efficiency	High (1)	Medium (2)	Low (3)	Difference (1)-(2)	Difference (1)-(3)
Arrears	0.0093	0.0100	0.0114	-0.0007***	-0.0021***
	(N=412,704)	(N=893,913)	(N=527,026)	(N=1,306,627)	(N=939,730)

Note: This table shows the share of mortgages in payment arrears in end-2017, Arrears, by energy efficiency ratings (EPC) of the underlying property (in columns (1)-(3)). Arrears is a discrete variable that equals 1 if the mortgage is in payment arrears; 0 otherwise. Columns (4)-(5) test the mean differences. N indicates the number of mortgages. ***, **, * denote statistical significance at the 0.01, 0.05 and 0.10 level respectively.

Source: Benjamin Guin and Perttu Korhonen, 2020

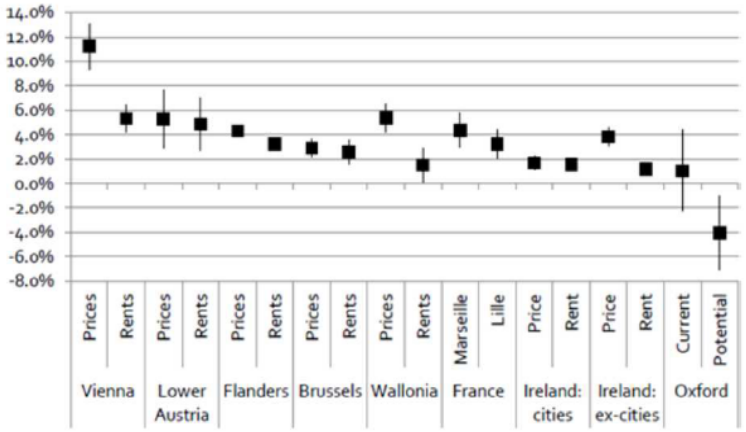
Energy efficiency, value of buildings, and payment default risk

The Joint Research Centre has authored a Science for Policy report on "Energy efficiency, the value of buildings and the payment default risk"[25] in 2018, reviewing the latest knowledge on the impact of energy efficiency on the value of buildings and creditor's default risk. The relation between energy efficiency and value of buildings was assessed based on an extensive review of literature (over 50 studies) and applicable methodologies. The main observations are as follows:

- Residential buildings: on average 3 - 8 % increase in asset price and 3-5% in rent as a result of energy efficiency improvements.
- Commercial buildings: on average ~10 % increase in asset price and 2-5% in rent as a result of energy efficiency improvements.
- There is a significant variation between types of properties, geographies and time, as the different labels are becoming more well-known.
- Besides the energy savings, the energy efficiency measures often result in multiple benefits in terms of comfort, safety, maintenance etc. that affect the asset value.

[25] *Joint Research Centre. 2018. "JRC Science For Policy Report: Energy efficiency, the value of buildings and the payment default risk." Retrieved January 6, 2020 (https://publications.jrc.ec.europa.eu/repository/bitstream/JRC113215/jrc113215_kjna29471enn_v2_ipo_final.pdf)*

Figure 0-11 Impact of one-letter improvement in the EPC label category on the transaction price and rental prices in selected regions of the EU



Source: Mudgal, Lyons, Cohen, Lyons, & Fedrigo-Fazio (2013) in Brocklehurst (2017). Note: "Oxford potential" is a category created by the authors based on (Killip, 2011) meaning the EPC category the building could receive were it renovated, as opposed to the EPC label it fits into in the current state. Ex-cities in Ireland means non-urban areas.

In line with this, the link between energy efficiency and default risk was found to be evidenced only to a limited extent i.e. within three US-focused studies, out of which only one was on residential sector. The other two studies documented higher return on assets and equity (ROA, ROE) for a Real Estate Investment Trust with larger share of commercial buildings with higher energy and environmental performance as well as negative relationship between the environmental performance and systematic risk.

Home energy efficiency and mortgage risks

The research report "Home Energy Efficiency and Mortgage Risks"[26] by Institute for Market Transformation published in 2013 is among the most referenced papers on energy efficiency and default risk. It was one of the first extensive research pieces on this topic having identified a significant and large negative correlation between energy certification and mortgage default risk.

Based on a study of 71,000 single-family home mortgages in 37 US states over a decade through a competing default and prepayment risk framework, the following key findings were made:

- Default rates on ENERGY-Star rated homes are on average 32% lower than in non-rated homes, controlling for other loan determinants, household, and neighbourhood characteristics.
- Within ENERGY STAR-rated residences, the default risk is lower for more energy-efficient homes.

[26] *Institute for Market Transformation. March 2013. "Home Energy Efficiency and Mortgage Risks". Retrieved January 6, 2020 (https://www.imt.org/wp-content/uploads/2018/02/IMT_UNC_HomeEEMortgageRisksfinal.pdf)*

- The mortgage prepayment risk for an ENERGY STAR home is 25% lower than in non-rated home.

Building's energy efficiency and the probably of mortgage default (Dutch case)

The Sustainable Architecture for Finance in Europe (SAFE), in cooperation with the Goethe University (Frankfurt) published a working paper in October 2019 on "Buildings' Energy Efficiency and the Probability of Mortgage Default: The Dutch Case"[27]. The report focuses on investigating the relation between buildings' energy efficiency and the probability of mortgage default. To this end, a dataset was constructed combining Dutch loan-level mortgage information with provisional building energy ratings as provided by the Netherlands Enterprise Agency. The study followed the logistic regression and the extended Cox model and concluded that:

- Buildings' energy efficiency is associated with lower likelihood of mortgage default; and
- Energy efficiency provides a further mitigation of default risk for borrowers with a lower income potentially because of the savings coming from lower utility bills, which have a major impact on the borrower with less disposable income.

2.2.2 Energy efficiency and the financial performance of assets – the "green premium"

The following section provides an overview of the more widely researched topic of "green premium" for higher energy performing buildings, which – at the time of this report, and as listed – has over 30 reports having been identified and read by members of the WG. The following is a summary of the key reports and a listing of the others:

Recent analysis by SR08 WG member Nationwide Building Societ

As part of their monthly "House Price Index" Special Reports, Nationwide Building Society recently conducted an analysis into the impact of energy efficiency, as measured by EPC, on house prices in the UK[28]. Compared to a D-rated home, NBS find evidence for a 1.7% premium for A/B and a 3.5% discount for F/G. The report also highlights that social housing is more efficient than the private-rented sector and identifies some differences between those who own outright (less efficient) compared to those with a mortgage (more efficient). The report also the decline in the pace of improvements corresponds with reduced government support and suggests incentive need to increase in order to achieve climate objectives.

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[27] *SAFE Working Paper No. 261. 14.10.2019. "Buildings' Energy Efficiency and the Probability of Mortgage Default: The Dutch Case". Retrieved November 10, 2020 (https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3601723)*

[28] *https://www.nationwidehousepriceindex.co.uk/reports/energy-efficiency-ratings-currently-having-limited-impact-on-house-prices-despite-push-to-go-green*

Energy performance and valuation of social housin

"Energy Performance and Valuation of Social housing in Europe"[29]: a quantitative study by Maastricht University (Feb 2018) funded by Horizon 2020 programme analyses the relation between the energy efficiency and property valuation in social housing across several European countries.

The study first reviews the available international academic literature on the topic with a focus on 16 studies listed in Table 0-4 below. The main findings are as follows:

- Most of the quantitative studies find that higher energy efficiency (as per EPCs or their international equivalents) has an upward influence on the overall housing market prices;
- The extent of the effect depends on the levels of energy efficiency and other factors including geography and market conditions.

Supplementing the above-mentioned findings, the following tables present a number of relevant empirical studies on the value of energy-efficiency in the residential market:

- Table 0-4 lists the 16 studies included in the Exhibit of the paper mentioned above. These initial 16 studies are supplemented with other literature, as based on desk research by the WG and consortium.
- Table 0-5 presents studies on the relationship between capital and/or rental values and energy efficiency in the owner-occupied, private rented and social housing sectors, based on desk research.

[29] *Revalue. 1.2.2018. "Energy Performance and Valuation of Social housing in Europe: a quantitative analysis." Retrieved January 6, 2020 (https://revalue-project.eu/wp-content/uploads/2019/08/D3.3-Regression-Analysis.pdf)*

Table 0-4 Exhibit: Empirical Studies on the Value of Energy-efficiency in the Residential Market[30]

STUDY (YEAR)	COUNTRY	TRANSACTION TYPE	ENERGY-EFFICIENCY MEASUREMENT	FINDINGS	NOTES
Brounen (2011)	NE	Sales	EPC	+15 for a G to A label jump. Low label implies less liquidity	Dwellings with high-quality energy label, C and above, trade at premium
Deng (2012)	Singapore	Sales	Green Mark certification	+4-6 for certified buildings	Transaction premium varies with quality of label
Yoshida, Sugiura (2012)	Japan	Sales	Tokyo Green Building Program certification	-12 for certified buildings	Initially green apartments sell at a discount; slower depreciation rate leads to a premium
Zheng et al. (2012)	China	Sales	"Marketing greenness" (Google Green Index)	+17.7 for the greenest dwelling	Properties marketed as green sell at a premium, but resell and re-rent at a discount
Dastrup (2012)	US	Sales	Solar panels	+3.5-4 for homes with solar	Premium higher in streets where less homes have solar PV
Hyland et al. (2013)	Ireland	Sales, rents	Building Energy Ratings	+16.6 in price, +4.6 in rent for label G to A	The impact of a Building Energy Rating is stronger when selling conditions deteriorate
Feige et al. (2013)	Switzerland	Rents	Sustainability features	- 2.9 for a +0.1 in the energy efficiency rating	All sustainability features except energy efficiency positively related to rent levels
Kahn and Kok (2013)	US	Sales	Energy Star, LEED GreenPoint	+2-4 for certified buildings	Certification matters more in hotter climates and in areas with higher energy prices
Cerin et al. (2014)	SE	Sales	Electricity use per m2	+0.03 for -1 in consumption	Only the most energy-efficient homes benefit from a slight transaction premium
Hu et al. (2014)	China	Sales	Willingness to pay Conjoint analysis	Willing to pay up to 1139 yuan/m2 for efficient homes	Results based on survey data, mainly driven by upper class individuals

[30] *Paper Revalue. 1.2.2018. "Energy Performance and Valuation of Social housing in Europe: a quantitative analysis." Retrieved January 6, 2020 (https://revalue-project.eu/wp-content/uploads/2019/08/D3.3-Regression-Analysis.pdf)*

Fuerst et al. (2015)	England	Sales	EPC	+5 for a A/B, +1.8 for C label, −0.7, −0.9 for E, F	Energy premium highest for terraced dwellings and flats
Chegut (2016)	NE	Sales	EPC	+2-6 for label A and B	Label effects plus renovation effects up to 26
Cajias et al. (2016)	DE	Rents	EPC	+0.6-4 for label A to C. Low label implies less liquidity	The premium not confirmed for the largest metropolitan markets
Zhang et al. (2016)	China	Sales	EPC	+ 6.9 for certified dwellings	Analysis based on newly built housing projects
Bond, Devine(2016)	US	Rents	LEED certificate	+7-9 for certified buildings	Sample consists of multi-family dwellings. LEED premiums in both urban and rural areas
Chegut, A., Eichholtz, P., Holtermans, R., Palacios, J. (2020)[31]	NE	Rents	EPC	England: energy performance does not impact assessed values in 2012. For 2015, there is a significant discount in assessed values for D-, E- and F- relative to C-labelled dwellings. For the Netherlands, no significant relationship between energy efficiency and assessed values in 2010. In 2015, found that more energy efficiency leads to higher external valuations.	Two large samples of external valuations of individual dwellings, owned by one English (conducted in two waves being, 2012 and 2015) and one Dutch affordable housing provider 9conducted in two waves, 2010 and 2015).
Holtermans, H., Kok, N. (2017)[32]	US	Rents	Environmental certification	40% of space in the 30 largest U.S. commercial real estate markets holds some kind of environmental certification in 2014, as compared to less than 5% in 2005.	The study analyses the adoption and financial outcomes of environmentally certified commercial real estate over time.
Zhang, L., Liu, H., & Wu, J. (2017)[33]	CN	China	Chinese Green Building Label	The labelled housing projects attract a price premium of 6.9% compared with their non-labelled counterparts	Study based on a unique data set of green-labelled, newly built housing projects and their non-labelled counterparts from around the country based on 2013 data.

[31] *Chegut, A., Eichholtz, P., Holtermans, R. et al. (2020). "Energy Efficiency Information and Valuation Practices in Rental Housing". J Real Estate Finan Econ 60, 181–204. Retrieved November 10, 2020. (https://doi.org/10.1007/s11146-019-09720-0)*

[32] *Holtermans R., Kok N. (2017). "On the value of environmental certification in the commercial real estate market. forthcoming Real Estate Economics". Retrieved November 10, 2020. (https://onlinelibrary.wiley.com/doi/abs/10.1111/1540-6229.12223)*

[33] *Zhang, L., Liu, H., & Wu, J. (2017). "The price premium for green-labelled housing: Evidence from China". Urban Studies, 54(15), 3524–3541.*

Aydun, E., Kok, N., Brounen, DK. (2017)[34]	NL	Sales, rents	Analysis of energy efficiency improvement programs	The results show a rebound effect of 26.7% among homeowners, and 41.3% among tenants.	Sample of 563,000 households in the Netherlands.
Franke, M., Nadler, C. (2019)[35]	DE	Sales, rents	EPC	The EPC is no longer of minor importance in residential real estate decision-making. The influence of energy efficiency is analysed by a direct and an indirect (CBC) method. The role of the EPC can be further strengthened by implementing a financial indicator.	The paper analysed survey responses of 206 participants (108 tenants, 98 owners), which had been collected between May and July 2017. Owners showed to be significantly more familiar with the EPC tool, giving it stronger consideration than tenants do. The results indicate three main policy implications concerning enhanced (i) transparency regulation and its compliance, (ii) environmental awareness, and (iii) communication of economic incentives.
Aydin, E., Brounen, D., Kok, N. (2020)[36]	NL	Sales	EPC	The level of energy efficiency increases by ten percent, the market value of the dwelling increases by around 2.2 percent.	The paper investigates how private consumers capitalize energy efficiency in the housing market, and the extent to which the provision of an EPC affects such capitalization.
Nationwide Building Society (2020)	UK	Sales	EPC	Compared to a D-rated home, premium of 1.7% for A/B and discount of 3.5% for F/G.	EPC data was included into NBS House Price Index model. Effect of EPC was estimated controlling for other relevant house price determinants.

[34] *Aydin, E., Kok. N., Brounen, D. (2017). "Energy efficiency and household behavior: the rebound effect in the residential sector". Retrieved November 16, 2020. (https://onlinelibrary.wiley.com/doi/abs/10.1111/1756-2171.12190)*

[35] *Franke, M., Nadler, C. (2019). "Energy efficiency in the German residential housing market: Its influence on tenants and owners". Retrieved November 15, 2020. (https://www.sciencedirect.com/science/article/abs/pii/S0301421519300540)*

[36] *Aydin, E., Kok, N., Brounen, B. (2020). "The capitalisation of energy efficiency: Evidence from the housing market". Retrieved November 17, 2020.*

Table 0-5 Recent studies on the relationship between capital and/or rental values and energy efficiency in the owner-occupied, private rented and social housing sectors[37] (identified studies published after 2017)

STUDY (YEAR)	COUNTRY	SAMPLE SIZE	VALUATION (V), PRICE (P), ASKING PRICE (AP)	METHOD	OWNER-OCCUPIED (OO), SOCIAL HOUSING (S), PRIVATE RENTED (PRS)	MAIN FINDINGS
Germany Kholodilin et al. (2017)	Germany	Not stated	AP	Hedonic regression	PRS	Price premiums for investment sales exist based on future expectations, but less so than in the OO market. Explanations are proffered but it is concluded that investors place less emphasis on energy efficiency that do owner occupiers
Cajias et al. (2017)	Germany	570,230	AP	Hedonic regression	PRS	Significant evidence of premium rents general, but less so in major cities where stock is short. Some evidence that time to rent is reduced.
Baumont et al. (2019)	France	2,549	P	Hedonic regression with spatial Durbin Model	OO	Homes Using the Diagnostic de Performance Energetique (DPE) rating, Transactions of apartments and houses in Dijon revealed a low level of green premium of up to 9.75% for highly rated houses but higher levels of discount for worst low rated flats (6.8 to 11.5%) and more so for houses (16.5 to 30%). It is acknowledged that this also relates to age and condition.
Fregonora et al. (2017)	Italy	870		Hedonic regression	OO	Study of older apartments showed that the EPC rating made no real difference to the sales price of the unit.
Evangelista et al.(2019)	Portugal	256,000	P	Hedonic regression and quartile analysis	OO	Sales price premiums of up to 13% for flats and 6% for houses were found for A/B rated buildings during a depressed market period but no real discount for lower grades.
Taltavull et al. (2020)	Romania	16,433	P	Hedonic regression and spatial diffusion	OO	Properties in Bucharest retrofitted to 'green' showed price premiums of between 2.2% and 6.5%
Adan and Fuers; and Fuerst et al. (2016; 2020)	England	Approx. 4,000	P	Hedonic regression	PRS	Houses sold and then let were analysed. Rental premiums of 5.3 (houses) and 8.7% (flats) for A/B over D found but 6% discount for F/G houses with no discount for flats. Further analysis confirmed evidence of a negative relationship between time-on-market and energy efficiency rating

[37] *Based on Exhibit in: Wilkinson, S.J. and Sayce, S. (2020). "Decarbonising real estate: The evolving relationship between energy efficiency and housing in Europe". Journal of European Real Estate Research. Retrieved November 16, 2020 (https://www.emerald.com/insight/content/doi/10.1108/JERER-11-2019-0045/full/html). Additional desk research has been performed. The sources are added in footnotes.*

A regression analysis of valuations of thousands of dwellings owned by large housing associations in the Netherlands, UK, Sweden and Germany with respect to energy efficiency was performed. The relation of the capital and rental value to energy efficiency is studied using a standard hedonic pricing model, accounting for the building's quality, location and local market considerations.

Specifically, the energy efficiency is assessed on the basis of energy use, labels i.e. Energy Performance Certificates (EPC labels, EPC and SAP indexes), energy-related components (e.g. window frames, glazing types), technical characteristics and location of the dwellings. The value of social housing is based on the assessed value by independent valuers rather than market prices as the transactions in social housing segment are not very frequent and valuation is affected by different regulations and rent control. These aspects also limit the representativeness of the results to private sector or owner-occupied buildings.

The main findings per each country case are as summarized in the table below.

Table 0-6 The main findings per country case

	DATA	RESULTS
NE	Data from three valuation firms covering over 40,000 dwellings for 2010 and 2015	Asset value: In 2011, there was no discernible correlation with energy efficiency. In 2015, affordable dwellings with the best energy labels (A, B) had higher values than peers. A-labelled buildings had a premium compared to buildings with no energy labels in line with premiums in the Dutch real estate market and a higher premium as compared to lower-label buildings.
UK	Data on over 150,000 dwellings in different regions of England from three social housing companies	Asset value: the study finds a 'brown discount' in the market, with lower valuations attached to D labelled dwellings compared to C label dwellings. Among the technical specifications, windows had bigger effect on value than any other measure i.e. dwellings without double glazing are discounted. The results are weaker for London likely due to stock shortage and value compression.
SE	Over 7,000 rents and dwelling valuations for 2015 and 2016	Asset value: asset value was higher with high uptake energy efficiency components (triple glazing) and lower energy use (heating costs). Rents: similar patterns with lower magnitude
DE	Data on over 56,000 dwellings provided by a social housing company in Berlin area	Asset value: Energy efficiency was strongly correlated with the level of rents, but not with long term vacancy level of the properties nor the associated maintenance costs. Rents: rents play a significant role in influencing asset value but do not fully reflect total effect of energy efficiency.

Decarbonising real estate: The evolving relationship between energy efficiency and housing in Europe

Supplementing the overview of empirical studies on the value of energy-efficiency in the residential market in prior Table 0-4 and Table 0-5, interesting research was conducted in 2020 on "Decarbonising real estate: the evolving relationship between energy efficiency and housing in Europe"[38]. The paper was submitted to the Journal of European Real Estate Research and aims to gain a deeper understanding of the relationship between energy efficiency and the value of residential property over time as well as to determine whether stronger policies are required in Europe to realise decarbonisation. The paper reviews current academic literature and a selection of case studies of a selection of large-scale consortia projects conducted in Europe (i.e. EU case studies: REVALUE, EeMap and one UK case study: LENDERS). The majority of the research uses hedonic pricing analysis, in order to identify a relationship between EPCs and either capital or rental residential values across Europe. It compares the data to the reported findings of three case study projects that take a variety of different research approaches.

The research generally showed a positive relationship between observed market prices and EPCs, which are commonly taken as surrogates for efficiency. Nevertheless, the outcomes were variable. Whereas one study observed that energy upgrades may increase value, but not to the point where costs outweigh the value gain; other studies observed high returns on investment in energy efficiency technologies.

Generally, the case studies revealed that while there is evidence that energy efficiency is starting to impact the value, it was considered small compared to other value drivers and other drivers, such as health, well-being and private sector finance deals. Moreover, the quantitative evidence pointed to the emergence of a 'green premium' for residential values when prices achieved, or rent achieved, are regressed against EPC data. The studies also pointed to a continued lack of data on which to evidence market movements accurately, but showed the emerging role that finance is likely to play in decision making.

Green buildings survey

A dedicated market report "World Green Building Trends in 2018"[39] further clarifies the effects of energy performance on asset value and their geographic variation. Conducted by Dodge Data & Analytics in partnership with U.S. Green Building Council in 2018, it presents results of a survey of 2,078 architects, engineers, contractors, owners, developers and specialists/consultants from 87 countries on green buildings.

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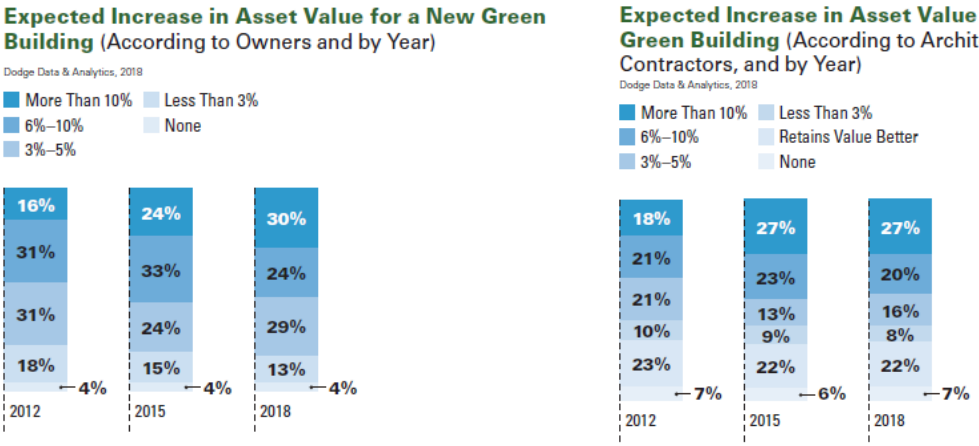
[38] *Wilkinson, S.J. and Sayce, S. (2020). "Decarbonising real estate: The evolving relationship between energy efficiency and housing in Europe", Journal of European Real Estate Research. Retrieved November 16, 2020 (https://www.emerald.com/insight/content/doi/10.1108/JERER-11-2019-0045/full/html)*

[39] *Dodge Data and Analytics. (2018). "World Green Building Trends in 2018. Smart Market Report" Retrieved January 6, 2020 (http://fidic.org/sites/default/files/World%20Green%20Building%20Trends%202016%20SmartMarket%20Report%20FINAL.pdf)*

The higher value at sale was seen as the fourth most important benefit of green buildings (out of the list of 10 benefits), selected by 32% of respondents world-wide, with the highest scores in Norway (53%), Saudi Arabia (53%), Vietnam (52%), Germany (50%) and Poland (48%). The only three benefits ranking higher globally were lower operating costs (65%), improved occupant health/well-being (58%) and documentation providing quality assurance (34%). The expectations in terms of value of new green buildings have grown gradually since 2012 as illustrated below.

Figure 0-12 Green mortgage vs. standard mortgage



Source: Dodge Data & Analytics, 2018[40]

Report on energy certification in buildings[41]

The Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile (ENEA) published in September 2020 an "Annual Report on the Energy certification of buildings". The report provides an overview of the implementation of the energy certification of Italy's national building sector in the period 2016-2019, in particular through in-depth assessments of the construction features and energy performance aspects of the Italian buildings, obtained from EPCs (APE in Italy).

The report includes a useful monitoring tool to evaluate the incentive mechanisms in Italy, it shows the progress of the transition towards energy efficiency in the building sector and quantifies the potential contribution of the sector to EU energy saving objectives, to the use of energy sources renewable energy and towards the reduction of CO2 emissions.

Italian EPCs issued in the 2016-2019 period, accounted for 85% of the residential and 15% non-residential market. Analysis of the residential market shows that over 60% of the data sample is characterized with poor energy performance, falling into the energy classes F and G, while only 8% belongs to the highest energy classes (A4-B). However, an improvement was noted of the energy quality of buildings, with a percentage increase in

[40] *Dodge Data & Analytics. 2018. World Green Building Trends 2018. Retrieved November 2020.* https://www.worldgbc.org/sites/default/files/World%20Green%20Building%20Trends%202018%20SMR%20FINAL%2010-11.pdf

[41] *ENEA. 11.2020 " Rapporto Annuale sulla Certificazione Energetica degli Edifici 2020". Retrieved 10 November 2020 (*https://www.efficienzaenergetica.enea.it/pubblicazioni/rapporto-annuale-sulla-certificazione-energetica-degli-edifici-2020.html*)*

EPCs relating to energy classes A4-B in the 2016-2019 issuance period, due the application of energy policies in the building sector.

The non-residential market had a higher share of properties in the energy classes C and D (over 30%) compared to the residential market, and over 10% of the EPCs in the classes A4-B energy sources. The trend in the 2016-2019 issue period shows an increase in the percentage of units in the best energy classes (A4-B) and a decrease in the percentage of properties in the intermediate energy classes (C-E).

Capital requirement incentives to promote energy efficient loans in Hungary

A presentation from the Hungarian Central Bank, Magyar Nemzeti Bank (MNB), was provided to the WG in February 2020, and outlined the bank's initiative to promote energy efficient loans in Hungary. This was done by launching a "Green Program" in 2019/2020 to mitigate the risks associated with climate change and other environmental problems, to expand green financial services in Hungary, to widen the related knowledge base in Hungary and abroad, and to reduce financial market participants' and its own ecological footprint. The presentation offered many options to stimulate energy efficient lending.

This is important, as when looking at the Hungarian housing market, buildings account for 40% of the country's energy consumption: per capita greenhouse gas emissions from the heating and cooling of homes put the country in the bottom third of EU countries. Housing loans are many financial institutions' largest asset class. Moreover, the number of new constructions and housing market transactions have been both rising since 2013.

The presentation also outlined the further plans of the MNB, which include the launch of a green product search website to increase customer awareness and decrease search costs for customers. To prepare for purchases of green mortgage bonds, MNB also plans to further develop its mortgage bond purchase programme and in the future, it will purchase mortgage bonds qualifying for green bond status.

Measuring the financial impact of climate change on real assets

Buildings are a key focus for achieving the reductions from the Paris Climate Agreement as they are responsible for around a third of all CO2 emissions. The major task for the real estate industry is that over 70% of the European building stock will have to undergo energetic retrofitting, which requires significant financial investments which will have an impact on the value of assets.

Following this background, a 2020 presentation from PwC on "Measuring the financial impact of climate change on real assets"[42] looked at the materiality of climate-related risks and opportunities. The presentation showed that climate risks and opportunities are driven by changing

[42] *PWC, 2020. "Measuring the financial impact of climate change on real assets". Retrieved November 17, 2020. (https://www.rics.org/globalassets/wbef-pwc---financial-impact-of-climate-change.pdf)*

operating contexts and own climate activities and elaborates amongst others on how potential climate regulation could impact building valuation. One of the key findings from PwC based on their research was that Energy-efficient buildings have huge market potential because they present fewer financial risks related to climate policy.

To quantify the financial impact on the value on commercial buildings in relation to their carbon performance, PwC developed an approached that ended up in the Carbon Value Analyser. In specific, the Carbon Value Analyser property valuation tool has been developed by PwC, Deutsche Unternehmensinitiative Energieeffizienz e. V. – DENEFF and the Buildings Performance Institute Europe (BPIE). The project was supported by the Redevco Foundation and the German Federal Environment Foundation (Deutsche Bundesstiftung Umwelt). The Carbon Value Analyser offers a way to quantify the benefits of energy-efficient buildings and that financially quantifies a property's potential risks relating to climate policy. Specifically, the Carbon Value Analyser calculates changes in the market value of a property, based on a standard discounted cash flow model. As such, any interested party can apply the tool and make use of the results, irrespective of the approach they use for valuation. Moreover, during the development process, PwC and the project partners held more than 40 interviews with property valuers, property surveyors, asset managers and other experts from industry associations and leading companies. They tested the approach with more than 200 buildings from our road resting companies.

Commercial building value is often calculated based on the discounted income (e.g. rent) and cost (maintenance, investments etc.) over time. The approach of the Carbon Value Analyser integrates the effects from hypothetical regulations into the different aspect in the valuation approach. For example, the Carbon Value Analyser calculates the impact from:

- CO_2-price on heating emissions, which increases the operating cost and therefore reduces the value;
- Mandatory energetic upgrades (such as in the Netherlands), which increase future capex and decrease the asset value; and
- Future-proof buildings, which generate positive impacts e.g. through increasing rent

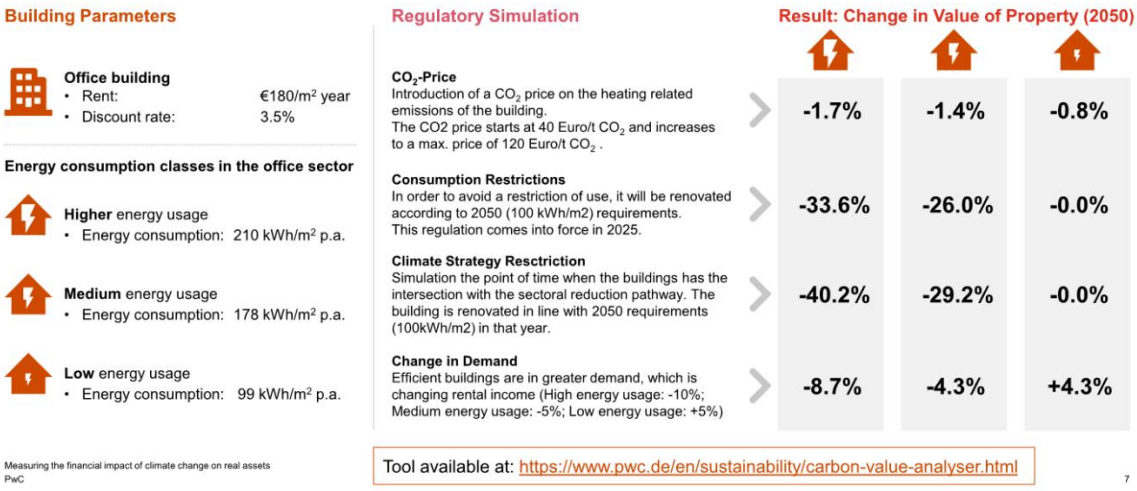
These analyses came up with three key findings:

- Energy-efficient buildings can have a significant market potential because they present fewer financial risks related to climate policy;
- Systematic reviews of entire portfolios or individual buildings can enable property owners to identify major risks relating to climate policy at an early stage and take targeted measures to manage these risks; and

› If the necessary investments in energy efficiency are to be made at the right time, property owners need long-term strategies for renovating their properties and financing this work.

An example is provided of the outcomes of the review of building valuations impacts. Figure 0-13 illustrates the materiality of energy efficiency-related regulations (as based on the property valuation tool):

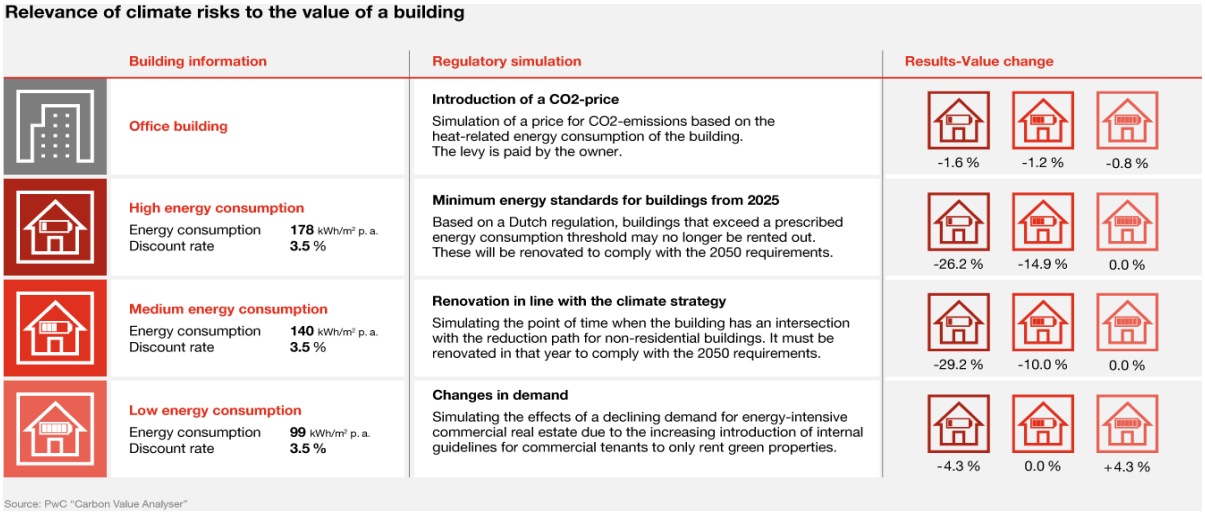
Figure 0-13 A review of building valuation impacts illustrates the materiality of energy efficiency-related regulations mortgage[43]



The Carbon Value Analyser gives companies the opportunity to calculate how the value of their properties may change in the future due to hypothetical climate-related regulations. PwC is currently developing ways of comprehensively analysing risks related to technology and the market in a holistic scenario analyses tool Climate Excellence – Real Estate. In the context of this WG, and the European Sustainable Finance Action Plan, the extent of the findings illustrate that historic correlations might no longer be indicative of the future. Under these circumstances, it would be valuable to design future risk assessment approaches with a view on scenario analyses (as described by the TCFD), extending this analysis even further to also cover technology and market changes.

[43] https://www.pwc.de/en/sustainability/carbon-value-analyser.html

Figure 0-14 A review of valuation impacts illustrates the materiality of energy efficiency-related regulations[44]



Other reference papers for "Green Premium" in real estate

A decade of academic research identified herein suggests that there is a positive correlation between a property's energy performance and its financial value. The following academic papers were further identified by the WG steering group and they develop the relationship between energy labels and "green characteristics" of real estate in terms of EPC, house prices and rents, with most recent additions at the end of the table together with three contemplating overall climate-related risks which are also material for this assessment:

Table 0-7 List of Other Green Premium references and papers

ACADEMIC PUBLICATION REFERENCE
Brounen, Dirk, and Nils Kok. 2014. "On the economics of energy labels in the housing market." Journal of Environmental Economics and Management 62.2: *166-179.*
Hyland, Marie, Ronan C. Lyons, and Sean Lyons. 2013. "The value of domestic building energy efficiency—evidence from Ireland." Energy Economics 40: 943-952.
Stanley, Sarah, Ronan C. Lyons, and Sean Lyons. 2016. "The price effect of building energy ratings in the Dublin residential market." Energy Efficiency 9.4: 875-885.
Kok, Nils, and Maarten Jennen. 2012. "The impact of energy labels and accessibility on office rents." Energy Policy 46: 489-497.
Fuerst, Franz, et al. 2012. "Does energy efficiency matter to home-buyers? An investigation of EPC ratings and transaction prices in England." Energy Economics 48 (2015): 145-156.Amecke, Hermann. "The impact of energy performance certificates: A survey of German home owners." Energy Policy 46: 4-14.

[44] PWC, 2020. "Carbon Value Analyser". Retrieved November 17, 2020. (https://www.pwc.de/en/sustainability/carbon-value-analyser.html). Tool available https://www.pwc.de/en/sustainability/carbon-value-analyser.html

Devine, A. and Kok, N., 2015. "Green certification and building performance: Implications for tangibles and intangibles". Journal of Portfolio Management 41:161-163.
Eichholtz, P., Kok, N. and Quigley, J.M., 2013. "The economics of green building." Review of Economics and Statistics, 95(1): 50-63.
Eichholtz, P., Kok, N. and Quigley, J.M., 2010. "Doing well by doing good? Green office buildings". American Economic Review, 100(5): 2492-2509.
Ablaza, A., Yang, Yang, L., Fiorello, Llado, M., 2020. "Off-balance-sheet equity: the engine for energy efficiency capital mobilisation. ADB Institute Working Paper 1183. Asian Development Bank Institute. https://www.adb.org/publications/off-balance-sheet-equity-energy-efficiency-capital-mobilization
Zhou, Xiaoyan and Caldecott, Ben and Hoepner, Andreas G. F. and Wang, Yao, 2020. "Bank Green Lending and Credit Risk." (June 3, 2020). https://ssrn.com/abstract=3618744 or http://dx.doi.org/10.2139/ssrn.3618744
Bertoldi, P., Economidou, M., Palermo, V., Boza-Kiss, B., 2020. "How to finance energy renovation of residential buildings: Review of current and emerging financing instruments in the EU. Wiley Interdisciplinary Reviews: Energy and Environment." https://onlinelibrary.wiley.com/doi/full/10.1002/wene.384
Curtis, J., Devitt, N., Whelan, A., 2015. "Using census and administrative records to identify the location and occupancy type of energy inefficient residential properties." Sustainable Cities and Society 18 (2015) 56–65
Council on Economic Policies, Monnin, P., 2010. "Shifting Gears: Integrating Climate Risks in Monetary Policy Operations." https://www.cepweb.org/shifting-gears-integrating-climate-risks-in-monetary-policy-operations/
Banque de France, 2020. "Working Paper on climate-related scenarios for Financial Stability Assessment: an Application to France." https://publications.banque-france.fr/en/climate-related-scenarios-financial-stability-assessment-application-france
European Central Bank, 2020. "Guide on climate-related and environmental risks." Supervisory expectations relating to risk management and disclosure. https://www.bankingsupervision.europa.eu/legalframework/publiccons/pdf/climate-related_risks/ssm.202005_draft_guide_on_climate-related_and_environmental_risks.en.pdf

2.2.3 Asset performance and Environmental, Social, and Governance (ESG) effects

Members of the WG are also interested in the impacts of overall ESG and climate-related environmental performance impacts on unsecured and infrastructure finance. The following section summarises some of the key research reports in this area which have been identified and summarised by the WG:

Default and recovery rates for project finance loans

Moody's published a research report in September 2018 entitled: "Default and recovery rates for project finance bank loans, 1983-2016: Green

projects demonstrate lower default risk"[45] as an addendum to a March 2018 study on default and recovery rates for unrated project finance loans.

The report covers 5,859 projects as per Moody's definition of infrastructure categorised as green and non-green on the basis of use of proceeds eligibility criteria under the Green Bond Principles by the International Capital Markets Association, including renewable energy, energy efficiency, pollution prevention, clean transportation, climate change adaptation and environmental conservation. The data is further segmented by advanced economy, emerging market and developing economy regions.

The key highlights of the analysis include:

- Green use-of-proceeds project finance bank loans experienced a lower default rate than non-green project loans in infrastructure and power sectors. However, the difference may be due to sub-sample characteristics other than greenness as the default rate on loans whose use-of-proceeds could not be determined was lower than that of green loans. The 10-year cumulative default rate (Basel II) for green projects within the total infrastructure basket is 5.7%, lower than that of 8.5% for non-green projects, but higher than that of 2.9% for indeterminate use-of-proceeds projects. As a comparison, corresponding default rates for Baa3-rated and Ba1-rated corporates are 5.4% and 10.4% respectively.

- The average ultimate recovery rates in green and non-green use-of-proceeds differ, but are overall consistent with the study average of 83.5%, with certain variations across regional subsets.

Environmental performance of commercial real estate

"Environmental Performance of Commercial Real Estate: New Insights into Energy Efficiency Improvements"[46] a 2019 paper by Piet Eichholtz, Rogier Holter-mans and Nilks Kok, provides insights into the environmental performance of commercial real estate which has had limited coverage to date.

The authors employ a proprietary dataset of energy use data including more than 26,000 commercial buildings between 2009 and 2018 owned and managed by large institutional investors such as Clarion Partners, CBRE Global Investors, and USAA Real Estate. They evaluate the energy performance of these assets and using difference-in-difference analysis

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[45] Moody's Investors Services. 18.9.2018. "Default research - Global: Default and recovery rates for project finance bank loans, 1983-2016: Green projects demonstrate lower default risk". Retrieved January 6, 2020 (https://www.moodys.com/login?ReturnUrl=https%3a%2f%2fwww.moodys.com%2fresearchdocumentcontentpage.aspx%3fdocid%3dPBC_1138618)

[46] Piet Eichholtz, Rogier Holter-mans and Nilks Kok. 2019. " Environmental Performance of Commercial Real Estate: New Insights into Energy Efficiency Improvements". The Journal of Portfolio Management: Special Real Estate Issue. Retrieved January 6, 2020 (http://maastrichtrealestate.com/upload/researches/EHK_JPM.pdf)

assess impacts of environmental building certification (Leadership in Energy and Environmental Design).

Specifically, the main conclusions from the study are as follows:

- The median energy consumption of commercial real estate within the sample declined by 42% over past ten years.
- On average, the real estate's energy use decreased by 8 percent after obtaining the environmental building certification, with a significant variation in total reduction based on certification level, program and green label tenure.

The representativeness of the results may be, however, affected by the sample which focused on the most renowned institutional real estate investors.

Carbon emissions from the commercial building sector

The 2014 study on "Carbon emissions from the commercial building sector: the role of climate, quality and incentives"[47] describes the need to develop proxy measures for energy efficiency in the commercial sector. The report questions why there is little known about environmental performance of different buildings at a point in time or how the same buildings perform over time. It specifically explored the association between a building's electricity consumption and the physical attributes of buildings, lease incentive terms, indicators of human capital and climatic conditions. Data was based on a dataset studying the electricity consumption of a large sample of commercial buildings located in a country in the Western United States. The study concluded that buildings that are newer, as well as of higher quality, consume more electricity – contrasting evidence was found for the residential sector. Moreover, it found that newer buildings are most resilient when exposed to hotter weather. Buildings with a building manager on-site, and with tenants facing a positive marginal cost for electricity also showed to have a better environmental performance.

ESG and corporate financial performance

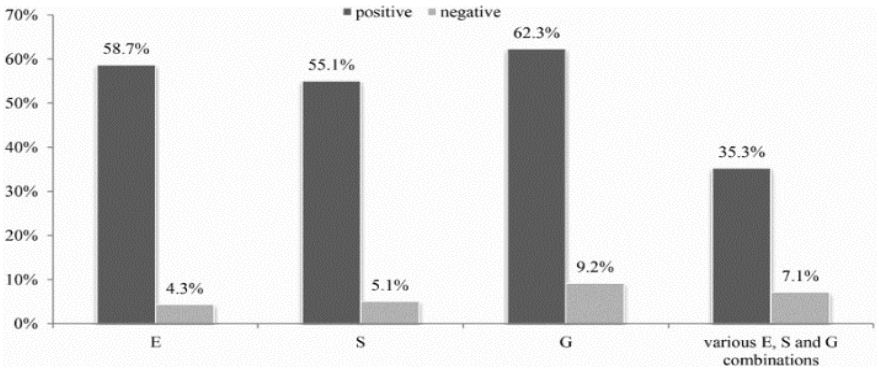
"ESG and financial performance: aggregated evidence from more than 2000 empirical studies"[48] presents one of the most exhaustive reviews of link between ESG and corporate financial performance conducted by Deutsche Bank and University of Hamburg and published in Journal of Sustainable Finance & Investment in 2015. The study extracts primary and secondary data i.e. over 3,700 study results from over 2,200 individual academic review studies. Thereby, it provides for a broad overview of the state of research on the topic.

According to the study approximately 90% of studies found a non-negative relation between ESG and corporate financial performance, with the large

[47] *Kahn, M. E., Kok, N., & Quigley, J. M. (2014). Carbon emissions from the commercial building sector: The role of climate, quality, and incentives. Journal of Public Economics, 113, 1-12.*
[48] *Friede, G., Busch, T., Bassen, A. (2015). "ESG and financial performance: aggregated evidence from more than 2000 empirical studies", Journal of Sustainable Finance & Investment, 5:4: 210-233. Retrieved January 6, 2020 (http://dx.doi.org/10.1080/20430795.2015.1118917)*

majority of studies reporting a positive ESG impact. The effect appears stable over time since mid-1990's. The opportunities for ESG outperformance were found in particular in North America, Emerging Markets, and in non-equity asset classes.

Figure 0-15 E, S, and G categories and their relation to CFP (vote-count studies sample), n = 644 net studies.



Source: Friede, Busch and Bassen, 2015

Sustainable investing and bond returns

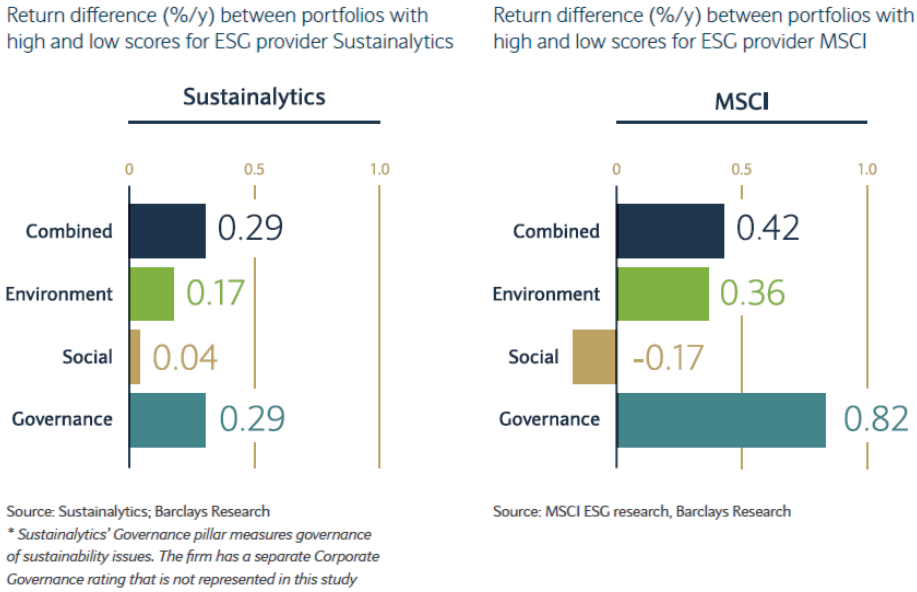
The paper by Barclays research team "Sustainable investing and bond returns"[49] published in 2017 in the Journal of Environmental Investing explored the link between ESG and financial performance of corporate bonds by comparative analysis of performance of the Bloomberg Barclays US Investment Grade Corporate Bond Index and a diversified portfolio matching its main characteristics such as sector, quality and duration albeit with positive and negative ESG tilts. The study's main finding are as follows:

- Positive tilt to ESG factors results in a small but steady performance improvement controlling for the change in relative evaluation during study period. No evidence of negative ESG impact was found. The price of the bonds was not significantly affected by the ESG features.
- In terms of separate tilts to E, S, and G attributes, the positive effect was highest with a positive tilt to governance and weakest with a tilt to social.

Despite significant differences in their methodologies, broadly similar results were observed using ratings from the two ESG providers considered in the study.

[49] *Barclays. (2017). "Sustainable investing and bond returns Research study into the impact of ESG on credit portfolio performance". Retrieved January 6, 2020 (https://www.investmentbank.barclays.com/content/dam/barclaysmicrosites/ibpublic/documents/our-insights/esg/barclays-sustainable-investing-and-bond-returns-3.6mb.pdf)*

Figure 0-16 Return difference based on ESG



Credit risks of high ESG scoring companies

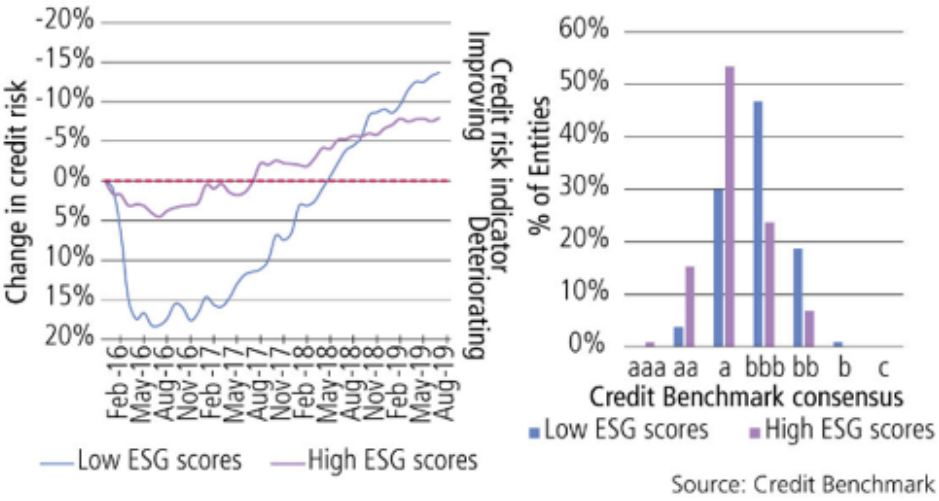
Credit Benchmarks in 2019 published a research note "Credit data: sustainable companies are better credit risks"[50] on the credit risk of companies with higher and lower ESG scores. The analysis was based on monthly credit risk inputs from 40+ leading financial institutions via consensus ratings on around 50,000 rated and unrated entities in different sectors globally.

The research finds significantly steeper and deeper credit deterioration for borrowers with low ESG scores with credit risk increase by almost 20% in the 2016H1 as compared to 4.5% in high ESG score category, but also a more rapid recovery.

The credit distributions shed some light on the differences between high and low ESG borrowers: over a half of the high ESG score companies are in category A, with only 7% are non-investment-grade. Most of low ESG score companies are in category BBB with 20% in non-investment-grade. There were no low ESG companies in the AAA category, and no B or C category among the high ESG companies.

[50] *David Carruthers. (2019). "Credit data: sustainable companies are better credit risks". Risk.net. Retrieved January 6, 2019 (https://www.risk.net/comment/7061506/credit-data-sustainable-companies-are-better-credit-risks)*

Figure 0-17 Credit trend and distribution: high and low ESG companies



The impact of sustainability on value

In 2020, Jones Lang LaSalle (JLL) published a report on "The impact of sustainability on value"[51] examining the trends in the performance of sustainable office buildings in central London, with regards to rental values and leasing velocity. The reports focused on the space that has a BREEAM rating or EPC certificate and sets out to quantify to what extent demand for sustainable offices is increasing.

The research demonstrates that sustainable buildings in central London have a rental premium in range of 6% and 11%**.** Moreover, at both 12 months and 24 months after completion, vacancy was lower in buildings with an Outstanding/ Excellent BREEAM rating[52] compared to those that were rated Very Good. The report also reveals that demand for sustainable office space is rapidly increasing and this growth has happened over a relatively short time-period. To illustrate, the number of companies signing up to science-based targets, with a central London presence, has doubled since December 2018 and now totals 126 firms. These companies occupy around 12 million square feet of space in the capital and nearly 4 million square feet will be subject to a lease event in the next five years.

Lastly, the report concludes that there will be a rental premium for net zero carbon buildings in central London for those that can deliver effectively and fast. Even with a potential increase in construction costs, the researchers of the paper estimate that the rental premium and yield compression could take a typical scheme from 15% profit on cost to over 20% profit on cost.

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[51] Jones Lang LaSalle (JLL) (2020). "The impact of sustainability on value". JLL website. Retrieved November 2020 (https://www.jll.co.uk/en/trends-and-insights/research/the-impact-of-sustainability-on-value)

[52] BREEAM is a world-renowned sustainability rating scheme, to assist the real estate industry to deliver sustainable buildings and was introduced into the UK back in 1990.
Buildings are essentially rated Outstanding, Excellent, Very Good, Good, Pass or Passable.

Statistical analysis of the correlation of credit risk with underlying asset energy performance

3 Statistical analysis of the correlation of credit risk with underlying asset energy performance

This chapter describes in detail the new primary statistical work uncovered over the two years by EEFIG's members. It provides an overview of the method and then presents the specific results from each of the key elements.

3.1 Methodology adopted by WG

The analytical approach, as determined and assessed by a methodology sub-WG, used by the WG to develop the quantitative relationships between energy efficiency improvements and the credit risk of associated loans was developed to understand and address the following key research questions:

Q1: To what extent is asset energy performance correlated with credit risk?

Q2: How does this vary by other commonly observed risk factors such as asset owner income or employment/ business status and wider macroeconomic conditions?

Q3: How does this vary within the different EU Member States?

Q4: Is there evidence of a causal link between improved asset energy performance and improved credit risk?

To answer these questions, a set of appropriate statistical analysis were defined and performed. The applied criteria for defining such analyses include:

- Sufficient sample sizes
- Clear data quality controls and representativeness of data
- Stratification and statistical controls to avoid systematic bias
- Well-defined set of analysis to derive sound conclusions

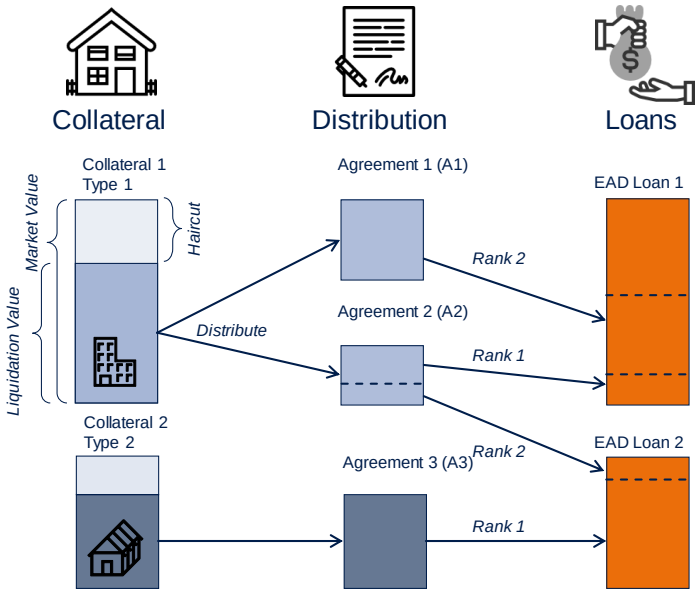
Additionally, the right aggregation level has to be determined in order to link the data sets correctly:

- EPC data on address level can be linked to assets directly

› EE data available on county or state level can be linked to segment or portfolio level data

Furthermore, the specificities of the credit business might render linkages less obvious as illustrated and explained below:

Figure 0-18 Linkages from collateral to loans



Source: Own production

In many cases, there is a many-to-many relationship that links assets (e.g. collateral) to loans including effects of seniority of claims and multiple agreements referring to the same asset. Such effects can create rather complex types of analysis, which – for some asset classes – cannot be avoided, e.g. commercial real estate financing. These effects have to be considered especially in the case of LGD data.

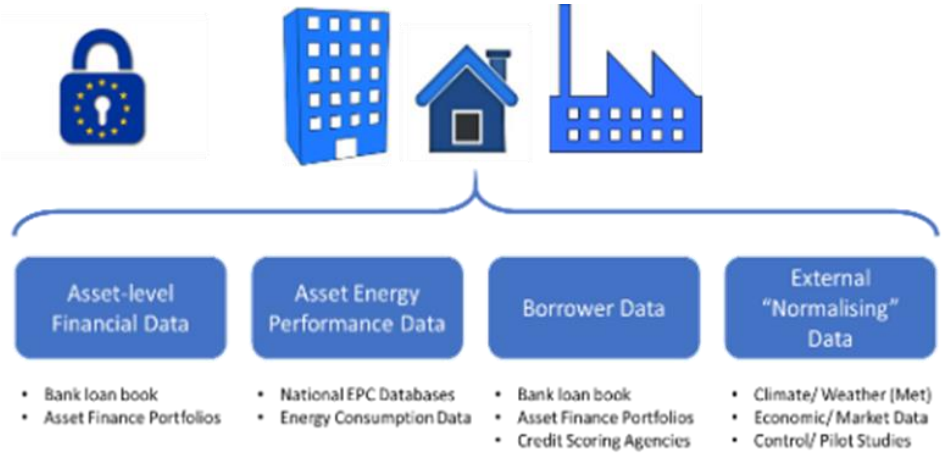
The following sections describe the approaches selected and applied by the WG in respect of the above demands, criteria and concerns.

3.1.1 Data sourcing and preparation

Key data sources used in analysis

There are four types of data which are relevant for the statistical analysis undertaken by the WG, or institutions working with the WG. These can be summarised as: Asset-level financial data, asset-level energy performance data, borrower (or asset owner) data and external "normalising" data (pertinent to the meteorological, economic and market environment for the asset). These types of data, together with example data sources in each case, is summarised in Figure 0-19 below. Asset-level financial data and borrower data is typically held by financial institutions, but may be held by other organisations, such as GCD or EDW.

Figure 0-19 Data architecture for statistical analysis



Source: Own production

For the purposes of the WG, the primary analysis was conducted using the residential mortgage books of Nationwide Building Society (NBS) in the UK, Allianz in Germany and OP Financial Group in Finland. An overview is provided in Table 3-1. In total, the analysis was conducted on a sample of almost 800,000 residential mortgages across all three countries. A forward-looking analysis was undertaken in each case with common control variables including borrower credit score, income, loan term, loan-to-value, along with a range of variables relating to the building and additional controls capturing municipality-level economic and the broader economic indicators.

Energy performance data came from a combination of domestic EPC registers (where available) and proxy models based on energy demand or characteristics of the building. Further details on energy data sources are provided within the country case-studies in Section 3.2.

Table 0-8 Summary of data sources and analysis performed by members of the WG

	Allianz	NBS	OP Financial Group
Country	Germany	UK	Finland
Loan-data	Residential mortgages	Residential mortgages	Residential mortgages
Energy performance data	Proxy model based on energy demand	UK EPC register	Finnish EPC register and proxy model
Sample size	35,175	657,838	102,225
Forward-looking period	5 year	1 year	2 year
Primary outcome vars	Arrears	IRB Default, Arrears	Arrears
Methods used	Stepwise logistic regression	Stepwise logistic regression	Stepwise logistic regression

Linking financial data with energy performance data

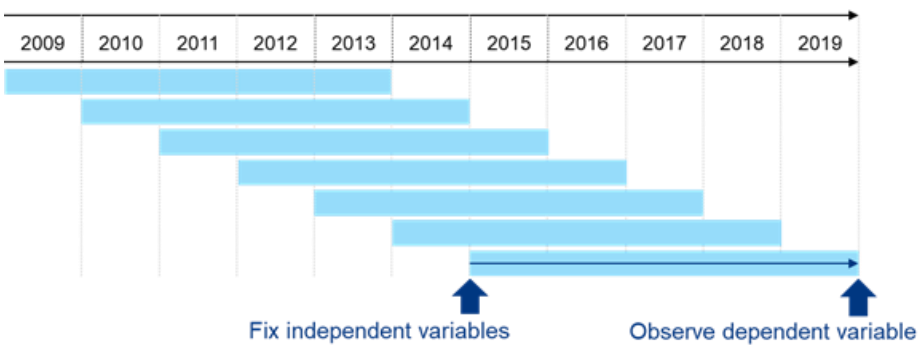
Data Matching: Loan Records and National EPCs were matched using either a building reference number or other identifiers, such as the address and post-code. While national EPC databases may contain unique building reference numbers (such as the Unique Property Reference Number or UPRN in the UK EPC database), loan-level databases typically will not contain this information. For the WG's analysis, matching on addresses and post-code information was applied in the UK case. Various data cleaning and matching techniques were applied to perform deduplication, entity resolution and matching of address strings, resulting in a high level of correspondence (above 60% on average) between EPC and loan-level databases.

Proxy models: In cases where we could not access enough EPC data (such as in Germany and Finland) proxy models were developed to approximate energy efficiency labels. The Allianz analysis exploits the historical dates of thermal insulation regulations, employing a decision tree with non-linear cut-off dates for year of construction with an accuracy (the ratio of predicted and true positives) of 79%. The proxy model of OP Financial Group was derived from data of the Finnish EPC register, using building age and the main heating source as main variables. This model was applied to the 85% of OP's portfolio sample where no data from the Finnish EPC register was available with 95-97% accuracy for good EPC labels (A, B, C). Proxy models for energy efficiency may help to overcome data availability issues. Ultimately however, existing data has to be made available and new data sources e.g. on energy consumption have to be unlocked by Member States enabling more precise analyses.

Creation of a reference data set (RDS)

Credit risk is cumulative in time, i.e. the longer the observation period, the more likely a credit risk event will be. Therefore, we consider a forward-looking observation period of 1-5 years across the country case studies. This means that we assess the probability of a borrower entering into arrears or default during this period, conditional on them not being in arrears prior to the observation period. Independent or control variables are fixed prior to the observation period. A graphical example for a forward-looking definition of the observation period is provided in Figure 0-20.

Figure 0-20 Forward-looking definition of observation periods



3.1.2 Analytical framework

Credit risk of customers can be observed using many different indicators, ranging from early warning indicators to "days past due" and finally to a full default or an unlikeliness to pay assessment. Accounting (e.g. IFRS 9, an International Financial Reporting Standard (IFRS)) as well as supervisory rules (e.g. Art. 178 CRR and EBA/GL/2016/07) provide a detailed guidance on how to assess the different stages of credit risk. The assessment of portfolio-level credit risk depends on the intrinsic frequency of defaults in such loan portfolios. Mortgages backed by real estate collateral are well known to exhibit – under normal economic conditions – very low default rates, on the order of 0.1% or even lower. This imposes a severe challenge for any kind of credit risk analysis in real life mortgage portfolios, as typically no or only very few observations will be available for analysis. This challenge was addressed by the WG in its methods sub-group by looking for alternative target variables.

Suitable target variables

With CRR defaults being rare in mortgage portfolios, more frequently occurring indicators are typically used as target variables for analysis. One of those early indicators of a borrower's financial difficulties are occurrences of missed or late payments, i.e. payments being in arrears. Although this is typically a very good predictor of serious financial difficulties at a later stage, it is also prone to various artefacts such as a customer changing bank accounts or issues with payments systems on the bank's side. In an ideal setting, one would focus on the proper CRR default definition[53] and only count those events when running the analysis. Depending on the overall portfolio size, this is however not always feasible. Therefore, we propose a staged approach when performing the analysis of the impact of energy efficiency on credit risk with respect to the probability of default:

- For portfolio sizes below of about 200,000 customers, any statistical analysis on CRR defaults leads relatively large statistical errors due to a low number of expected default (approx. 200). Therefore, the analysis of customers in arrears is an appropriate fall-back solution, however, with certain quality assurance measures being applied:
  - Definition of homogenous customer groups, e.g. by year of loan origination, allows to reduce the impact of spurious effects in arrears data which might capture other sources of payment delays as well, which are not related to credit risk.
  - Where possible, compare expectation in terms of variation to the actual behaviour, e.g. showing an increasing probability of arrears for worse credit scores.
  - Qualitative analysis regarding historical process-related changes within a bank, which may affect the treatment of customers one or

[53] As found in Article 178 of Regulation (EU) No 575/2013.

two months in arrears, i.e. before the Basel 2 default at 90 days past due.

Data quality assurance is even more important for in-arrears data compared to e.g. Basel IRB default data.

- For portfolio sizes above 200,000 customers, the application of the CRR default definition is the method of choice. CRR default definition and recognition is highly standardised across Europe and quality assurance is a standard procedure at every bank. This also allows paving the way for inclusion of energy efficiency indicators into IRB models, which are used to determine regulatory requirements (see NBS study in section 3.2.1).

For both target variables, Basel IRB defaults as well as "in arrears", data quality cross-checks and an analysis of consistency of the observation in any given data set is of utmost importance for the reliability of results.

Analytical methods

Both a CRR default flag and an indicator of an in-arrears event, represent binary target variables. A standard procedure for analysing such data and extracting correlations is logistic regression. However, since these variables are dependent and confounded by strong risk factors like credit scores and net income, it is important build up such models in a careful and stepwise manner:

- Perform a graphical analysis of effects. If the human eye is not able to identify a relationship in suitable graphs, there might not be one.
- Introduce the risk factors one by one, starting from simple ones to more complex ones. Check whether the changes in regression coefficients match expectations, taking into account the expected sign of the coefficients as well.
- Check for highly correlated factors and exclude them where possible.
- When using proxy models e.g. for energy efficiency, check how the constituting variables in such a model affect the logistic regression directly, i.e. without the proxy model as an intermediary.
- Once a full model including all planned variables has been estimated, check the impact of removing the target variable, i.e. energy efficiency. In case the model does not then deteriorate, then the effect might have been overestimated in the first place.

Models based on arrears data provide a first insight into potential relationships, however, the most stringent test of such preliminary findings is the inclusion of new variables into IRB rating models, which are based on the official CRR definition of customer default. IRB models must be approved by supervisory authorities and are subject to stringent and precise requirements regarding data quality, model development and

validation. Typically, they represent the maximum of information which can be reliably extracted from credit data. Therefore, adding further variables to such models normally does not improve these models. If in any case it can be shown that new, additional variables improve the performance of these models, e.g. with respect to discriminatory power, this provides a strong indication of a significant relationship between this variable and the observed credit risk. Banks with approved IRB models may use their internal validation methodologies to further assess the validity of new variables in such models for their specific portfolios. Ultimately, building on the well-established IRB framework may allow supervisory authorities and policy makers to seamlessly integrate these and further results into the globally and Europe-wide established procedures and guidelines.

In case the validity of the new variables like energy efficiency can be substantiated by internal validation, a formal inclusion of such variables into upcoming model revisions, and subject to supervisory approval would allow using them for regulatory capital calculations, would have a direct impact on the bank's capital position, with the potential to provide lower interest rates for loans financing energy efficient buildings due to lower capital costs, with due consideration of the potential interaction between the IRB approach and the standardized approach in credit risk.

Most of the currently published studies (see Appendix B) focus on default risk, i.e. the probability of default of an obligor. Default risk, however, is not the only credit risk with "loss given default" (LGD) and "exposure at default" (EAD) being the other major risks. Similar carefully designed approaches should be used when analysing these risks, again with a strong recommendation to utilise the established and robust IRB frameworks for such analyses.

3.2 Individual studies contributed by WG members

Since the launch of the WG in 2019, the "holy grail" and focus of its work has been to uncover datasets from its members and combine them with energy performance data for deep statistical analysis. These processes are typically multi-year processes for extracting and cleansing data before data analysis can be performed. The fact that the WG has produced three detailed and new sets of analysis from diverse geographies (Finland, UK, and Germany) which corroborate its thesis and fall into line with evidence procured by parallel groups from Italy and the Netherlands, is a considerable achievement and is above the expectations which the WG had at its launch.

The following three case studies from NBS (UK), Allianz (Germany) and OP Financial Group (Finland) are robust, statistically relevant, methodologically aligned and reveal a clear underlying trend which allows this WG to provide firm and evidence-back conclusions. This section describes a summary of each of the three case studies and their results. Chapter 4 reveals some of

the more generic work of the national hubs to provide a wider context and contrast. It should be noted that each case study is available in its full from the WG secretariat, and is included in Appendix D accompanying this report.

3.2.1 Nationwide Building Society (UK)

Nationwide Building Society (NBS) is the UK's largest building society and the second largest mortgage provider in the UK. It is a mutual, which means that NBS is owned by its members, managing £248 billion of assets.

The NBS study conducted as part of the WG attempts to answer the questions:

> Q1: What relationship do we observe between energy efficiency and default risk for UK residential mortgages?[54]
>
> Q2: Is any observed relationship robust to the inclusion of a range of control variables? What might the results suggest for changes to capital requirements?[55]

Energy efficiency has so far not been a standard risk factor for the assessment of creditworthiness. Various studies[56] are now pointing towards a statistical relationship, which we would like to corroborate from a NBS perspective.

Preliminary Steps

The UK is fortunate to have a large and publicly accessible EPC national database available through the Ministry of Housing, Communities & Local Government.[4] This database contains information about the energy efficiency of over 19 million properties recorded since 2008 for England and Wales. In addition to the information on EPC rating, this database also contains detailed dwelling information on expected energy costs. NBS were able to match addresses in the EPC database to their portfolio of residential mortgages. A high matching rate of 67%, on average, was achieved, with an even higher rate for new-build properties. This first step enabled the NBS IRB modelling team to create a matched EPC and mortgage database of over 600k households.

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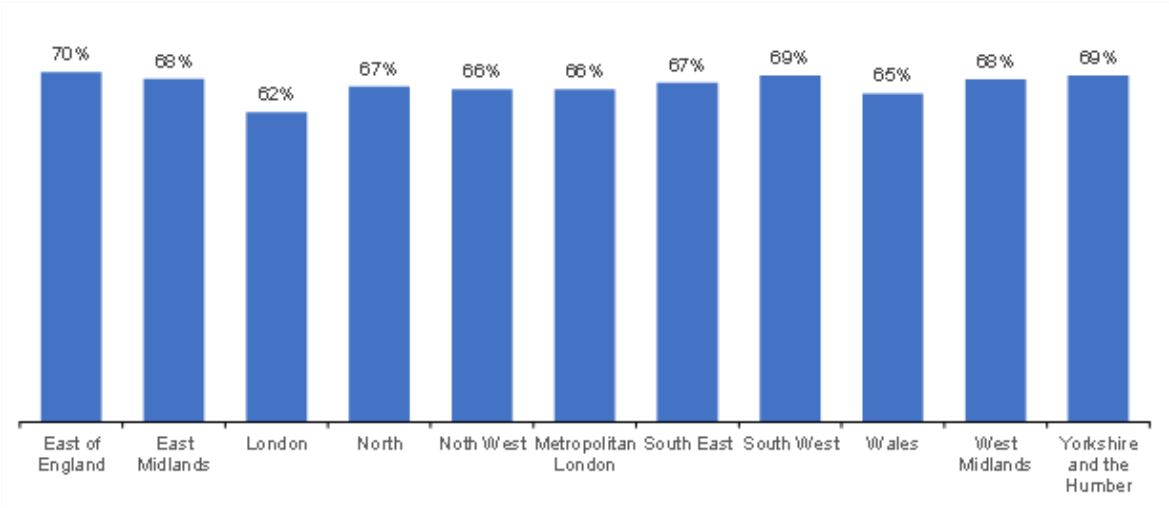
[54] Properties rated under the IRB approach for NBS portfolio.

[55] NBS does not currently incorporate information about the energy efficiency of the properties into the IRB rating system. This analysis has been completed for research purposes only.

[56] e.g. Bank of England, January 2020; "Are high energy efficient properties less likely to default?"

Figure 0-21 EPC matching rate by region



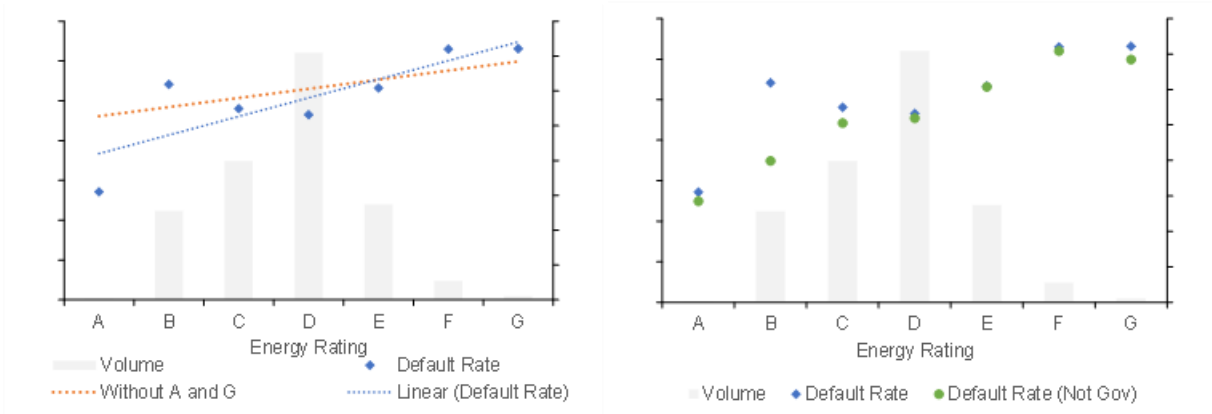
Methodological considerations and refinement

NBS took recent analysis by the BoE and expanded this work by focusing on prime residential mortgages of NBS by September 2019 with either an IRB default definition (which includes Arrears and Unlikeliness to Pay or Concession statuses) or Arrears only definition (Months in Arrears equal or above 3 months). The sample contains properties whose customers are not in default at September 2019 but might default in the following 12 months.

Before selecting the final sample for analysis, a subsample of certain UK Government funded schemes such as Help to Buy, Shared Ownership or Right to Buy[57] was studied for potential exclusion. Most of the properties whose owners accessed any of these government schemes had a rating of B or C. The default characteristics of these customers were different to the rest of the sample, and for this reason, it was decided to exclude them from the final sample.

As demonstrated in Figure 0-22, analysing the proportion of defaults by each EPC band without the government schemes eliminates the anomaly in the default rate relationship and illustrates a clear negative relationship between energy efficiency and defaults (green dots on chart on the right).

Figure 0-22 Cause of anomalies in the EPC-Default relationship



Each panel in Figure 0-22 shows the relationship between Default and EPC level. The left panel includes Govt. schemes and shows no clear relationship. The right chart illustrates the source of bias – government schemes contained both high energy efficiency properties (EPC of B) and a higher proportion of defaulted accounts. Data used to create the chart on the right was then used for modelling purposes to find any relationship between Default and EPC.

Results of analysis

Credit risk is cumulative in time, i.e. the longer the observation period, the higher the likeliness for a customer to default. For the NBS analysis, the observation period was fixed to one-year from the first observation in September 2019. Many well-known factors may influence the credit risk of borrowers. To be able to distinguish the additional effect of energy efficiency, control variables are required, and a clean data set was constructed, which reduces any bias as much as possible. Control variables considered in the NBS analysis can be categorised as relating to the borrower (household income), the mortgage (age, loan term and original L ratio), and the property (valuation amount and property type). Additionally, NBS included an indicator variable to control for whether the loan was originated before or after the previous recession in the UK.

Table 0-9, columns 1-9 display results from a Logistic regression model in which energy efficiency was banded into High (A-C), Medium (D) and Low (E-G) EPC level, starting with a parsimonious model (column 1) and inclusion of additional significant controls in subsequent models (columns 2-9).

The coefficients of high (-0.1979) and medium (-0.1691) energy efficiency are expressed relative to the low energy efficiency category with a coefficient of 0. A negative coefficient for both high and medium ratings means that the likeliness to default for customers that hold these properties is lower than the likeliness to default for customers that hold low energy efficient properties. The difference in the likeliness to default between customers that hold high and medium energy efficient properties is lower than the difference to low energy efficient properties.

The results suggest that:

- Customers that hold high and medium energy efficient properties are ~20% less likely to default than customers that hold low energy efficient properties, "all other things being equal",
- this relationship is stable and intuitive, after including control variables that might explain the relationship between EPC and default,
- the coefficients are statistically significant with *p*-value < 0.01 meaning that the probability of the results being random is less than 1%,
- and the results are also robust to the inclusion of a battery of control variables and with a large sample of more than 600k properties.

Table 0-9 Logistic regression with categorical EPC variable

	Default (1)	Default (2)	Default (4)	Default (5)	Default (6)	Default (7)	Default (8)	Default (9)
Energy efficiency								
EE Continuous								
High energy efficiency	-0.2699***	-0.2772***	-0.2641***	-0.2688***	-0.2265***	-0.238***	-0.2148***	-0.1979***
	[0.06452]	[0.06453]	[0.06459]	[0.06459]	[0.06474]	[0.06482]	[0.06489]	[0.06497]
Medium energy efficiency	-0.1848***	-0.1868***	-0.18***	-0.1871***	-0.1735***	-0.171***	-0.1463**	-0.1691***
	[0.05857]	[0.05858]	[0.0586]	[0.05861]	[0.05863]	[0.05864]	[0.05867]	[0.05871]
Main control variables								
Household Income (£'000)	Borrower	-0.00877***	-0.00881***	-0.00977***	-0.00749***	-0.00662***	-0.00379***	-0.00497***
		[0.000888]	[0.000883]	[0.000898]	[0.000963]	[0.00098]	[0.000925]	[0.000934]
Loan Term (Years)	Mortgage Control		-0.01524***	-0.03767***	-0.029***	-0.02774***	-0.0043	-0.01962***
			[0.003214]	[0.003947]	[0.004032]	[0.004033]	[0.004309]	[0.004457]
Original LTV (%)				0.01415***	0.01017***	0.009742***	0.01199***	0.01244***
				[0.001438]	[0.001488]	[0.001487]	[0.00147]	[0.001439]
Valuation Amount (£/sqm)	Property Control				-0.00022***	-0.00025***	-0.00026***	-0.00016***
					[0.000024]	[0.000025]	[0.000024]	[0.000024]
House Indicator						-0.2772***	-0.1477**	-0.1097
						[0.06585]	[0.0671]	[0.06721]
Age							0.03663***	0.01869***
							[0.002653]	[0.002988]
Age*Recession								0.0178***
								[0.001228]
Regional x Recession Ind	No	No	No	No	No	No	No	No
Inspection Year FE	No	No	No	No	No	No	No	No
Observations	657,838	657,838	657,838	657,838	657,838	657,838	657,838	657,838
Gini	5.2%	16.09%	16.64%	20.7%	24.8%	25.5%	31.1%	34.0%

Source: EEFIG Working Groups, "Are green loans less risky?" (2021)[58]

Table 0-9 models tried to include all information which might affect the relationship between EPC and default. However, controlling for all the information of the customer, the property, the mortgage, the region, etc. is not possible due to the lack of data. For this reason, the IRB team included the behavioural score obtained using the IRB behavioural scorecard which aim is to predict the likeliness to default using past payment behaviour

[58] NBS, 2021: https://hypo.org/app/uploads/sites/3/2021/03/BAUHAUS-4_NationwideBuildingSociety.pdf

information. The IRB Credit Score variable holds a very high discriminatory power, with a Gini=70% and strong accuracy.

This analysis has also been replicated using the continuous version of the energy efficiency rating. These continuous variable ranges from 0 to 100, with properties rated as 100 being the most efficient buildings. The results with the inclusion of this energy efficiency rating reached the same conclusion, model (1) in Table 0-10. The negative sign of the coefficients means that the higher the energy efficiency of the property, the lower the likeliness to default, and indicates that we see an effect in-line with the postulated economic rationale.

Table 0-10 below presents results for both Default and Arrears. Results show that the EPC rating is still significant after the inclusion of the IRB behavioural scorecard score, model (3). This is an important result as the EPC seems to add value on top of the IRB behavioural scorecard without impacting the accuracy or discriminatory power of the IRB scorecard.

Table 0-10 Logistic regression results with continuous EPC variable and NBS IRB Credit Score

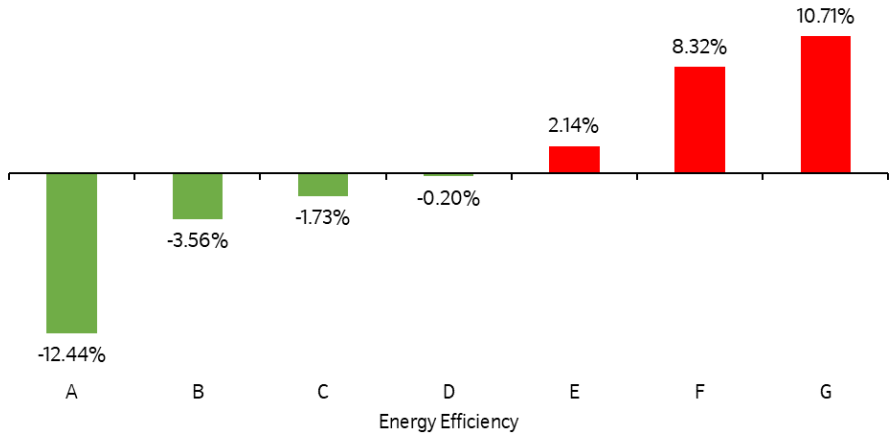
	Default (1)	Default (2)	Default (3)	Arrears (1)	Arrears (2)	Arrears (3)	Arrears (4)
Energy efficiency							
EE Continuous	-0.00898***		-0.00376*	-0.01572***		-0.01065***	
	[0.001777]		[0.001946]	[0.002843]		[0.003129]	
High energy efficiency							-0.3058***
							[0.1139]
Medium energy efficiency							-0.2495**
							[0.101]
Main control variables							
IRB Credit Score		-1.0551***	-1.0536***		-1.109***	-1.1064***	-1.1069***
		[0.01164]	[0.01166]		[0.01673]	[0.01675]	[0.01675]
Original LTV							
Loan Term (Years)							
House Indicator							
Valuation Amount (£/sqm)							
Regional x Recession Ind	No	No	No	No	No	No	No
Inspection Year FE	No	No	No	No	No	No	No
Observations	657,838	657,838	657,838	657,838	657,838	657,838	657,838
Gini	4.7%	70.28%	70.31%	7.9%	81.1%	82.0%	81.3%

Source: EEFIG Working Groups, "Are green loans less risky?" (2021)[59]

The IRB team studied the effect of using model (3) in Table 0-10 to calculate capital requirements as research purposes (information about energy efficiency has not been included in the NBS rating system, this exercise has been completed with research purposes only).

Figure 0-23 below demonstrates that whilst the overall capital requirement barely changed for the sample, the potential inclusion of EPC into the IRB rating system might allow for a better allocation of capital with lower capital requirements towards more efficient properties.

Figure 0-23 Capital change by inclusion of energy efficiency rating



Source: EEFIG Working Groups, "Are green loans less risky?" (2021)[60]

Additional analyses

Data about the EPC of properties in Scotland is stored in a different database from the Scottish government[61]. The inclusion of Scottish data into the model did not affect the results. With a total sample of 700,000 properties, the negative relationship between energy efficiency and default still holds. However, the issuing of EPCs in Scotland is different that the methodology followed in England and Wales. For this reason, the results must be interpreted carefully.

This analysis has also been replicated in the Buy To Let (BTL) portfolio with a sample of 173,000 properties. This analysis showed a similar trend that indicates a negative relationship between energy efficiency and probability of default. It has not been possible, however, to control for income or age of the landlord due to the lack of data.

Summary

[59] NBS, 2021: https://hypo.org/app/uploads/sites/3/2021/03/BAUHAUS-4_NationwideBuildingSociety.pdf

[60] NBS, 2021: https://hypo.org/app/uploads/sites/3/2021/03/BAUHAUS-4_NationwideBuildingSociety.pdf

[61] https://www.gov.scot/publications/energy-performance-certificates-introduction/

In summary, the NBS data and analysis suggest that there seems to be a significant difference in the probability of default between high/medium energy efficient (EPC A/B/C/D) properties and low energy efficient (EPC E/F/G) properties. The relationship is still strong and significant after controlling for characteristics that might affect it, such as information about the customer, the mortgage, or the property. This relationship still holds when including the IRB behavioural score as a control variable. The statistically significant negative relationship is also confirmed by introducing the continuous form of energy efficiency into the model.

Further ongoing work involves examining heterogeneities in the relationship for different income groups and applying different analytical techniques such as Survival Analysis to further understand the mechanisms behind the observed relationship between energy efficiency and credit risk.

3.2.2 Allianz (Germany)

Allianz is financing a significant loan book of EUR 25.6 bn of German mortgages, which is managed by Allianz Lebensversicherungs-AG and, more specifically, the Fachbereich Baufinanzierung. In 2020, 12,000 new loan contracts have been concluded, corresponding to €4.7 bn of new business volume. Allianz' mortgage business focuses on residential real estate, residential and commercial premises, as well as office real estate.

The Allianz study conducted as a contribution to this WG tries to answer the question:

> Q1: Do customers with the same credit rating differ in terms of their credit risk by the energy efficiency of the financed building?

Energy efficiency has so far not been a standard risk factor for the assessment of creditworthiness. Various studies now point at a statistical relationship, which Allianz wanted to corroborate.

Challenges and pitfalls

First, data availability of EPCs is still low in Germany. Additionally, there are significant deviations between EPC based on energy demand or on energy consumption. Therefore, both methods are compared for modelling purposes in this study. In order to provide sufficient coverage of the Allianz loan book, a proxy model for energy performance is developed and applied. More specifically, a simple model was used to predict whether a building is energy efficient (A,A+) or non-energy efficient (B to H) based on property specifics.

Many well-known factors may influence the credit risk of borrowers. In order to be able to distinguish the additional effect of energy efficiency, control variables are required and a clean data set has to be constructed, which reduces any bias as far as possible. For example, there might be an

underlying income selection along the lines of "well-off customers could simply prefer energy efficient buildings". Various strategies need to be applied to avoid and reduce potential bias whenever possible, e.g. by investigating differences in arrears probabilities in groups of similar credit rating and with a set of control variables.

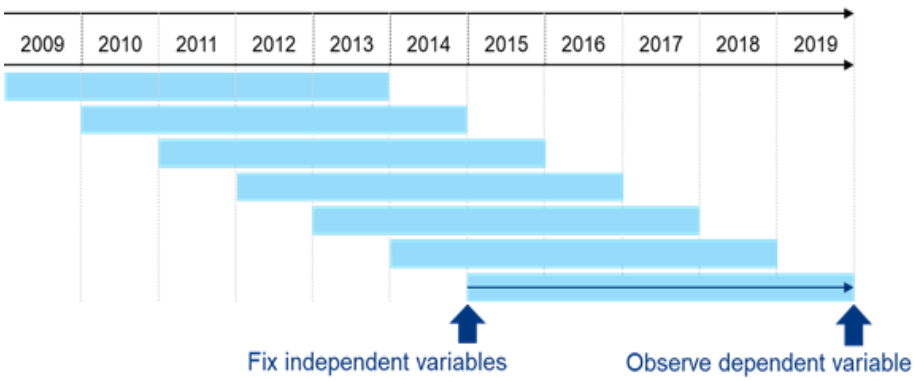
This study comprises four major steps: a) select relevant data, b) build approximate energy efficiency labels, c) perform a graphical analysis of risk drivers, and finally d) perform a stepwise logistic regression.

Forward looking perspective and removing bias

Credit risk is cumulative in time, i.e. the longer the observation period, the more likely a credit risk event will be. Therefore, the observation period was fixed to 5 years starting with loan origination. Given the usual term structure of mortgage credit risk, 5 years is long enough to observe the first peak after loan origination. All loans originated at a given year are assigned to one observation cohort.

Macroeconomic factors like the interest rate environment strongly affect credit risk. Therefore, the period of time after the financial crisis was used, in which interest rates declined steadily. Similarly, the 2020 Covid crisis is excluded. To avoid the "self-fulfilling prophecy" effect, any independent variables at the beginning of our observation periods were observed, and the outcome in terms of "the contract has been in arrears (yes/no)" is observed at the end of the observation period (see Figure 0-24). The final data set contained 35,175 loans in 7 cohorts shown in Figure 0-24.

Figure 0-24 Design of the observation periods

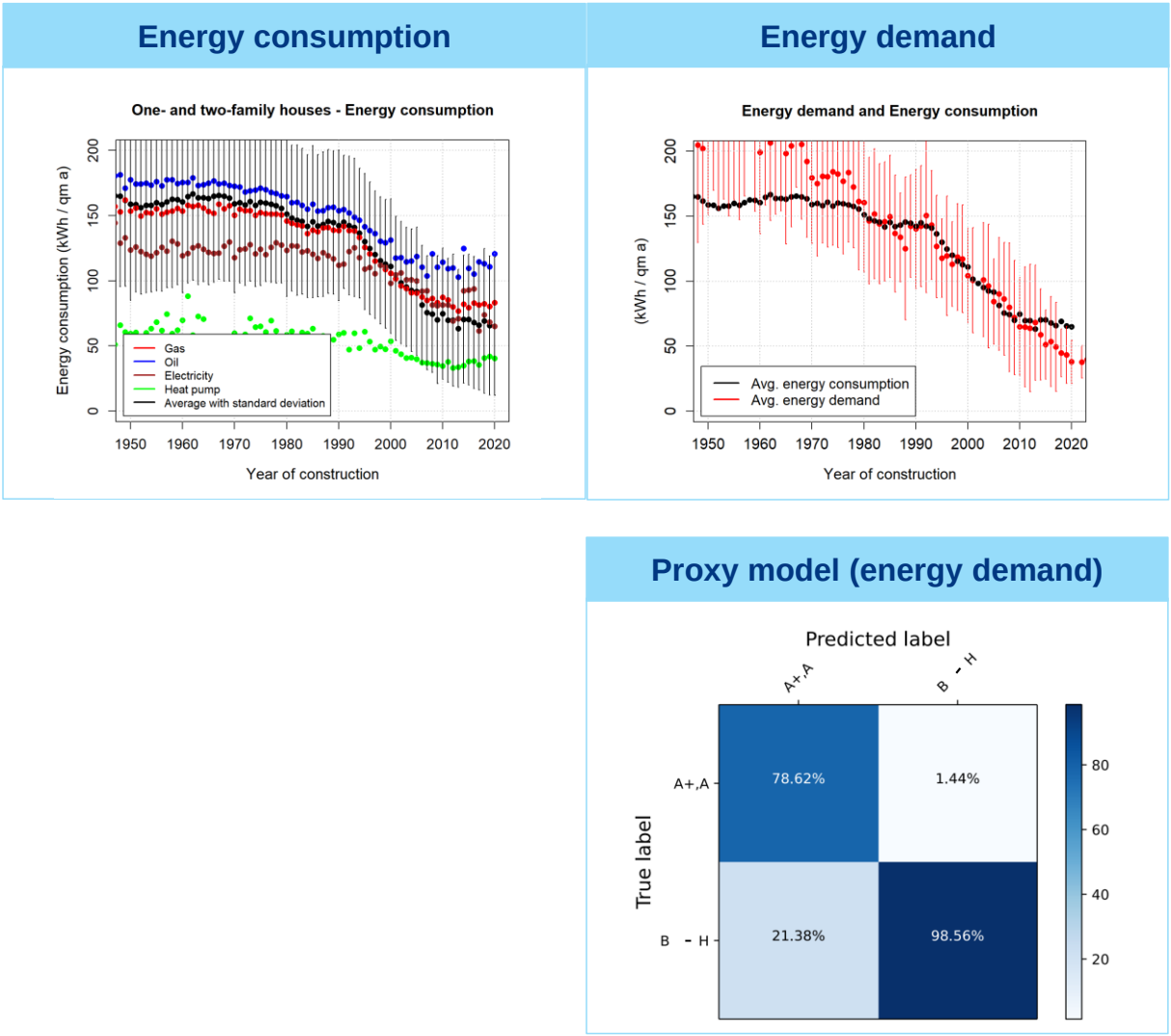


Approximate energy efficiency labels

To provide the energy efficiency information required for this analysis, a model for approximate energy efficiency labels has been developed. For both energy consumption as well as energy demand, the year of construction of the building is the most predictive factor, with both dropping significantly starting in the 1980s due to thermal insulation regulation. Thorough investigation showed that the best performing proxy model can be achieved by focusing on energy demand and assessing two groups (a low number of data points only allows for these two groups to be analysed): energy efficient houses (A+,A) and energy inefficient houses (B to H). Furthermore, a decision tree with non-linear cut-off dates for year of

construction provides a precision, i.e. the ratio of predicted and true positives, of 79% (see Figure 0-25).

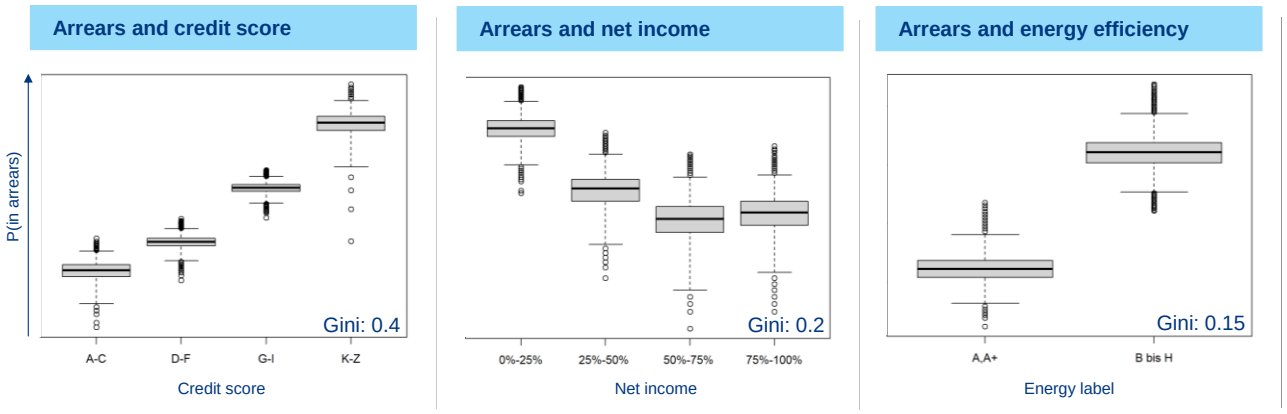
Figure 0-25 Approximate energy labels based on German data. Energy consumption data is based on an excerpt from the buildings database provided by co2online (2021).



Graphical analysis of effects

When analysing the data with many confounding factors, a stepwise and graphical analysis is highly recommended. A univariate analysis of expected effects is used to start. For example, arrears should be verified as they are more likely for worse credit scores and arrears drop off with increasing net income of the customer. Interestingly, a dependency of arrears on the energy efficiency of the building is observed already in this simple analysis (see Figure 0-26, right hand side). The energy label clearly contributes to the predictive power, as denoted by the Gini coefficient, even in comparison to the obviously very predictive credit scores and net income.

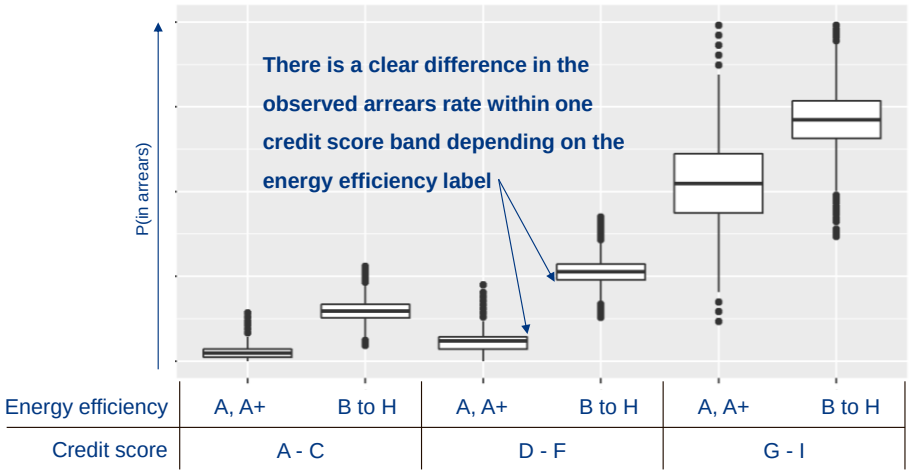
Figure 0-26 Univariate analysis of the probability of being in arrears



Note: Figure 0-26 to be found in Appendix D accompanying this report.

To assess whether the credit score is driving the effect of energy labels seen in Figure 0-27, this effect is assessed in bands of constant or similar credit scores. Again, a clear effect of energy labels is observed, highlighting that there is indeed an effect, which goes beyond a simple credit score. In all of the different bands of credit scores, loans associated with buildings of higher energy efficiency show a lower probability of being in arrears.[62] This result encourages a more elaborate analysis based on a stepwise logistic regression.

Figure 0-27 Bivariate analysis based on energy efficiency and credit score together.



[62] Note by WG members: this result highlights that current credit score do not fully capture this risk, which might become even more important in the future, when risk of becoming a stranded asset will increase for buildings with low energy efficiencies like B to H.

Stepwise logistic regression

Energy efficiency seems to affect credit risk, on top of well-established factors like credit scores. Since this effect might be confounded by other factors, we need to understand the impact of adding and removing factors to the statistical model:

1 The correlation between high energy efficiency and lower credit risk is highly significant, with the appropriate negative sign of the effect, i.e. good energy efficiency means less likelihood of being in arrears.

2 When adding credit scores, the effect of energy efficiency stays significant. Good, medium, and bad credit score show increasing add-ons to arrears probability, as expected. The steep increase in the Gini coefficient indicates that the model becomes measurably better, again in line with expectations.

3 Adding net income in the next step does not improve the model, and this coefficient is only barely significant. Again, this behaviour is expected, as net income is a typical variable included in a credit score.

4 Contract term does not add any information, which confirms that the time bias has been eliminated successfully by the study design.

5 Year of construction is the major variable of our proxy model for energy efficiency. Adding it with the high energy efficiency flag present reduces the significance of energy efficiency as a factor, since there is now overlapping information present. Nevertheless, energy efficiency remains significant on the 5% level as the EE label depends on a non-linear decision tree, comprising some additional information.

6 The distinction between smaller and larger houses does contribute information to some extent, with larger houses being less likely to be in arrears.

7 When removing the EE variable, the model no. 7 is less predictive than model no. 6 (see Table 0-11) and – not unsurprisingly – the year of construction gets highly significant, picking up most of the information previously contained in the EE variable.

8 A model with EE and year of construction is still predictive, but clearly discriminatory power is lost, confirming expectations.

Overall, this procedure confirms that statistically higher energy efficiency is associated with lower credit risk, and that it adds value to credit risk measurement even on top of well-established and powerful factors like credit scores.

Table 0-11 Results of the stepwise logistic regression procedure[63]

Stepwise modelling	1		2		3		4		5		6		7		8	
Model quality																
Gini coefficient	0,156		0,470		0,489		0,494		0,498		0,515		0,494		0,453	
Independent variable																
Energy efficiency (A,A+)	**-0,97**	***	**-0,91**	***	**-0,87**	***	**-0,81**	***	**-0,61**	*	**-0,66**	**	**-/-**		**-/-**	
	0,22		0,22		0,22		0,22		0,24		0,24					
Set of control variables																
Credit score																
D-F (good)			**0,61**	**	**0,59**	**	**0,60**	**	**0,60**	**	**0,59**	**	**0,60**	**	**0,60**	**
			0,22		0,22		0,22		0,22		0,22		0,22		0,22	
G-I (medium)			**1,79**	***	**1,77**	***	**1,78**	***	**1,76**	***	**1,76**	***	**1,76**	***	**1,79**	***
			0,21		0,21		0,21		0,21		0,21		0,21		0,21	
K-Z (bad)			**3,17**	***	**3,14**	***	**3,15**	***	**3,15**	***	**3,17**	***	**3,22**	***	**3,22**	***
			0,34		0,34		0,34		0,34		0,34		0,34		0,33	
Net income					**-1,06**	*	**-1,07**	*	**-1,05**	*	**-1,00**	*	**-1,1**	**	**-1,23**	**
					0,42		0,42		0,41		0,41		0,42		0,44	
Contract term							**-0,42**		**-0,40**		**-0,46**		**-0,58**	*	**-0,69**	**
							0,25		0,25		0,25		0,24		0,24	'
Year of construction									**-7,64**	*	**-7,80**	*	**-11,96**	***		
									3,60		3,48		2,84			
More than two-family house (Y/N)											**-0,55**	**	**-0,51**	*	**-0,47**	*
											0,20		0,20		0,20	

[63] Significance codes for p-values are '***' <0.1%, '**' 1% '*' 5%; coefficients of regression α are shown in boldface $\ln\frac{p_{arrears}}{1-p_{arrears}} = \alpha + \sum_{i=1}^{N} \alpha_i x_i$; cross-correlation between the variables has been assessed and strongly correlated variables have been excluded; variables are calibrated to a common scale. Final variable selection is based on the discriminatory power (Gini).

Summary

The results confirm a clear indication that energy efficiency label might be a relevant risk factor for mortgages. However, more in-depth investigations are required to further underpin the usefulness of the risk factor in credit risk models: Although much care has been taken to remove sources of bias, the data set might still contain residual bias (e.g. due to using a proxy model for energy efficiency). More data, in particular EPCs, are required to further investigate this effect in more detail. Overall, this study definitely corroborates the analysis performed by the Bank of England and others using data from Germany.

3.2.3 OP Financial Group (Finland)

OP Financial Group, owned by its customers, is Finland's largest financial services group. OP Financial Group is made up of over 100 OP cooperative banks and the central cooperative which they own, including its subsidiaries and affiliated entities.

This OP study was conducted as part of this WG and tries to answer the questions:

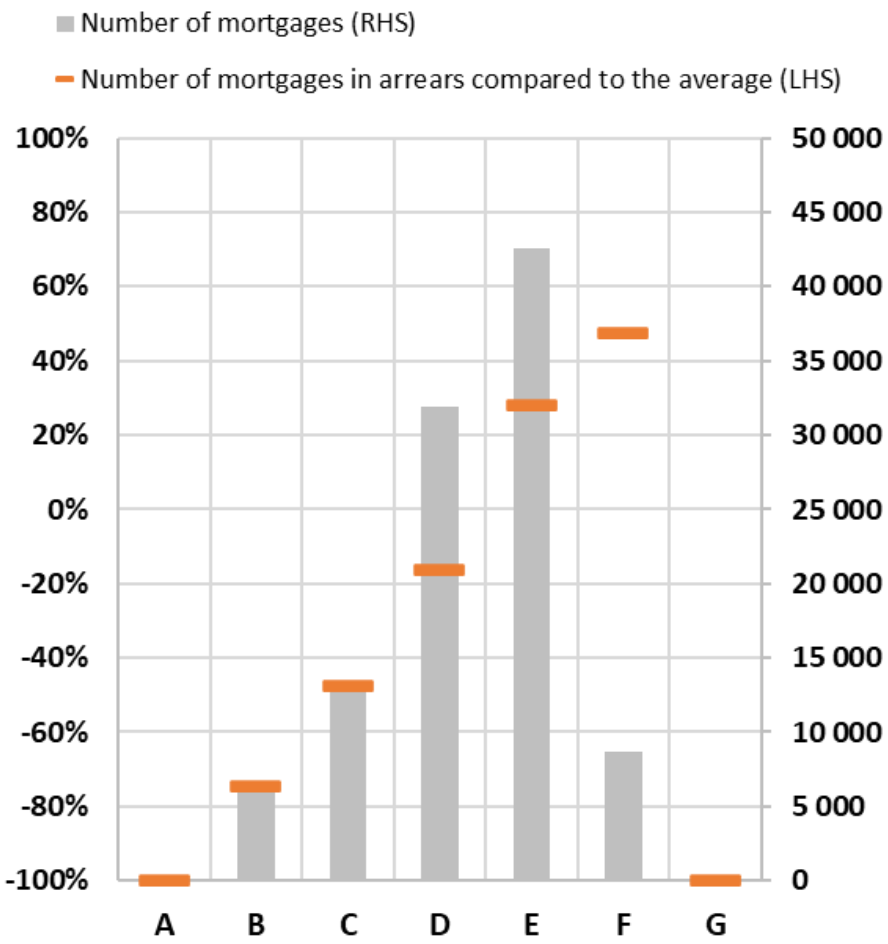
> Q1: What relationship do we observe between energy efficiency and default risk for Finnish residential mortgages?
>
> Q2: Is any observed relationship robust to the inclusion of a range of control variables?

Energy efficiency has so far not been a standard risk factor for the assessment of creditworthiness. Various studies[64] are now pointing towards a statistical relationship, which OP Financial Group wished to corroborate using their own data. As outlined in section 3.1.1, OP applied a proxy model to calculate EPC labels based on building age and the main heating source when actual data from the Finnish EPC registry was not available. Thereby the coverage of the OP portfolio with EPC labels was significantly improved.

Preliminary descriptive statistics show a negative relationship between mortgage arrears and EPC level. Figure 0-28 compares arrears at high and low EPC labels to the average. Compared to a D-rated home, B-C have lower arrears while E-F have higher - over 40% more mortgages are in arrears for F rated houses, with around 20% less for D rated houses. Both A and G also have low arrears however low observations in both groups make inference unreliable for these categories.

[64] e.g. Bank of England, January 2020; "Are high energy efficient properties less likely to default?"

Figure 0-28 Mortgages in arrears by EPC label



Econometric results

Credit risk is cumulative over time, i.e. the longer the observation period, the more likely a credit risk event will be. For the OP analysis, the observation period is fixed to a two-year period following first observation in Q1 2019. Many well-known factors may influence the credit risk of borrowers. In order to be able to distinguish the additional effect of energy efficiency, control variables are required and a clean data set has to be constructed, which reduces any bias as far as possible. Control variables considered in the OP analysis can be categorised as relating to the borrower (credit score, borrower age, number of debtors), the mortgage (loan-to-value, percentage loan-term remaining, loan-term) and wider economic indicators (municipality unemployment rate). Due to the OP cover pool sample having low numbers of observed defaults, robustly identifying a relationship between EPC rating and default is challenging. To that end, the primary outcome variable for all reported regressions is a binary variable indicating whether a mortgage is in arrears between Q1 2019 and Q1 2021.

Columns 1-6 in Table 0-12 below present results from a range of Logistic regression models, including a categorical measure of EPC along with additional control variables. Column 1 presents a parsimonious model with no other controls. In Table 0-12, columns 1-6 display results from a Logistic regression model in which energy efficiency is banded into High (A-C),

Medium (D) and Low (E-G) EPC level, starting with a parsimonious model with no controls (column 1) and step-wise inclusion of additional controls in subsequent models (columns 2-6). The results suggest that, relative to medium EPC, good EPC has a lower probability of arrears and bad higher. Taking the simplest model (1), the coefficients indicate that arrears are much less likely for good EPCs, roughly by a factor 3 in terms of probability. That result is in-line with the observation in Figure 0-28. The signs of the EPC coefficients remain consistent across models, however it should be noted that the magnitude changes substantially and coefficients are not statistically significant in models 5 and 6. Model 6 includes a number of additional control variables including whether a Government guarantee was in place, house type, value (€/m2) and average house prices and income in the municipality. Inclusion of these additional controls resulted in higher multicollinearity issues and reduced sample as the smallest municipalities were not included due to data availability.

Table 0-12 Logistic regression results with categorical EPC variable

		(1)	(2)	(3)	(4)	(5)	(6)
	Good EPC (A, B, C)	-0.6577	-0.4885	-0.4269	-0.4129	-0.2139	-0.0797
		(0.003)	(0.028)	(0.056)	(0.065)	(0.351)	(0.741)
	Bad EPC (E, F, G)	0.4401	0.2889	0.2892	0.2992	0.2244	0.2104
		(0.000)	(0.024)	(0.024)	(0.020)	(0.095)	(0.132)
	Control variables:						
Mortgage	LOAN-TO-VALUE		0.0582	0.0582	0.058	0.008	0.0079
			(0.000)	(0.000)	(0.000)	(0.006)	(0.007)
	Loan term left, %		-2.4894	-2.4174	-2.3964	-1.3229	-1.2119
			(0.000)	(0.000)	(0.000)	(0.000)	(0,000)
	Loan term		-0.0306	-0.0222	-0.0214	-0.019	-0.0208
			(0.009)	(0.060)	(0.071)	(0.113)	(0.099)
Borrower	Credit score					0.4544	0.4522
						(0.000)	(0.000)
	Borrower age			0.0138	0.0139	0.0229	0.0243
				(0.010)	(0.010)	(0.000)	(0.000)
	Number of debtors			-0.3468	-0.3347	-0.3098	-0.3203
				(0.000)	(0.001)	(0.002)	(0.002)
Macro	Unemployment (municipality)				0.0203	0.0342	0.0587
					(0.308)	(0.104)	(0.074)
	5 other available variables						Yes
	Observations	102,225	102,225	102,225	101,919	101,918	99,012
	Notes: all models estimated with a binary dependent indicating whether a mortgage is in arrears between Q1 2019 and Q1 2021. p-values indicating statistical significance in parenthesis						

Following on from the work of NBS, OP next undertake a similar analysis except using a continuous measure of EPC, Table 0-13 presents results. Again, column 1 starts with a parsimonious model and subsequent models include additional control variables added in a step-wise manner. The results suggest that a better EPC is associated with lower risk in all model set-ups, the result is statistically significant in all models, except model 6.

Table 0-13 Logistic regression results with continuous EPC variable

		(1)	(2)	(3)	(4)	(5)	(6)
	EPC, continuous	0.3606	0.2391	0.2191	0.2204	0.1383	0.0858
		(0.000)	(0.000)	(0.000)	(0.000)	(0.047)	(0.263)
	Control variables:						
Mortgage	Loan-to-value		0.0582	0.0582	0.0581	0.008	0.0079
			(0.000)	(0.000)	(0.000)	(0.006)	(0.008)
	Loan term left, %		-2.515	-2.4402	-2.418	-1.3384	-1.2209
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	Loan term		-0.0298	-0.0215	-0.0208	-0.0188	-0.0207
			(0.011)	(0.069)	(0.081)	(0.118)	(0.100)
Borrower	Credit score					0.4549	0.4524
						(0.000)	(0.000)
	Borrower age			0.0139	0.014	0.0229	0.0243
				(0.009)	(0.009)	(0.000)	(0.000)
	Number of debtors			-0.3436	-0.3315	-0.3083	-0.3201
				(0.000)	(0.001)	(0.002)	(0.002)
Macro	Unemployment (municipality)				0.0193	0.0337	0.0595
					(0.335)	(0.108)	(0.070)
	5 other available variables						Yes
	Observations	102,225	102,225	102,225	101,919	101,918	99,012
	Notes: all models estimated with a binary dependent indicating whether a mortgage is in arrears between Q1 2019 and Q1 2021. p-values indicating statistical significance in parenthesis						

Summary

The OP results certainly point in the direction that more energy efficient buildings have lower risk. In most model set-ups the results are statistically significant, however inclusion of additional controls does have a substantial effect on the EPC coefficients. Further ongoing work involves sourcing additional data as the sample is relatively small and due to its lower credit risk, on average is not representative of the overall Finnish building stock. Expanding the sample would potentially allow an analysis of defaults in addition to the analysis on arrears provided in this case-study.

3.3 Methodological challenges and solutions

This section takes a critical look at the three new WG case studies, other presented work and academic research to assess where potential methodological problems may exist and what their solutions are for next steps of the Working Group and follow-up work by others.

3.3.1 Challenges

Challenge: Potentially biased data due to inclusion of government schemes (NBS and OP)

Not all borrowers are alike. Within the statistical models we can control for observables such as income or loan-to-value. However, there may be systematic differences across borrowers which are not explained by these variables. One such example is borrowers who availed of certain UK Government funded schemes such as Help to Buy, Shared Ownership or Right to Buy. These schemes typically funded high energy efficiency properties but were also characterised by high default rates. Including these mortgages in the analysis systematically biased the results. After thorough data inspection and cleaning, NBS removed these mortgages from the analysis. OP Financial Group followed a similar sequence of data check when analysing the Finnish data and controlled for such schemes with the inclusion of indicator variables in their statistical models.

Challenge: Correlation of control variables

In any multivariate analysis it is important to check for the collinearity of control and primary explanatory variables. If highly correlated control variables are included, this may bias the coefficient on the target variable and result in either an understatement or overstatement of the true relationship, depending on the direction of the bias. For example, evidence has shown that the energy efficiency of a property can be correlated with its market value, therefore including property value as a control in the regressions may impact the results. A number of steps can be taken to mitigate this issue (i) generate a correlation matrix for outcome and all explanatory variables, (ii) introduce control variables into the model in a step-wise manner, omitting any that are highly correlated with the primary explanatory variable, (iii) at each step assess the improvement to model fit of adding additional controls and the change (if any) in the coefficient of the key explanatory variable, and (iv) select the set of controls that maximise the explanatory power of the model (Gini and AIC).

Challenge: Detecting the additional effect of energy efficiency (beyond credit scores, net income, etc.)

Before the effect of energy efficiency on credit risk can be assessed, it is important to account for the variance explained by well-known credit risk drivers in the first place. Therefore, it is important to consider a set of classical risk drivers as controls in a stepwise regression analysis as outlined above, e.g. including:

- Aggregated factors:
  - Credit score (developed internally or by external rating agencies) [*][65]
- Customer properties:

[65] [*] indicates a minimum set of highly recommended control variables

- Borrower age
- Socio-economic factors like for example education
- Net income [*]
- Number of borrowers

- Contract properties:
  - Loan term at origination [*]
  - Relative loan term (current date – date of origination) / loan term
  - Loan term left
- Collateral properties:
  - Size and type of building
  - Building age or year of construction [*]
  - Location and regional information
  - Valuation of the building (at a defined point in time e.g. at loan origination)
  - Loan-to-value ratio for collateralized loans (at a defined point in time e.g. at loan origination)
- Macroeconomic factors (optionally and depending on length of observation period)
  - Inflation
  - HPI growth
  - Recession indicator
  - Unemployment rate in municipality

Most of the analysis carried out so far has been focussed on retail mortgage portfolios which typically contain rather straightforward contractual agreements and collateral structures. Non-retail loans and in particular SME loans are typically more complex and need to be analysed carefully.

The application of control variables is also linked to question of data set construction, e.g. which cohorts are defined and the time horizon over which they are tracked (see section on Data Sourcing and Preparation). Mortgage portfolios require long time horizons due to low default rates, but this may negatively affect the results when macroeconomic effects overlay the effects to be observed. Homogeneity of the observed cohorts as well as of the observed periods of time is a prerequisite for robustly assessing the effect of energy efficiency.

Challenge: Shedding light on the potential causalities behind the observed correlation

Obviously, observing a correlation does not necessarily imply causation. Statistical methods per se can only reveal the patterns within the datasets under consideration. Rigorously determining whether a causal mechanism explains the observed patterns requires applying active interventions in suitably designed experiments, e.g. in randomized clinical trials. Such designed experiments were out of scope for the WG, however there was a specific discussion on how to provide further evidence for causalities, in particular pushed by the members of the Dutch hub.

One possible causal transmission mechanism would be that more energy efficient houses save energy costs which in turn increases available household income, and thereby improves the ability to serve the mortgage. Such a mechanism could be tested to some extend by a sensitivity analysis,

e.g. by simulating increased/decreased energy costs on household income and probability of default. However, there was a general agreement that the currently observed impacts on energy costs (mostly in the range of tens of Euros per month) could not explain a substantial impact given typical monthly mortgages payments (on the order of hundreds to a thousand Euro depending on repayment schedules). This might change in the future when fossil energy costs substantially increase, but such effects are not yet present in the current data sets which observe current and past behaviour. Therefore, this route was not pursued further, but causal analysis remains on the list of useful methods for future study. For example, it has been discussed in the WG whether or not homeowners who renovate their home make more prudent economic decisions in general.

3.3.2 Methodological outlook

Once the basic effect is clearly established, more advanced methods of analysis can be applied. In particular, more advanced methods can go beyond simple correlation to establish a first assessment of causality.

For example, matching procedures[66] allow to establish pairs of observations which are similar with respect to all but one factor, thereby effectively creating a control group as well as treatment group. However, this method has to be applied carefully in case of correlated matching variables.

Heterogeneity analysis: Differential effects by income and other covariates

The analysis and results produced by the WG point to a clear relationship between energy efficiency and credit risk. This result is statistically significant even after including variables such as NBS's IRB Behavioural scorecard, which is a highly informative predictor of credit risk. Therefore, we cannot rule out that a relationship exists, but it is still not clear what the exact mechanism is behind this result. The analysis can control for a number of observed borrower-, loan and building characteristics, but unobserved and omitted variables may still play a role.

Further, ongoing work is trying to unpick this result by exploring heterogeneity in the relationship between EPC and credit risk for different income groups. Essentially this analysis asks the question – is there the same (or linear) relationship between energy efficiency and credit risk for all income groups, or is it a differential effect (or non-linear) at different points in the income distribution?

NBS are currently exploring this very question. Preliminary results suggest that energy efficiency has a bigger impact at the lower end of the income distribution which would make intuitive sense – borrowers who are already

[66] E.g. the procedure 'MatchIt' for nonparametric pre-processing in order to perform a parametric causal inference selects matched samples of the original treated and control groups with similar covariate distributions. It can be used to match exactly on covariates, to match on propensity scores, or perform a variety of other matching procedures c.f. [Ho, Imai, King, and Stuart (2007) <DOI:10.1093/pan/mpl013>]

income constrained are less likely to default when their energy costs are lower. Further analysis is required to fully understand this result.

Alternative methods

The primary methods employed by this WG were stepwise Logistic Regression on a binary dependent variable. A range of other modelling frameworks exist which take the form of parametric, non-parametric, econometric and machine learning techniques. Widely used in the literature are survival analysis techniques, such as the Cox Proportional Hazards model. These are estimated as maximum-likelihood models, which seek to estimate the probability of delinquency, default and/or prepayment, conditional on the loan surviving to date as a function of observed characteristics. This estimation can also be generalised to include time-varying coefficients.

In this WG analysis, the probability of default (or arrears) was examined. Another framework that could be applied is the "competing risks framework". This approach considers default and prepayment as competing risks to be estimated jointly.[67] In addition, one could also examine the role of "trigger events" or economic shocks, such as unemployment in causing default.[68] In both cases the identification strategy involves modelling the probability of default and/or prepayment as a function of loan and borrower characteristics, such as the loan-to value ratio, the borrower's credit score, debt to income ratio and other characteristics. Further work could expand the analysis by incorporating such methods.

[67] Deng, Y., Quigley, J.M. and Order, R., 2000. Mortgage terminations, heterogeneity and the exercise of mortgage options. Econometrica, 68(2), pp.275-307.

[68] Elul, Ronel, Nicholas S. Souleles, Souphala Chomsisengphet, Dennis Glennon, and Robert Hunt. "What" Triggers" Mortgage Default?." American Economic Review 100, no. 2 (2010): 490-94.

Findings at Member State level from national hubs

4 Findings at Member State level from national hubs

Different European countries are at different stages in the development of their energy efficiency investment and financing markets. The working group's national hubs were tasked to identify findings which would enable the reader of the EU-level recommendations to understand national contexts.[69]

The Netherlands and UK are countries with large and mature mortgage markets and have also led with public EPC databases, aligned regulators and banks actively promoting the renovation of their existing mortgage portfolio with attractive products. Germany has been a benchmark for two decades in public-private collaboration in buildings energy renovation through its state backed KfW's leading programme that drives customers to higher energy efficiency standards but delivering these directly through all German retail banks. Germany is yet to empower their retail lenders with an easily accessible database of energy performance certificates. Italian banks have embraced energy efficient mortgages, having been among the first to develop correlation data, and Italy to offer fiscal incentives to support renovation. Spain, France and Scandinavia have leading banks that have been very engaged with EFFIG's work and while their detailed work was not undertaken in time for this report, EEFIG expects this analysis will be available in the near future.

The following findings from the work of EEFIG WG hubs have been grouped into sets emerging from the different geographies covered. It should be noted that Appendix C contains a fuller description of the Hub methods and minutes. Also, this should not be considered a full nor complete assessment of 27 member states, as the EEFIG WG did not have experts from all 27 countries.

Germany: Improved EPC data and stronger strategic and consistent approaches

The German hub considered the potential for improvements which facilitate the financing of more energy efficient buildings especially in relation to data, policy alignment and guidelines for implementing energy efficiency further into the bank credit processes:

- Reliable and comparable, yet pragmatic data access required: To comply with the EU taxonomy, disclosure regulation, future stress testing, risk assessment etc. banks need a sound, robust and efficient way to either acquire data on the energy efficiency of buildings and the impact of renovation measures, or at least measures need to be taken to calculate the energy efficiency with an agreed methodology. Coordination is required to achieve a level playing field and provide agreed best practices for an efficient data supply. Such a data supply should comprise at least: the information according to §§ 16 of the

[69] See Appendix C

German Energy Saving Ordinance (EnEV), date of validity, Type of building, address or post code, year of construction, year of installation of the heating system, number of apartments, floor space in square meters, type of energy source for heating, energy consumption of the building (kWh/(m²*a), primary energy demand of the building (kWh/(m²*a).

- Impacts on valuation and credit process: There is a need to consider solutions which fit into the operational needs of financial institutions, thereby facilitating the fast and effective uptake and implementation of the required measures. Training programs for appraisers as well as standards for an efficient data supply are crucial in this context. EPC data is key across Europe to assess energy efficiency on a standardised basis. For example, it would be helpful to be provided with two to four EPCs per loan over the lifetime of a retail mortgage loan. The Sustainable Finance Committee of the German government has proposed to build up a European database, which would share standardised EPC data with owners, lenders, and investors. This would dramatically reduce the costs for owners, lenders, and investors.

- Effective and consistent regulatory framework: A reliable, effective, and consistent regulatory framework supports the fast and efficient build-up of the necessary capabilities at financial institutions to perform their role in promoting energy efficiency and the effective adaption of business and risk management schemes. Financial regulation on national and EU level should consider the full framework of buildings finance e.g. existing building legislation and create common minimum standards across jurisdictions and levels of government. Alignment of buildings and financial regulation timelines would contribute to an efficient and faster implementation of new standards.

- Strategic risks for residential real estate include the need for increased governmental support for private clients: Smart approaches, policy-based as well as market-based, are needed to further incentivise the uptake of green financial products in the residential real estate market as well as to avoid cliff effects for older or even historical buildings, which could have social effects, in particular to elderly people living in older buildings.

Scandinavia and Netherlands: Improved financial regulatory guidance based upon the statistical evidence

Lower risk weights for energy efficient mortgages in Finland would possibly make higher energy efficient mortgage pricing more competitive and thereby attract greater investment in the energy efficiency of buildings (both new construction and renovation). This would improve the overall energy efficiency of buildings and hence their CO2-emissions performance. Clear guidelines would accelerate uptake as EU Taxonomy's criteria for buildings (especially DNSH criteria) are applied in practice and the quality of EPC and other energy performance data must be improved. Without clear guidelines, the uptake of the EU Taxonomy in the building finance sector will likely be delayed.

In Sweden, banks are keen to make products and offers easy to understand and easy to engage into renovations for customers. Product development as well as communication strategies for energy efficiency improvements must improve. Construction of new buildings is much easier to handle in terms of energy efficiency, whereas renovations and upgrades need more attention and maybe also clarifications in order for the banks to push energy efficiency improvements.

In Denmark, an increased focus on energy renovation of homes is one of the key sustainability activities for banks along with greater integration of sustainability into advisory services, incorporation of climate factors info risk management, and the development of new green and sustainable products. The financial sector is committed to actively use its established points of contact with customers to engage in dialogues about possible energy improvements, for instance in connection with renovations and house purchases. Finance Denmark has, together with the Danish Energy Agency, launched a home energy renovation campaign "Build it better – Renovate for the climate" and developed a series of tools to be used by financial advisers when engaging in dialogue with customers on energy improvements. Further, the Danish Energy Agency provides webinars to better prepare financial advisers for the energy renovation dialogue with customers.

In the Netherlands, as banks commit to greater engagement with existing mortgage clients further improvement of data quality for EPCs is required. Further, as ING, ABN Amro and Triodos are advanced in their own thinking on the precise causal mechanism of the observed correlation effects uncovered by EEFIG, a local assessment of these in the Netherlands is considered beneficial.

France: Calls for greater regulatory guidance and data transparency

With the support of the French supervisory authorities, a national framework would accelerate a common approach and improved data availability. The impact on the credit processes of such data should be considered when setting up such a framework (reflecting the results of the EBF case study[70]).

More specifically in the context of the broader work of the EEFIG, the French hub is keen to see further development of a proxy Green Ranking (pGR) of the shared loan books by leveraging existing approaches (e.g. GWF by Natixis) and public standards (cf. PCAF initiative, Paris Agreement Capital Transition Assessment (PACTA) methodology) with a focus on energy efficiency. For wholesale banking, the impact of such a pGR and energy efficiency rating can be assessed on credit losses using defaulted loans data detailing work-out processes, cure rates, final losses, and differences with performing loans, such as that housed and collected by GCD. For retail banking the impact of energy performance can be further

[70] https://www.ebf.eu/wp-content/uploads/2021/01/EBF-UNEPFI-report-on-EU-Taxonomy-Case-studies-Annex.pdf

explored on residential mortgage PD, observed defaults rates, LGD, final losses (data to be collected).

Finally, the Open-Source Metric PACTA and its stress test module can be amplified to include energy performance as a variable and measure the alignment with climate change scenarios of a cross-financial-institution shared loan and investment book (to be consolidated by GCD) in eight economic sectors: power, coal mining, oil gas upstream sectors, auto manufacturing, cement, steel, aviation and shipping (75% of global greenhouse gas emissions).

Conclusions and recommendations

5 Conclusions and recommendations

This chapter summarises the working group's key conclusions across all three of the pillars of the framework described in the introduction. It ends with a series of EU-level recommendations which are built from the primary statistical analysis conducted by a few members of the working group, the overall conclusions of the work, as well as drawing from the findings of selected national hubs which are summarised in chapter 4.

5.1 Working Group Conclusions

The work of this WG has uncovered and robustly assessed new evidence from nearly 800,000 mortgages across several countries in Europe to conclude that there is a statistically significant correlation between the energy performance of building collateral and mortgage credit performance.

EEFIG's work described here suggests a negative relationship between energy efficiency and probability of default (PD). The degree of energy efficiency matters i.e., more energy efficient buildings are associated with relatively lower risk of default. In fact, the work suggests that **mortgages associated with high and medium energy efficiency properties are in the region of 20% less likely to default than those associated with low energy efficiency properties.**

This conclusion is directionally supported by years of academic and parallel studies conducted in other contexts which point in a similar direction and that were reviewed by the WG over the last two years. While EEFIG work has demonstrated a statistically significant correlation between energy efficiency and credit risk in multiple geographies, additional work should continue to corroborate this relationship in additional EU Members States and to further assess the causality of the relationship.

Furthermore, a review of the literature on green premium in real estate including studies from several European countries (NL, IE, DE, FR, PT, RO, UK) showed that higher energy efficiency (as per EPC rating) has an upward influence on the overall housing market prices and rental values. The studies indicate that the most efficient properties can attract a price premium of up to 10% for valuations and approximately 5% for rentals, compared to the least efficient or non-rated properties. Several studies furthermore find less liquidity for the lowest rated buildings. The literature review which includes several more recent studies (2019-2020) hence confirms the JRC 2018 findings of an observed increase of 3-8% in the sale price of residential assets resulting from energy efficiency improvements, as well as an increase of around 3-5% in residential rents compared to similar properties.

However, the evidence is variable and effect sizes depend on the level of energy efficiency and other factors including geography and prevailing housing market conditions.

These two results are complimented by research which shows that green project finance, commercial real estate and empirical work on ESG-rated companies tends to show a non-negative relationship between the better performing ones and those in non-compliance or less sustainable. We note that this latter conclusion is from a review of the research. Overall, the bulk of the evidence produced by this WG's members has come from the UK, Finland, Germany and Italy, and through thirty national hub meetings conducted over the last two years covering seven geographical areas. The significant majority of the primary and secondary evidence reviewed and produced supports the hypothesis that energy efficiency is negatively correlated with credit risk. While national circumstances differ greatly, there is a general consensus that where EPC data is more widely available, there is a likelihood for these results to be replicated the findings across more markets.

The technical and research work of this WG supports the Commission's position on energy efficiency and mortgage collateral value which was contained in its new sustainable finance strategy adopted on 6th July 2021. Specifically, the observation that measures to enhance the energy efficiency of a mortgage collateral can be considered as increasing property values.

The data from mortgage secured loans is better structured and more widely available than that from unsecured green loans and finance. Notwithstanding efforts with its members, the WG was unable to significantly advance its understanding of correlations between energy efficiency and creditworthiness in the unsecured loan sector.

The major barrier which has prevented further evidence from emerging and a greater assignment of resources by financial institutions to energy efficiency is the lack of access to EPC data for banks: Countries that do not enable mortgage lenders to access (publicly or privately) the data from EPCs lag behind in their ability to unlock the statistical evidence that could support improved capital treatment for energy efficient mortgages, and thereby encourage the growth of that market. While it is universally true that even where EPCs have been publicly available for almost 10 years, data quality and a stronger connection to real usage is required, any real data is better than a proxy estimate. Having said that, proxies have been surprisingly good at predicting EPC levels in countries where only a small number of EPCs are available.

Finally, the overall results and conclusions are more robust and clearer than the consortium had expected at the start of this process two years ago. The success of proxy methods and the coherent statistical analysis undertaken on 800,000 mortgages was considerably higher than anticipated. Contributions from all active working group members far exceeded the consortium's initial expectations. This report is testimony to the strength of

the EEFIG group and its work in its third phase and continues to innovate and produce market leading work. All Member States are invited to replicate and encourage those banks not participating in EEFIG to join or repeat this work locally.

5.2 Working Group Recommendations

Building upon the statistically significant correlation between energy efficiency and credit risk identified through this new primary and secondary work (described here) in multiple European geographies, the following are related recommendations for further work that were also identified by the working group:

1 **Continue to explore the relationships between energy efficiency and credit performance in additional geographies and for a wide base of risk parameters:** The statistically relevant evidence in this report comes substantially from the UK, Finland, Germany and Italy. The working group is also aware of on-going work in Scandinavia, France and Spain which was not ready for the time of publication of this report. We note the difficulty of finding available and relevant statistical knowledge and depth within financial institutions, the time taken for such work and the data confidentiality issues of banks which make it harder for academic statisticians to access to their data. National supervisory authority engagement would be helpful in addressing this resource-prioritisation-privacy gap. Furthermore, additional risk parameters like LGD, where data could not be made available by banks for this WG, should be investigated. LGD data requires long time series of historical data, which needs to be collected appropriately and in high quality and needs specific methodologies for their assessment.

2 **Encourage energy efficiency to be considered as a specific component of the EBA's 2023 assessment of whether a dedicated prudential treatment of exposures related to assets and activities associated substantially with environmental and/or social objectives could be justified.** The evidence provided in the context of this WG supports this recommendation and members of this WG hope that by 2023 other evidence will also have emerged from other markets including Germany, Netherlands, Scandinavia, Spain, France and Italy on this point through work initiated in the context of the EEFIG WG. When being considered as input to the EBA work on the potential for a dedicated prudential treatment of exposures related to assets or activities associated substantially with environmental and/or social objectives, EEFIG however notes that the clarity and concreteness of energy efficiency as a unique component of possibly hundreds of other less clear and less well understood ESG factors merits separate consideration from the generic ESG classification.

3 **Promote further work with mortgage lenders in country-level working groups can build on the causality of the evidenced statistical relationships between energy efficiency and credit risk:** Large data sets are required to isolate the specific causal factors for a correlation, and while this was available in three samples for this work, it is clear that larger datasets from additional countries in different cultural environments would be additive to the existing evidence. This would require better quality EPC data and can only be undertaken with considerable ex-ante resource commitment by leading lenders in those countries targeted.

4 **Track the evolution of the green premium and brown discount research over time:** While there is a significant amount of work documenting the evidence for material valuation differences between low and high energy performing buildings, the shape and mid-point of this relationship appears to be migrating as the regulatory environment changes. It would be useful to track the evolution of the green premium and brown discount research over time especially as more countries implement minimum energy performance standards and align buildings with new 2030 climate and energy efficiency targets. This specific assignment could be the basis for a new EEFIG working group as the fit-for-55 package is implemented.

5 **Consider further work to advance the understanding of correlations between energy efficiency and creditworthiness in the unsecured loan sector.** In the unsecured loan sector classifications according to energy efficiency are still in the process of being implemented at banks, which prevented this working group from undertaking statistical analysis in the unsecured lending sector over the last two years. However, from 2022, as financial institutions start to provide better non-financial disclosure and embed the EU Taxonomy definitions across their loan books, this statistical work will become more possible to do. A specific working group to undertake this work at EU level could be launched in 2023.

6 **Develop and price dedicated products based on the identified relationship between credit risk and energy efficiency.** Lenders and in particular mortgage lender should consider collecting data on EPC and other relevant energy performance metrics. This will support the development of dedicated products as well as the adoption of energy efficiency in IRB models, impacting the calibration of adequate prices for such products.

7 **Amend the EU regulatory framework to ensure that lenders identify, record, and maintain current the energy performance of their buildings' collateral including the assessment of energy efficiency as a risk factor in their IRB PD and LGD models.** Data availability regarding energy performance of collateral turned out as one of the major factors determining the range of analysis possible to this working group. Further analysis based on enhanced data

collections by financial institutions will facilitate a better understanding of risks within financial institutions.

8 **To achieve all of the above, Member States must promote and fund increased availability of standardised information on the thermal performance of both residential and commercial buildings so that their banks' understanding of all of these relationships can be enriched.** Easy access to national EPC data is essential and a harmonized interface to national EPC registers would be beneficial for access to EPC information. The necessary EPC data that banks require to undertake and replicate the analysis described herein is urgently required to avoid the need for the use of proxies and improve geographical relevance of the results. This can certainly be achieved in the current review of EU legislation in the fit-for-55 package.

PowerPoint presentation of the main results, conclusions, and recommendations

Appendix A PowerPoint presentation of the main results, conclusions, and recommendations

[This section will be completed after WG review and be a precis of the report and its conclusions without any new information – until written please focus on the report content]

Further references

Appendix B Further references

This section provides an overview of the steps taken to compile the knowledge base that was collected during the term of the EEFIG working group.

B.1 Identifying relevant knowledge

The WG has identified and placed key reports, research and information in a shared WG knowledge library, to ensure that all WG members and the wider EEFIG have access to the latest knowledge on this subject. These library items were categorised by the secretariat for the WG and placed into the area of the shared drive structure which is most relevant and practical – geographical (from National Hubs), methodological (from the Methods sub-WG) and general.

Knowledge library items have been provided by WG members, desk-based research on behalf of the WG by the consortium and from a wider request for materials to the EEFIG and parallel initiatives. The contributed items target knowledge that increase WG members' understanding and evidence on the following:

- Understanding how the level of energy efficiency of an asset impacts the default risks to lenders. This is critical to scale-up energy efficiency finance and drive business models for banks and asset managers.

- Evidence or analysis undertaken on the quantitative relationships between energy efficiency improvements and lower credit risk in associated loans. This has the potential to unlock benefits for borrowers, lenders and investors alike, thus mobilising additional investments in energy efficiency in Europe.

- Analyses or studies designed to assess a correlation between energy efficiency, sustainable components / ESG and credit risk. These may also help shape future banking regulatory considerations for energy efficient and related assets.

- Evidence and projects designed to support the Commission's Action Plan on Financing Sustainable Growth,[71] Action 8 on "Incorporating sustainability in prudential requirements". Here, the Commission will explore the feasibility of the inclusion of risks associated with climate and other environmental factors in institutions' risk management policies and the potential calibration of capital requirements of banks as part of the Capital Requirement Regulation and Directive[72]. Also the Supervisory Review and Evaluation Process (SREP) will separately

[71] ibid COM/2018/097 final

[72] Noting that the Commission has mandated the EBA, through CRR 501c, to assess and report by June 2025 on whether "a dedicated prudential treatment of exposures related to assets or activities associated substantially with environmental and/or social objectives would be justified."

address this. Projects or methods allowing for a recalibration of capital requirements, based on data and the assessment of the prudential risk of banks exposures, would also need to be coherent with the EU taxonomy on sustainable activities (connecting to other EEFIG WGs and partners).

- There is also a "miscellaneous category" (general) which collates items which WG members believe are pertinent to the WG's goals, but do not easily fit the above framework.

The studies described in this report and assembled in the WG knowledge Hub are examples of the current broad landscape and they frame this WG's and the consortium's understanding of the current state of play. Concise summaries of the reports and their impact have been used to keep WG members up to pace with recent research and progress by "fellow travellers" (authors, WG members, observers and research hubs supporting and in contact with the WG).

Appendix C National hub assessments at Member State level

The "Hub-and-Spoke" with specific national hubs structure was set in motion by the WG as a way to contrast and discuss the deep statistical analysis being performed by banks in the national contexts, recruit new observers from each Member State and stimulate replication studies that would use the methods and insights produced by the WG members (see section 1.4).

This section provides a summary of the findings over the past two years from the meetings of the seven national hubs of the WG. The seven national hubs each met between four and six times over the period to discuss activities related to the WG at Member State level. Over the two years there were an aggregate number of 30-40 separate national hub meetings. All of the national hubs were offered the opportunity to present at each formal WG meeting, and in most cases a selected spokesperson provided a clear and succinct summary of relevant matters from their hub's discussion.

Given the incredible volume and depth of discussions in each national context, hubs were asked to prepare a two-page summary of their insights for this report by answering four key questions:

> Q1: What are currently the main drivers pushing forward energy efficiency in the financial sector in your country?
>
> Q2: What are currently the main activities in the financial sector of your country, reacting to those drivers?
>
> Q3: What are the main lessons learned from the discussion in the WG for the activities in your country? What did the WG contribute to these discussions / policy actions?
>
> Q4: What are the explicit recommendations to further promote energy efficiency in the financial sector of your country?

The seven responses from each geographic hub are summarised for this report in the below four consecutive sections that provide the consolidated pan-European response to the four questions in the following sections.

C.1 Main drivers for energy efficiency in the financial sector

For most European financial institutions, the initial drivers are divided between a client's needs for specific green financial instruments, and the government regulatory initiatives. However, in Germany, banks' commitments to climate targets and external regulatory requirements is driving a focus on energy efficiency. Due to the long duration of maturity of

real estate loans and the low investment budgets of private individuals, energy efficiency is one of the main focus areas in the short term (including e.g. measurement of energy efficiency, risk assessment, development of adequate products and trainings)

Overall, German banks are working proactively towards a financial market, which supports the delivery of the EU's "Green Deal" agenda, in parallel to providing the economic impulse post-COVID. In Germany, two main drivers are pushing the developments in the financial market: incoming regulation and market forces anticipating the effects on the market. Starting with regulations, the EU taxonomy, SFDR, NFRD (to be replaced by the new CSRD) as well as EBA and ECB supervisory guidelines not only substantially broadened the perception of the necessities of these changes, but also lead to the initiation of projects at German banks to practically implement these policies in business and risk management.

All of the major German market participants, including private banks, cooperative banks, savings banks, as well as more specialised banks are driving the developments. Markets for green loans and bonds received a significant boost in the last two years, and many market participants start to assess their portfolios in terms of their alignment with the Paris goals. However, the financial markets seem to react faster than the consumer markets and more incentives for upgrading buildings are required for a better synchronisation of both markets in a target-oriented manner.

EU Taxonomy and climate targets

The EU Taxonomy has also increased the interest in energy efficiency in the financial sector, as illustrated in Finland. In addition, investor demand for green bonds grows rapidly and that makes banks put more emphasis on energy efficiency, for example energy efficiency of residential mortgages for green covered bonds. So far in Finland there has not been a strong push from retail customers. Regulators require financial sector operators to understand and integrate sustainability into lending and investment activities. Furthermore, Finland aims for carbon neutrality by 2035 and that also affects banks.

In Sweden, government ambitions regarding reduced CO_2 emissions are high. Sustainability is a key focus for all major financial institutions today, and there has been a dramatic increase the last two years. The taxonomy has accelerated the interest and is in focus in the financial market in 2021. Banks and financial institutions already have had a high focus on both green bond issuance and green loans based on energy efficiency in the last two to three years. All major real-estate developers demand access to green loans as they build according to high energy efficiency standards. There is also an increasing demand from households and tenants to increase energy efficiency and increase usage of solar panels and energy efficiency measures.

To achieve its ambitious goal of reducing Denmark's CO2 emissions by 70 percent by 2030, the government established 13 climate partnerships in 2019 tasked with proposing specific initiatives to reduce carbon emissions

and strengthen the green competitiveness of the corporate sector. Finance Denmark, together with Insurance & Pension Denmark, Active Owners Denmark and the Danish Association of Asset Management and Investment Firms, participate in the financial sector's climate partnership. Furthermore, the EU taxonomy for sustainable activities, and the sustainability-related disclosure requirements are key driving factors.

The UK has been very actively pushing its mortgage lenders with a number of initiatives which have taken place in recent years including the launch of UK Government schemes such as the Green Home Finance Initiative and the Green Home Grants Scheme. In addition, the Green Finance Institute launched the UK's Green Home Finance Principles. This initiative is supported by a number of lenders and seeks to provide financial institutions with clear guidance and methodology for allocating finance towards retrofitting works in the UK.[73]

Text box 0-1 Case study: The UK

Case Study: UK Government Consultation requiring all lenders to link Energy Performance Certificate (EPC) data to their mortgage books.

The UK Government recognises that lenders are uniquely placed to influence their client's perspective on energy performance at critical trigger points such as home purchase, renovation, or re-mortgage. These critical interactions with customers provide an opportunity for lenders to develop products that promote investment in improving the energy performance of homes. The consultation report also sees lenders' developing this market as a way of reducing the risk of homes becoming stranded assets as energy performance standards are tightened.

The UK regulatory proposal is two-fold. Firstly, there would be mandatory disclosure of energy performance for all registered mortgage lenders on their websites and to Government on an annual basis, including (i) current percentage of properties in each EPC Band A to G; (ii) percentage of the portfolio with an existing EPC; (iii) gross value of mortgage lending by EPC band each year; and (iv) gross value of 'green' mortgage lending for energy performance improvement works by EPC band.

Secondly, UK lenders should voluntarily agree to meet a portfolio average of EPC Band C by 2030. To meet this target, the homes within a lender's portfolio would be required to have a mean average SAP point score of at least 69. SAP is the UK's Standard Assessment Procedure for Energy Rating of Dwellings, and the score is expressed on a scale of 1-100 with the higher the number the lower the running costs.

[73] https://www.greenfinanceinstitute.co.uk/wp-content/uploads/2021/05/GREEN-FINANCE-GREEN-MORTGAGES.pdf

Leading with Sustainability, fiscal programmes and delivering the Paris Agreement

Italian banks came together early in the first roundtable of the Energy Efficient Mortgage Action Plan (EeMAP)[74] in Milan in 2017 to help prepare of the energy efficiency mortgage pilot phase. Subsequent to that the Italian government has introduced one of the most generous fiscal credits to promote home renovation in Europe – known as the Ecobonus system – as well as promoting buildings renovation through a strong allocation from its recovery funds. In Italy, mortgage lenders quickly saw their game-changing role in relation to energy efficiency investment in buildings, opening new market opportunities, stimulating best practices and making banks' portfolios more resilient. Italian banks also saw energy efficiency as playing an important role in relation to sustainability issues, especially in synergy with all relevant stakeholders, to enrich the whole economic system and its actors.

Spanish banks have recognised the importance of energy efficiency in their real estate portfolios jointly driven by regulation as well as market needs. For example, Spain's BBVA is a green leader and has been participating in this WG methods sub-group. The Dow Jones Sustainability Index (DJSI), has been a strong driver for some banks to improve their sustainable bank positioning. Further, three leading Spanish banks are founding members of the Net-Zero Banking Alliance (NZBA),[75] whose mission is to ensure that their members' credit and investment portfolios are carbon neutral by 2050.

In the Netherlands, universal banks (like ING and ABN Amro) and specialised banks (like Triodos) have been proactively driving the market towards more sustainable real estate financing, with a particular focus on energy efficiency since 2015. These developments are driven not just by regulation, but also by a clear decision among these banks to align with the Paris Agreement.

French banks have also responded proactively to the novel challenges of climate risk, which has also been driven by the initiatives of the French banking supervisor, in particular since the Paris Agreement and the France's energy transition law.

C.2 Main activities in each Member State

Most European banks have started projects and initiatives to cover ESG related topics. The main activities include the implementation of the new regulatory requirements, including the EU taxonomy, non-financial

[74] Led by the European Mortgage Federation-European Covered Bond Council (EMF-ECBC) together with Ca' Foscari University of Venice, RICS, the Europe Regional Network of the World Green Building Council, E.ON and SAFE Goethe University Frankfurt– EeMAP sought to design and deliver an energy efficient mortgage product framework and accompanying framework, with a focus on property valuation guidelines and building energy performance indicators. It furthermore pioneered the analysis of the correlation between building energy performance and credit risk, with research conducted in Belgium, Italy, the Netherlands and the UK, which was later further developed under EeDaPP (see later in this report for more information).

[75] BBVA. (2021). BBVA joins the NZBA promoted by UN. [Website]. Retrieved from https://www.bbva.com/en/sustainability/bbva-joins-the-net-zero-emission-banking-alliance-promoted-by-the-united-nations/

reporting requirements, EBA and ECB guidelines on ESG and climate risk, as well as activities directed towards reshaping the markets with green loan offerings or green bond issues. These initiatives require upgrades in the banks' processes and IT systems which are currently under way in many institutions. Devising data collection strategies is one of the major focus areas at the moment as no comprehensive standard procedures exist yet.

Federated and regional approaches

The German financial market is more federated compared to other European markets, and initiatives have been started to improve data collection across banks, with some institutions pooling data e.g. to improve rating models or perform data analytics on ESG data sets. These topics have been discussed intensively in the German hub, and steady progress is being made.

In the German market, financial institutions have been working together in:

- the Asset Class Energy Efficiency WG developing an online calculation tool for six cross-sectional energy efficiency technologies as well as a first prototype of a financing platform for energy efficiency projects (link to platform in beta version: https://www.effinvest.de/)
- a mainstream data standard among real estate practitioners and data providers for maximum coverage (link to IBPDI: https://ibpdi.org/)
- an energy intensity and carbon footprint standard data in real estate valuation (according to recommendations of Sustainable Finance Committee (Link to Carbon Value Analyser: https://www.finanzforum-energieeffizienz.de/nc/tools-fuer-mehr-klimaschutz-in-gebaeuden/gewerbeimmobilien/carbon-value-analyser.html)
- On February 25, 2019, the State Secretaries' Committee for Sustainable Development decided to develop a sustainable finance strategy for the German federal government with the goal of making Germany a leading centre for sustainable finance. The Sustainable Finance Committee comprised of 38 practitioners from the financial industry and real economy, academia, and civil society. In February 2021, the Committee published its final report endorsing 31 recommendations (Link to report: https://sustainable-finance-beirat.de/wp-content/uploads/2021/03/210319_SustainableFinanceCommiteeRecommendations.pdf)

French banks have experience with green tagging their loan books for many years internally with ESG and Climate Risk indicators, which includes the topic of energy efficiency and credit risk, yet French banks do not have a common framework to share and analyse data. GCD has started to develop such a starting point by also considering the necessity for the financial sector to integrate a variety of climate related requirements into the entire investment chain. There is a strong need for open-source shared data – starting with agreeing cross-industry on common language and concepts,

because no unique approach is currently available. Institutions have started works on a variety of different metrics and are beginning to get a holistic picture that can be consolidated cross-industry for helping to understand main-stream dynamics as well as allowing like-for-like comparisons or the identification of extreme specific situations (outliers).

In the context of the WG French hub, GCD and Natixis are engaging in a collaboration to amend GCD's data set with a further contribution from Natixis, which would enable the study of LGD in relation to green loan criteria.

In the UK, a number of banks and building societies have taken steps to link their mortgage books with energy performance data. This is an important first step in building the evidence base. In terms of opportunities for banks and borrowers, eleven banks and building societies have launched green mortgages since the beginning of 2020. These products offer discounted mortgages to buyers of energy efficient homes and additional credit for home renovations.

The Danish financial sector launched its first sustainability report in June 2021. At the end of 2020, more than nine in ten financial institutions offered sustainable products, e.g. green and sustainable loans to finance home energy improvements. The sector organisation Finance Denmark has developed a framework for financed emissions accounting for the financial sector, paving the way for members to deliver on the recommendation of setting targets for the reduction of carbon emissions from investments and lending in connection with the annual report from 2021 and 2022, respectively. Furthermore, the Danish Investment Association made the first sector-wide commitment to reduce the carbon footprint of Danish retail equity investment funds by 75% in 2030 relative to the MSCI All Countries World Index in 2020. Further to this, several banks and mortgage banks have developed user-friendly tools to help homeowners assess the benefits of home energy improvements.

In Finland, banks are working on how the EU Taxonomy can be applied in the national context. For example, it is unclear how the Do no significant harm (DNSH) criteria should be proved for buildings with available data. In Sweden, the interpretation of the EU Taxonomy and managing data related to the taxonomy and other regulatory requirements remain paramount. Furthermore, integration of external data regarding energy efficiency and system development for capturing and using data is critical to allow Swedish banks to advance their analysis in this area. Across Scandinavia, banks are trying to understand their lending and investing better from sustainability point of view.

In Spain, leading mortgage lender BBVA, where mortgages account for 55% of its retail portfolio,[76] has carried out a detailed analysis looking to establish a relationship between energy efficiency of the buildings it finances and the clients' probability of default and arrears. The analysis includes an assessment of the collateral value and the coverage proportion with respect to the energy efficiency of the building, to also assess any potential impact on the LGD variations due to energy performance. Work is ongoing and this WG hopes to include the results in its final report.

Text box 0-2 Case study: Italy

Case Study: Italy focus from EeDaPP report on correlation analysis between energy efficiency and risk

72,980 individual Italian mortgage loans were selected by the EeDaPP project from an initial sample from Italian banks according to a set of criteria. Each loan was required to have borrower credit score which reduced the sample period to mortgage origination years 2012 to 2019. To exclude outliers, the loan-to-value was restricted to a maximum value of 1.1. The type of borrower is "individual" with one mortgage per borrower. The property type was required to be either "apartment" or "house". The property status falls into one of the three categories: new/retrofitted, used, to be renovated. The buildings' construction year ranges between 1900 and 2019. Finally, each individual borrower is associated with exactly one building and vice versa. After applying the above selection criteria, our final dataset totals

For the EeDaPP econometric evaluations, two major methodologies were used: the Logit model and the Cox model. **Both estimations showed a negative correlation between EE and the owners' probability of default, 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.**

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.

Indeed, several initiatives and market-based mechanisms have been developed with the aim to foster and guide EE investments in Italian buildings, such as tax rebates, subsidies, grants, green loans, energy efficiency obligation schemes, credit facilitating procedures through specially dedicated EE funds, EPCs, nearly zero-energy buildings requirements, etc.

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.

[76] BBVA. (2020). BBVA Report on TCFD. Retrieved from https://shareholdersandinvestors.bbva.com/wp-content/uploads/2020/10/BBVA-report-on-TCFD_Eng.pdf

New product development

In the Netherlands, Triodos and ING have developed new products, which promote energy efficiency in the real estate sector. For example, Triodos Bank offers very competitive interest rates for highly energy efficient real estate. They reported that they have built up relatively young portfolio with a particularly low amount of defaults, which for the moment precludes statistical analysis. Default rates are in general relatively low in the Netherlands due to a consistent attitude regarding the fulfilment of the debt service for mortgage loans. Nevertheless, the Triodos example shows that the low default rates are also the result of the particular choice of business model, which attracts green customers. Triodos benefits from energy efficient investments with lower risk costs, which in turn reinforces the assumption that there is a correlation between energy efficient investments and lower credit risk.

C.3 Lessons learned from the EEFIG WG discussions

France is illustrative of many EU countries where EPCs are not publicly available nor collected and presented in a central database. The situation is similar in Spain, Germany and several CEE countries. French banks have been active participants in the WG, and are leading in the move towards to ESG and green tagging, and yet they are significantly disadvantaged from taking the lead when compared with the UK, Netherlands or Italy. Nevertheless, GCD holds enormous amounts of French banks' commercial real estate data and is working with French banks to develop a proxy-approach (similar to that presented by OP Financial Group in Finland in section 3.2.3), possibly expanding to retail mortgage data when these would be collected.

For many banks, energy efficiency is already one of their major business goal for the coming years. Banks will be needed to support the improvement of energy-efficiency for commercial and residential buildings. The discussion in the German hub clearly highlighted the need for a broader, long-term view: mortgages are long-term and will remain on the books of the banks for decades. At the same time, currently only 23.8% of residential real estate properties in Germany are financed by a mortgage loan.[77] Therefore, the financial industry only has the lever to promote energy efficient investments in about 25% to 50% of the residential building stock, depending on the turnover in the sales market. Therefore, there is a need to reduce the barriers for consumers to take advantage of sustainable finance products for investing in energy efficiency. That will also improve the stock of green investments available to investors.

The main findings of German WG hub can be summarised in four elements:

› Effective and consistent policy framework: The new policy framework goes well beyond the traditional business model of financial institutions

[77] German bureau of statistics, Wirtschaftsrechnungen Fachserie 15, Heft 2, 2019, page 74/75

and therefore represents significant challenges in its implementation. A major impact on credit processes, IT systems, required skill sets for staff, and portfolio structure is expected in the near future. Despite a clear commitment to Paris Agreement and target of a climate-neutral building stock by 2045 the current policy framework might not be able to trigger the needed target-oriented investments.

- Reliable and comparable, yet pragmatic data access required: For most countries, like Germany, data on energy efficiency (measures energy consumption on single building level or EPC) is still not publicly available or easy to collect. For a typical portfolio, only 60% of the clients may be legally required to have an EPC. Even if required, not all documentation for mortgage loans contain EPCs, e.g. in cases where the loan was contracted before the law was in place. Currently, only a minority of about 5% of the customers does hand over this information to the respective bank. These barriers have been discussed intensively in the German hub, resulting for example in the proposal to assess the feasibility of a proxy model for German residential buildings.

- Impacts on valuation and credit process: When originating a mortgage loan, banks are required to estimate the collateral value in the credit process. In this process, the needed renovations are included also as a haircut on the collateral value. As part of these renovation costs also energy-efficiency measures are included (e.g. heating system, windows). However, there are no legal obligations to estimate the energy efficiency of a building. Since most properties are required to have EPCs, it seems to be natural to require EPC data within the valuation process. However, in this regard, there are operational and cost driven possible barriers which should be taken into account: shortage of adequate appraisers, high cost of appropriate appraisals, amount of documentation required, complexity regarding building physics, and impact of customer behaviour.

- Strategic risks for residential real estate including the need for governmental support for private clients: In many mortgage loans for private clients, the duration for a new mortgages loan is up to between 30 and 40 years (only with regular repayments on the principal amount, no additional repayments). Therefore, already as of today banks are giving loans to private clients who are paying back this loan in 2050. Depending on the CO_2 reduction targets to achieve and the client's financial wealth, additional governmental effort/support is needed to reach the Paris targets 2045/50 while limiting the social impact on less wealthy homeowners. This will ultimately also have a strategic impact on whether German banks can deliver on the strategic commitment for net zero emission in 2050.

Very similar and complimentary to the German findings, the key lessons learned from the UK EEFIG WG hub's interaction are as follows:

- The availability of a large, publicly accessible EPC register makes the UK an attractive geography for conducting analyses similar to the studies in this report. EU countries should aim to follow the UK model by consolidating and making EPC data available.

- The Bank of England study that was updated and presented to the WG supports the relationship between energy efficiency and mortgage arrears in the UK Hub and has provided methodological guidance to the hub members and wider group.

- The Bank of England study provided a reference point for NBS to base their own analysis on. Ultimately, NBS was able to advance the work significantly by including the IRB default definition as the key outcome measure in their analysis.

- Data from UK Government funded schemes such as Help to Buy, Shared Ownership or Right to Buy had to be removed from the NBS and other records to see the underlying correlations. This data cleaning procedure was critical for the overall project as it removed a significant source of bias from the UK analysis, and also provided learnings for other country case studies, such as the OP Financial Group analysis in Finland.

There have been many discussions among Scandinavian hub members on whether there is enough evidence to lower the risk weights of energy efficient mortgages. In Sweden, presentations in the context of the WG showing the correlation found between energy efficiency and PD in other countries have propagated further domestic analysis.

In Spain, BBVA is using PACTA to steer its lending portfolios with climate scenarios compatible with the objectives of the Paris Agreement. PACTA's methodology has allowed BBVA to focus on sectors with the greatest climate impact, such as cement and steel,[78] and their supply chain for production. BBVA is also looking at the social as well as energy dimension of home renovation to tackle high energy prices and sustainability for customers to rally behind it.

In Italy, the eighth (2020) edition of the Italian Real Estate survey (a collaboration between ENEA, the Institute for Competitiveness (I-Com) and the Federation Italian Professional Real Estate Agents (FIAIP) involving about 550 agents) suggests that the ecobonus (and superbonus) scheme did not have a marked effect on the demand for the highest EPC properties but did increase demand for those in the lower EPC bands that could be upgraded with tax benefits. This has tended to support the view within

[78] BBVA. (2021). Annual Report 2020: Non-financial Information Report. [Website]. Retrieved from https://accionistaseinversores.bbva.com/microsites/cuentasanuales2020/en/management-report/non-financial-information-report/index.html

banks that energy efficient homes are worth more as collateral for mortgages in Italy.

Finally, among banks in the Netherlands, the WG hub enabled greater clarity on the problem and the sharing of previous research and work undertaken on the topic in the Netherlands and its relevance to other EU countries. The main lessons learned fall into three areas:

- Although EPC data is basically available in the Netherlands,[79] the accuracy of the EPC data is very poor since 80% of the energy labels in their portfolio are only preliminary and probably outdated. This observation was corroborated by all participants of the Dutch hub. However, as the example of Triodos shows, an appropriate data collection integrating the credit process allows for achieving a full portfolio coverage with high quality EPCs.

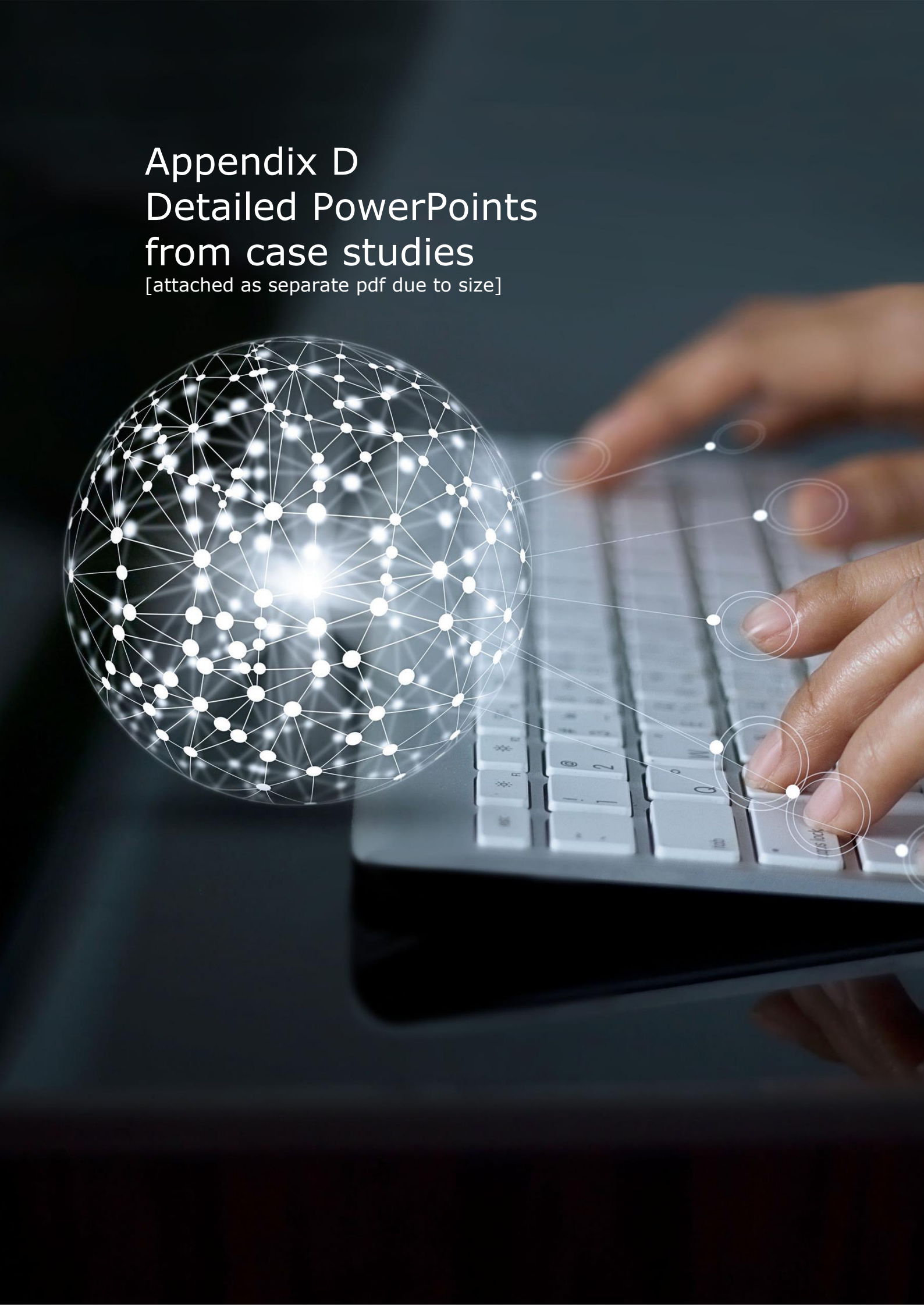
- Sharing data on (defaulted) mortgages in the Netherlands is difficult due to a number of confidentiality concerns and GDPR. The research being undertaken by Netherlands banks is done in house – yet data and analytical resources are scarce.

- The observation of a correlation between credit risk and energy efficiency may not necessarily imply a corresponding causal mechanism. This topic is currently investigated at Dutch banks, including the analysis of effects due to sample selection. For example, the Dutch hub discussed the findings from UK's Bank of England and the Italian results from Energy efficiency Data Protocol and Portal (EeDAP), as well as other related studies on value increase based on energy efficiency in Dutch buildings and studies trying to identify a correlation between energy efficiency and the probability of default (PD) for mortgages. In the Netherlands, average energy efficiency may save between EUR 25 and EUR50 per month and it is hard to imagine that this would be the exclusive reason for avoiding defaults. Notwithstanding this observation, several studies were added to the WG's knowledge base and the Dutch central bank was cited as an advanced regulator with respect of this area.

[79] Data availability at the OpenGeoPortaal, Ministerie van Ekonomische Zaken en Klimaat: https://ez.maps.arcgis.com/apps/webappviewer/index.html?id=fc93368cc92a4a39b5acc34017365c4f

Appendix D
Detailed PowerPoints from case studies

[attached as separate pdf due to size]



Appendix E
Overview of literature and documents

ORG.	AUTH.	YEAR	TITLE	TYPE	SECTOR	PRE-DEFINED KEYWORDS	KEYWORDS	CONFIDENTIAL	GEOGRAPHICAL COVERAGE	HUB
American Council for an Energy-Efficient Economy	Barrett, J. & Stickles, B.	2016	Lending for Energy Efficiency Upgrades in Low- to Moderate-Income Communities: Bank of America's Energy Efficiency Finance Program	Report	Residential buildings	SMEs;#Programmes;#Non-EU;#Residents	USA. America. Low- to Moderate-Income Communities. Energy Efficiency Finance Program (EEFP). community development financial institutions (CDFIs). Bank of America. ACEEE	No	USA	Italy - Hub
American Council for an Energy-Efficient Economy	Sussman, S. et al.	2020	Energy efficiency in real estate listings: a controlled experiment	Report	Residential buildings;#Non-residential buildings;#Commercial property	Real estate market;#Residents;#Tools;#Market-based mechanisms;#Energy performance;#Non-EU	Real estate, energy efficiency information	No	USA	General research
American Council for an Energy-Efficient Economy	Barrett, J.	2016	Bank of America's Energy Efficiency Financing Program shows path to combining energy savings and community development	Other	Residential buildings	Programmes;#Residents;#Energy performance	Financing, federal funding, efficiency potential	No	USA	General research
American Economic Review	Eichholtz, P. et al.	2010	Doing Well by Doing Good? Green Office Buildings	Research paper	Non-residential buildings	Real estate market;#Non-EU	Green building	Maybe	USA	Methods sub-WG

Asian Development Bank Institute	Ablaza, A. et al.	2020	Off-balance-sheet equity: the engine for energy	Report	Financial institutions	Market-based mechanisms;#Tools; #Non-EU	energy efficiency capital, energy efficiency finance, energy performance contracting (EPC), energy service company (ESCO), equity finance, off-balance sheet finance	Maybe	Asia	General research
Bank of England	Guin, B. & Korhonen, P.	2020	Staff Working Paper No. 852 - Does energy efficiency predict mortgage performance?	Report	Residential buildings	Residents;#Market-based mechanisms;#Non-EU	Credit risk, green mortgages	No	UK	United Kingdom - Hub
Bank of France	Allen, T. et al.	2020	Climate-Related Scenarios for Financial Stability Assessment: an Application to France	Report	Financial institutions	EU Regulation;#Market-based mechanisms	Climate Change, Scenario Analysis, Economic Modelling, Financial Stability	No	Global	General research
Barclays	Desclée, A. & Hyman, J.	2016	Sustainable investing and bond returns - Research study into the impact of ESG on credit portfolio performance	Report	Financial institutions	Market-based mechanisms	credit market, ESG	Yes	n.a.	General research
Board of Governors of the Federal Reserve System	n.a.	2019	Charge-Off and Delinquency Rates on Loans and Leases at Commercial Banks	Tool	Residential buildings;#Commercial property	Real estate market;#Residents; #Non-EU	Loans, Leases	No	USA	General research

BPIE	Volt, J. et al.	2020	Energy performance certificates - Assessing their status and potential	Report	Residential buildings;#Non-residential buildings;#Public buildings;#Commercial property	EU Policy;#EU Regulation;#Renovation	EPC markets, X-tendo project	No	EU27	General research
Bundesregierung	n.a.	2021	Shifting the Trillions - Ein nachhaltiges Finanzsystem für die Große Transformation	Policy Study	Financial institutions	Market-based mechanisms;#EU Policy	Sustainable finance	Maybe	Gernmany	General research
Central Bank of Hungary	Gyura, G.	2020	(Capital requirement) incentives to promote energy efficient loans in Hungary	Presentation	Residential buildings	Real estate market;#EU Policy;#Residents	Housing market, Mortgage	Maybe	Hungary	General research
Climate Strategy & the UN Environment Inquiry	Sweatman, P. & Robins, N.	2017	Green Tagging: Mobilising Bank Finance for Energy Efficiency in Real Estate	Report	Financial institutions	Real estate market;#EU Policy;#Market-based mechanisms	Green tagging	Maybe	Global	General research
Copenhagen Economics	Næss-Schmidt, S. et al.	2018	Kick-starting mortgage financing of energy savings renovations: digitalisation as a key driver	Report	Residential buildings	Residents;#Renovation	Mortgage, digitalisation	No	Global	General research

Council on Economic Policies	Monnin, P.	2020	Shifting Gears: Integrating Climate Risks in Monetary Policy Operations	Policy Study	Other	EU Regulation;#EU Policy;#Market-based mechanisms	Climate risks, monetary policy, central banks	No	EU27	General research
DENEFF, PwC, BPIE	n.d.	2020	Carbon Value Analyser	Tool	Financial institutions;#Commercial property	Tools	Property valuation,	Maybe	Global	Germany - Hub
Deutsche Bank	Horn, T.	2020	Analysis Energy Efficiency - Method Sub-group: 2nd Meeting "Retail Session"	Presentation	Residential buildings	Renovation;#Residents;#Real estate market;#EU Policy	Mortgage	Maybe	Gernmany	Methods sub-WG
DEXMA - Energy Management	n.a.	2016	The complete playbook for financing energy efficiency	Report	Financial institutions	Market-based mechanisms;#Programmes	Loans and Subsidies, Tax benefits	Maybe	Other	
DODGE Data & Analytics	n.a.	2016	World Green Building Trends 2016	Report	Residential buildings;#Non-residential buildings;#Commercial property	Real estate market;#Residents;#Non-EU	Green buildings	Maybe	Global	General research
DWS Research Institute	Birt, M.	2020	May 2020. Green, healthy buildings as economic stimulus EU policy recommendations on starting a paradigm shift	Other	Residential buildings;#Non-residential buildings;#Public buildings;#Financial institutions;	Energy performance;#Certification;#EU Policy;#EU Regulation	Rebuild Europe, renovation, building performance standards, CRREM,	No	EU27	Italy - Hub

					#Commercial property					
EeDaPP	n.a.	n.d.	The Energy Efficient Mortgages Initiative	Policy Study	Residential buildings;#Non-residential buildings;#Financial institutions;#Commercial property	EU Policy;#Market-based mechanisms;#Demand;#Supply;#Tools;#Programmes	Mortgage, tool, financing mechanism	No	EU27	General research
EEFIG	n.a.	2020	1st Meeting of the Method sub-group: Approach and Way Forward	Presentation	Other	EU Policy	Mission, next steps	Maybe	EU27	Methods sub-WG
Elsevier	Curtis, J. et al.	2015	Using census and administrative records to identify the location and occupancy type of energy inefficient residential properties	Research paper	Residential buildings	Energy performance;#Residents	Energy performance certificate, building energy rating	No	EU27	General research
Elsevier	Fuerst, F. & McAllister, P.	2011	The impact of Energy Performance Certificates on the rental and capital values of	Research paper	Commercial property	Energy performance;#Certification;#Real estate market;#Non-EU	Energy Performance Certificates, Commercial property values, Real estate appraisal	Maybe	UK	Methods sub-WG

			commercial property assets							
Elsevier	Kahn, M. et al.	2014	Carbon emissions from the commercial building sector: The role of climate, quality, and incentives	Research paper	Commercial property	Real estate market;#Demand;#Energy performance;#Non-EU	Durable capital, Technology, Human capital, Carbon mitigation	Maybe	USA	Methods sub-WG
Elsevier	Kok, N. & Jennen, M.	2012	The impact of energy labels and accessibility on office rents	Research paper	Commercial property	Real estate market;#Energy performance;#Demand;#EU Policy	Commercial real estate, Valuation	Maybe	EU27	Methods sub-WG
Energy efficiency Data Protocol and Portal	n.a.	2018	Energy efficient Data Protocol and Portal Presentation	Presentation	Residential buildings	Real estate market;#Tools	Mortgage, protocol	Maybe	EU27	General research
Energy efficiency Data Protocol and Portal	Bertalot, L. et al.	2018	Energy efficiency Data Protocol and Portal - Project website	Report	Residential buildings	Real estate market;#Tools	Mortgage, tool, financial mechanism	No	EU27	General research
Energy efficiency Data Protocol and Portal	European Data Warehouse, TXS GMBH, EMF-ECBC	2019	Technical report on existing template and key green data collected	Report	Residential buildings	EU Regulation;#Market-based mechanisms;#EU Policy	ECB templates, ESMA Templates, Harmonised Transparency Template	Maybe	EU27	General research
Energy efficiency Data Protocol and Portal	Bertalot, L. et al.	2019	White paper on a common minimum pan-European green reporting criteria	Report	Residential buildings;#Financial institutions	Real estate market	Mortgage, Data tree, Financial data	No	EU27	General research

Energy efficiency Data Protocol and Portal	Billio, M. et al.	2020	Final report on correlation analysis between energy efficiency and risk	Report	Residential buildings	Real estate market	Credit risk, Green mortgages	Maybe	EU27	General research
Energy efficiency Data Protocol and Portal	Bertalot, L. et al.	2018	Dissemination & Communication Plan	Report	Other	Tools	Communications, Dissemination plan	Maybe	EU27	General research
Energy efficiency Data Protocol and Portal	Bertalot, L. et al.	2019	Report on dissemination and networking – Year 1	Report	Residential buildings	Real estate market	Communications, Informational tools, Channels	Maybe	EU27	General research
Energy efficiency Data Protocol and Portal	Leboulle nger, D. et al.	2018	Technical report - Energy Efficiency Reporting Criteria Market Mapping	Report	Financial institutions	Real estate market;#Market-based mechanisms;#EU Policy	Market initiatives, Financing, Financial reporting criteria	Maybe	EU27	General research
Energy efficiency Data Protocol and Portal	Leboulle nger, D. et al.	2018	Market needs and gaps in energy efficient mortgages' reporting protocol and data portal implementation	Report	Residential buildings	Real estate market;#EU Policy;#EU Regulation	Mortgage market needs, Mortgage market gaps,	Maybe	EU27	General research
Energy efficient Data Protocol and Portal	n.d.	n.d.	Energy efficient Data Protocol and Portal (EeDaPP) Initiative	Report	Residential buildings	Real estate market;#Tools	Mortgage, protocol	Maybe	EU27	General research
Energy Efficient Mortgages Initiative	Mahieu, V.	n.a.	Energy efficient Mortgages Action Plan (EeMAP) & Energy efficiency Data Protocol and Portal (EeDaPP)	Presenta tion	Residential buildings	Real estate market	Mortgage	Maybe	EU27	General research

European Banking Federation & United Nations Environment Programme Finance Initiative	n.a.	2021	Case study: BNP Paribas - Application of the EU Taxonomy for mortgage loans granted to individuals	Other	Residential buildings	Renovation;#Residents;#EU Policy	Mortgage, EU Taxonomy	No	France	General research
European Banking Federation & United Nations Environment Programme Finance Initiative	n.a.	2021	Case study: Caixabank - Application of the EU Taxonomy for retail mortgage loans	Other	Residential buildings	Real estate market;#EU Policy;#Residents	Mortgage, EU Taxonomy	No	Spain	General research
European Banking Federation & United Nations Environment Programme Finance Initiative	n.a.	2021	Case study: Credit Suisse - Application of the EU Taxonomy for the real state sector & EFTA countries	Other	Residential buildings	Real estate market;#Non-EU;#Residents;#EU Policy	Mortgage, EU Taxonomy	No	Other	General research
European Banking Federation & United Nations Environment Programme Finance Initiative	Raux, C. & Fischer, S.	2021	Testing the application of the EU Taxonomy to core banking products: High level recommendations	Report	Financial institutions	SMEs;#EU Policy;#Market-based mechanisms	EU Taxonomy, banking products, retail lending, SME lending,	No	Global	General research
European Central Bank	n.a.	2020	Guide on climate-related and environmental risks - Supervisory expectations relating to risk management and disclosure	Report	Financial institutions	Market-based mechanisms;#EU Regulation	Climate and environmental risks, risk management, credit risk	No	EU27	General research

European Commission	n.a.	2018	Action Plan: Financing Sustainable Growth	Report	Financial institutions	EU Policy;#EU Regulation;#Programmes	Sustainable finance, EU	No	EU27	General research
Federazione Italiana Agenti Immobiliari Professionali	Campo, V.	2020	Immobiliare,Fiaip-Enea-I-com:Forte aumentodelle ristrutturazioniconstandardenergetici elevati	Other	Residential buildings;#Non-residential buildings	Energy performance;#Demand;#Residents;#Renovation	Impact of COVID-19 on positive energy renovations developments	No	Italy	Italy - Hub
Federazione Italiana Agenti Immobiliari Professionali	Campo, V.	2020	CentroStudiFIAIP: Con la pandemia a rischio 200mila postidi lavoro nella filiera del RealEstate	Other	Residential buildings;#Non-residential buildings;#Commercial property	Demand;#Supply	Real Estate Market, COVID-19.	No	Italy	Italy - Hub
Federazione Italiana Agenti Immobiliari Professionali	n.a.	2020	RAPPORTO ANNUALE 2020 LA CERTIFICAZIONE ENERGETICA DEGLI EDIFICI - EXECUTIVE SUMMARY	Report	Residential buildings;#Non-residential buildings;#Public buildings;#NZEB	Energy performance;#Certification	EPC, real estate market, executive summary	No	Italy	Italy - Hub
Federazione Italiana Agenti Immobiliari Professionali	n.a.	2019	OSSERVATORIO. immobiliare nazionalesettore urbano 2019	Report	Residential buildings;#Non-residential buildings;#Public buildings;#Commercial property	Real estate market	Real estate market in Italy 2019. Market overview	No	Italy	Italy - Hub

Federazione Italiana Agenti Immobiliari Professionali	Campo, V.	2020	OSSERVATORIO. immobiliare nazionale settore urbano 2019. SUMMARY OF	Other	Residential buildings;#Non-residential buildings;#Public buildings;#Commercial property	Real estate market	Real estate market Italy, market overview,	No	Italy	Italy - Hub
Federazione Italiana Agenti Immobiliari Professionali	n.a.	2020	RAPPORTO ANNUALE 2020. LA CERTIFICAZIONE ENERGETICA DEGLI EDIFICI	Report	Residential buildings;#Non-residential buildings;#Public buildings;#NZEB	Energy performance;#Certification	EPC, real estate market	No	Italy	Italy - Hub
Finanzforum energieeffiziens	n.d.	2017	Klimafreundliche Gewerbeimmobilien: Gebäudeeigentümer, Investitionsprozesse und neue Tools für mehr Investitionen in Klimaschutz	Report	Residential buildings;#Non-residential buildings;#Public buildings;#Financial institutions	Tools;#Market-based mechanisms	Commercial properties, investment processes, climate protection	No	Gernmany	Germany - Hub
Global Credit Data	n.a.	2020	Observed Recovery Rates Dashboard Real Estate	Report	Residential buildings	SMEs;#Real estate market	Collateral, Lending	Maybe	Global	Methods sub-WG
Global Credit Data	n.a.	2020	GCD for EEFIG	Presentation	Financial institutions	Real estate market;#SMEs	Default, Loans	Yes	EU27	Methods sub-WG

International Finance Corporation - World Bank	n.a.	2019	Green Buildings - A finance and policy blueprint for emerging markets	Report	Commercial property;#Residential buildings;#Non-residential buildings;#Public buildings;#NZEB	Real estate market;#Non-EU;#EU Policy;#Supply;#Demand;#Residents	Green buildings market	Maybe	Global	General research
Joint Research Centre	Zancanella, P. et al.	2018	Energy efficiency, the value of buildings and the payment default risk	Policy Study	Residential buildings	EU Policy;#EU Regulation;#Residents	Green value, Mortgage, Default risk	Maybe	EU27	General research
Jones Lang LaSalle	n.a.	2020	The impact of sustainability on value - Developing the business case for net zero carbon buildings in central London	Report	Non-residential buildings;#NZEB	Real estate market;#Non-EU	Real estate, BREEAM performance, green premium, brown discount	Yes	UK	United Kingdom - Hub
Journal of Sustainable Finance & Investment	Friede, G. et al.	2015	ESG and financial performance: aggregated evidence from more than 2000 empirical studies	Research paper	Financial institutions	Market-based mechanisms	second-order meta-analysis; vote-count studies; financial performance; ESG criteria; business case	No	Global	General research
Moody's Investors service	n.a.	2018	Default and recovery rates for project finance bank loans, 1983-2016: Green projects	Report	Residential buildings	Non-EU;#Market-based mechanisms	Credit performance, Green finance	Maybe	Global	General research

			demonstrate lower default risk							
Multidisciplinary Digital Publishing Institute - Energies	Crawley, J. et al.	2019	Quantifying the Measurement Error on England and Wales EPC Ratings	Research paper	Other	Energy performance;#Residents;#Non-EU	uncertainty; energy performance certificates; domestic buildings; dataset; mathematical modelling	No	UK	General research
National Energy Improvement Fund	n.a.	n.a.	Unsecured Energy Efficiency Loans Keystone HELP	Presentation	Residential buildings	Energy performance;#Residents	Data, HELP (Home Energy Loan Program)	Maybe	USA	General research
Nationwide Building Society	Benedi, C.	2020	Is EPC rating associated with default?	Presentation	Residential buildings	Real estate market;#Residents;#Non-EU	EPC, default rate	Maybe	UK	Methods sub-WG
Nature Energy	Shen, X. et al.	2020	Estimation of change in house sales prices in the United States after heat pump adoption	Research paper	Residential buildings	Residents;#Real estate market;#Non-EU	Electrification, Heat pumps	Maybe	USA	General research
OP Financial Group	Satka, V.	2020	EEFIG WG SR8 "Risk Assessment"	Presentation	Residential buildings	Real estate market;#Residents	Sustainability, Credit risk data	Maybe	Finland	Methods sub-WG
PwC	n.a.	2020	Measuring the financial impact of climate change on real assets	Presentation	Non-residential buildings	Real estate market;#EU Regulation	Real estate, financial impact	Maybe	EU27	General research
PwC	n.d.	2020	Risk & scenario analyses and asset valuation	Presentation	Financial institutions	EU Regulation;#Tools;#Market-based mechanisms	Valuation. climate-related risks and opportunities. financial impacts of climate policies. Carbon Value Analyzer	Maybe	Global	Germany - Hub

Real Estate Finance	Stevens, D. et al.	2019	Risks and Uncertainties Associated with Residential Energy Efficiency Investments	Research paper	Residential buildings	Residents	Energy efficiency investment, risks	No	Gernmany	General research
REVALUE	n.a.	2018	Energy Performance and Valuation of Social housing in Europe: a quantitative analysis	Report	Residential buildings	EU Policy;#EU Regulation;#Residents	Social housing	No	EU27	General research
Risk.net	Carruthers, D.	2019	Credit data: sustainable companies are better credit risks	Report	Financial institutions	Market-based mechanisms	Sustainable business, ESG, credit market	Maybe	Global	General research
RSU	Hansen, C.	2020	EE/ESG topics in wholesale financing - EEFIG Method Sub-group: 3rd Meeting "Non-retail Session"	Presentation	Residential buildings;#Non-residential buildings	Real estate market	Credit risk	Maybe	Gernmany	Methods sub-WG
Sustainable Architecture for Finance in Europe	Billio, M. et al.	2019	Buildings' Energy Efficiency and the Probability of Mortgage Default: The Dutch Case	Report	Residential buildings	Real estate market	Mortgage, Credit risk	No	Netherlands	General research
Sustainable Architecture for Finance in Europe	Pelizzon, L.	2017	Creating an energy efficient mortgage for Europe	Report	Residential buildings	Real estate market;#Residents	Mortgage, Default risk	Maybe	EU27	General research

The Institutional Investors Group on Climate Change	n.a.	2021	Net zero investment framework: implementation guide	Report	Financial institutions;#NZEB	Real estate market;#Tools;#EU Regulation;#Market-based mechanisms	Net zero investment framework	Maybe	Global	General research
UNC Center for Community Capital	n.a.	2013	Home Energy Efficiency and Mortgage Risks	Research paper	Residential buildings	Demand;#Supply;#Non-EU;#Residents	Mortgage	No	USA	
University	McCoy, D.	2020	EEFIG: Methods Hub: Non-retail session	Presentation	Commercial property	Real estate market;#Non-EU	Commercial assets, Green buildings	Maybe	UK	Methods sub-WG
University	Sayce, S. & Wilkinson, S.	2020	Decarbonising real estate: the evolving relationship between energy efficiency and housing in Europe	Research paper	Residential buildings	Demand;#Residents	Decarbonisation, European residential property	No	EU27	General research
University	Eichholtz, P. et al.	2013	The economics of green building	Research paper	Residential buildings;#Non-residential buildings	Real estate market	Green building	Maybe	USA	Methods sub-WG
University	Fowlie, M. et al.	2018	Do energy efficiency investments deliver? Evidence from the weatherization assistance program	Research paper	Residential buildings	Programmes;#Non-EU;#Residents;#Demand	WEATHERIZATION ASSISTANCE PROGRAM	No	USA	
University	Havlínová, J. &	2019	Verplichte energielabels hebben positief	Report	Residential buildings	Real estate market;#Residents	Green homes, Energy label	Maybe	Netherlands	Methods sub-WG

	Van Dijk, D.		effect op verduurzaming van huizen							
University	Eichholtz, P. et al.	2019	Moving to Productivity: The Benefits of Healthy Buildings	Research paper	Public buildings	Demand	Health of workers	No	Netherlands	
University	Eichholtz, P. et al.	2019	Environmental Performance of Commercial Real Estate: New Insights into Energy Efficiency Improvements	Research paper	Commercial property;#Residential buildings;#Non-residential buildings	Real estate market;#Certification;#Non-EU	Real estate, ESG investing	Maybe	USA	General research
University	Zhou, X. et al.	2020	Bank Green Lending and Credit Risk	Report	Financial institutions	Real estate market;#Non-EU	Green loan, Credit risk, China green credit policy	No	Asia	General research
University	Harenczyk, R.	2017	Mortgage delinquency risk and the energy efficiency of the collateral in the Netherlands	Other	Residential buildings	Residents;#Real estate market;#EU Policy	collateral, delinquency risk, mortgage bank	Maybe	Netherlands	General research
WIREs - Energy and Environment	Bertoldi, P. et al.	2020	How to finance energy renovation of residential buildings: Review of current and emerging financing instruments in the EU	Research paper	Residential buildings	Renovation;#EU Policy;#Energy performance	Building renovations. energy service companies, one-stop shops, sustainable energy financing	No	Global	General research

Appendix F Composition of the WG

FIRST NAME	LAST NAME	INSTITUTION	TYPE	HUB SUBGROUP	METHODS SUBGROUP	WG STATUS
Richard	Crecel	GCD	Other	FR	Methods	Member
Karen	Degeouve	Natixis	Private Sector Bank	FR		Member
Thierry	Laquitaine	AEW	Private Sector Bank	FR		Member
Elisabeth	Minjauw	BNP Paribas	Private Sector Bank	FR		Member
Giovanna	Santi	Allianz France	Financial Investor	FR		Member
Murray	Birt	DWS	Financial Investor	DE		Member
Wang	Diana	Institute for Energy Efficiency, University of Stuttgart	Research Institution	DE		Member
Simon	Hasse-Kleeberger	RSU Rating Service Unit	Other	DE	Methods	Member
Christoph	Hansen	RSU Rating Service Unit	Other	DE	Methods	Alternate
Volker	Heegemann	National Association of German Cooperative Banks (BVR)	Association (Finance Sector)	DE		Member
Benjamin	Langer	Allianz Deutschland AG	Financial Investor	DE		Member
Nicole	Röttmer	PwC	Consultancy	DE		Member
Anne	Michaels	PwC	Consultancy	DE		Alternate
Viola	Uphoff	National Association of German Cooperative Banks (BVR)	Association (Finance Sector)	DE		Member
Daniele	Westig	EMF-ECBC	Association (Finance Sector)	DE		Member
Tobias	Horn	Deutsche Bank	Private Sector Bank	DE	Methods	Member
Susann	Bollmann	DENEFF	Association	DE		Member
Christian	Elbers	Bafin	Regulator	DE		Member
Doris	Pluetzer	Bafin	Regulator	DE		Alternate
Frank	Pierschel	Bafin	Regulator	DE		Alternate
Bettina	Dorendorf	KfW	Public Sector Bank	DE		Member
Eva	Kracht	BMU	Regulator	DE		Member
Matthias	Morgenstern	GLS Immowert	Financial Investor	DE		Member
Christoph	Carlowitz	GLS Immowert	Financial Investor	DE		Alternate
Jonathan	Lynch	AIB plc	Private Sector Bank	IE		Member
Jana	Platau-Wagner	Bank of Ireland	Private Sector Bank	IE		Member

Harsha	Wadhwa	Bank of Ireland	Private Sector Bank	IE		Alternate
Luca	Bertalot	EMF-ECBC	Association (Finance Sector)	IT		Member
Silvia	Cappelli	CRIF	Association (Finance Sector)	IT		Member
Francesco	Portioli	CRIF	Association (Finance Sector)	IT		Alternate
Gianluca	Natalini	CRIF	Association (Finance Sector)	IT		Alternate
Alessandro	Fiorini	ENEA - Italian National Agency for New Technologies, Energy and Sustainable Development	Research Institution	IT		Member
Angelo	Peppetti	Italian Banking Association	Association (Finance Sector)	IT		Member
Ettore	Piantoni	CEN CENELEC JTC 14	Other	IT	Methods	Member
Serena	Razzi	Italian Banking Association	Association (Finance Sector)	IT		Member
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Mats	Olding	Swedbank AB	Private Sector Bank	SCAND		Member
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Mihkel	Utt	Swedbank AS	Private Sector Bank	SCAND		Member
Aneta	Lemler	BBVA	Private Sector Bank	ES	Methods	Member
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Benjamin	Guin	Bank of England	Central Bank	UK		Member
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Katrin	Weissenberg	EBA	Regulator	EC or OBS		Observer
Anne	Kleppe	BCG	Consultant	EC or OBS		Observer
		FISMA	Regulator	EC or OBS		
		FISMA	Regulator	EC or OBS		

Appendix G WG meetings package

[Presentations and minutes of meetings are attached as separate pdf due to size]

Table G-14 WG Timeline and key milestones

ACTIVITY	TIMING	NOTE
First WG Meeting	March 2020	Inception report (14 Jan 2020) circulated prior to meeting
1st Interim Report	April 2020	Inception Report, submitted with updated knowledge base and discussion and conclusions from the WG meeting
Invitation to second WG meeting	May 2020	Including agenda and 1st Interim Report
Second WG Meeting	June 2020	Update from national hub work, presentation by Bank of England and launch of Methods subgroup
Third WG Meeting	October 2020	Update from methods subgroup and national hubs, with presentation of EeDaPP Italian study
Invitation to fourth WG meeting	November 2020	Including agenda and draft 2nd Interim Report
Fourth WG Meeting	December 2020	Update from methods subgroup and seven national hubs, with presentation of H2020 projects and review of 2nd interim report
Submission of 2nd Interim Report	December 2020	2nd Interim Report, submitted with updated knowledge base, interim progress reports from the hubs and full workplan for 2021.
Agree 2021 "landing points" for the results which are being included in the final report (see below)	Jan-Feb 2021	WG members engaged in the identification of processes where the WG results can be useful and how to connect to them.
Fifth WG Meeting	February 2021	Update from methods subgroup and seven national hubs, with presentation of targets for final draft report (deliverable by April 2021)
National hubs and method subgroup conclude their work and inputs into the final report and provide written updates for inclusion in the draft.	Feb-Apr 2021	Each hub or subgroup to decide what is achievable and deliverable by end of April 2021 and establishes a process to deliver and document these objectives.
Sixth WG Meeting	May 2021	Final inputs from methods subgroup and seven national hubs, with presentation of

		inputs to final draft report and guests from EBA.
Submission of Draft final Report	August 2021	Draft final Report, submitted with updated knowledge base, final progress reports from the hubs and full conclusions.
Seventh WG Meeting	Sep 2021 / Oct 2021	Discussion of feedback to draft Final Report and review of conclusions with discussion of edits and final recommendations and how to communicate the results.
Submission of final report	October 2021	Final report, incorporating comments received to draft final report.

MJ-07-22-218-EN-N

Publications Office
of the European Union

ISBN 978-92-76-51512-8