Vrije Universiteit Amsterdam
Master Thesis

The Role of Green Bonds in the Energy Transition in the existing Housing Stock

Name: A.J. van der Ven (Hanne)

Studentnumber: 2622601

Supervisor: dr. H.L.F de Groot

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Abstract

Climate change is an urgent global matter. In the Paris Climate Agreement is agreed that greenhouse gas emissions must be halved by 2030 and that the EU should run entirely on sustainable energy by 2050. The built environment is responsible for approximately 40% of the greenhouse gas emissions of which about three-quarters is consumed by residential real estate. This Master Thesis investigates the policy instruments necessary to combat this pressing issue in the existing housing stock. A particular focus is given to green bonds, because it is a relatively new and understudied financial instrument. Green bonds can be of asset to existing policy instruments in order to speed up the energy transition. To determine the impact of green bonds on the energy transition in housing, an international empirical comparison analysis is conducted. No detailed data is available yet to estimate the effect of green bonds on real estate. Therefore, the international empirical comparison analysis estimated the associated effect of green bonds on the percentage renewable energy generated per country. This will still provide insight into the impact that green bonds have on the transition to sustainability. The analysis showed a positive effect of green bonds on the percentage of renewable energy. The pooled OLS regression showed a positive correlation with a value around 2.2 with and without time fixed effects of green bonds on the percentage of renewables at a 1% significant level. The fixed effects model showed a positive, yet insignificant result. Spatial differences among countries showed to be of some influence on the percentage of renewable energy. The availability of water and energy generated by hydro are positively correlated. Whereas the availability of wind showed no strong positive correlation with the percentage of energy generated by wind. The availability of sunlight provided inconclusive results and could benefit from a better database with a weighted average of sunlight per country. The vast majority of the use of proceeds of green bonds is in categories directly linked to real estate and its value chain, therefore it can be concluded that green bonds have a positive impact on the energy transition in real estate. The majority of the funds raised for real estate, namely 66%, is used for existing buildings. In order to let green bonds flourish and contribute to the energy transition the existing policy for green bonds needs to be enhanced. The policy recommendations consist of standardization of reporting and verification, additionality tests, standardization of taxonomies, certification of green bonds, public governance and the role of technological advancement.

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1 INTRODUCTION

Climate change is a worldwide phenomenon. The United Nations have made an agenda for sustainable development to combat this pressing issue. At its heart 17 goals have been designed requiring action of all countries. Regarding the built environment, number 7 and 11 of the sustainable development goals are directly linked. Namely, access to affordable and clean energy should be ensured and cities should be sustainable (United Nations, 2015).

In the Paris Climate Agreement, is therefore agreed that greenhouse gas emissions must be halved by 2030 and that the EU should run entirely on sustainable energy by 2050. The EU aims to be an economy with net-zero emissions (European Commission, 2022). This energy transition is an urgent matter. All economic sectors play a role in this transition to a climate neutral society. The built environment is responsible for approximately 40% of the greenhouse gas emissions (GRESB, 2018). About three-quarters of the energy consumption is consumed by residential real estate and the rest by commercial buildings (Nejat et al., 2015). Therefore, the residential sector plays a big part in the energy demand. There are drivers and also obstacles in this sustainable transition. Understanding the main drivers and obstacles provides insight into the type of policy that is necessary. The global demand for energy efficiency and retrofitting in buildings is growing. The policy instruments addressing the energy transition are of importance. The financial system is one of the policy measures that will undoubtedly play a crucial role in the acceleration of investments in clean energy and technologies. It represents vast green finance opportunities due to achievable short-term gains because of immediate cost-saving and value appreciation (Debrah, Chan, & Darko, 2022). This Master Thesis gives a particular focus to a relatively new financial instrument, namely green bonds. Green bonds are debt instruments that raise capital for projects that have a positive environmental impact. The green bond market is booming. It has reached over 1.5 trillion USD in cumulative issuance since the first green bond issued in 2007 (Jones, 2022). The green bond market has a high growth potential. Sean Kidney, the Climate Bonds CEO, has estimated a green bond issuance of 5 trillion USD by 2025 to deliver the necessary contribution to achieve the climate goals. It could enable an investment increase that is required. Little has been written about the impact of green bonds, solely on the yield difference with conventional bonds. In addition, the relation between green bonds and real estate is also an under-studied area (Debrah et al., 2022). According to the OECD quantitative scenarios, a push from policy makers and market participants is necessary in order to scale up the market to finance green projects that are vital for the energy transition (OECD, 2015). To achieve this target, policy makers should focus on overcoming current barriers as such to grow a green bond market with environmental integrity.

In this Master Thesis, the following research question is central: To what extent can green bonds contribute to the energy transition in housing and how should the policy design regarding green bonds look like in order to stimulate the energy transition as best as possible? To answer this question, the position of green bonds relative to other policy instruments will be examined and an empirical international comparison analysis with respect to green bonds is conducted to determine the impact. In addition, policy recommendations necessary for the green bond market to grow are discussed. When the answer to this question is identified and well understood, it contributes to the existing literature on green bonds and provides a clear incentive for enhancing the current policy in order to let green bonds reach their true potential.

This Master Thesis is structured as follows. In Section 2, the main drivers and barriers will be discussed. First a light is shed on the drivers in section 2.2, consisting of cognitive and financial drivers. Thereafter, in section 2.3 the main barriers will be reviewed. The financial investment, transaction costs and socioeconomic factors are of importance in these barriers. Section 3 will then examine policy implications. In section 3.1, policy instruments proposed in peer-reviewed literature are reviewed, consisting of normative incentives, economic incentives and communication.

An overview of these policy instruments will be shown in a table. Subsequently, in section 3.2 these policy instruments will be evaluated, compared and assessed whether they are of use in the case of the energy transition in the housing stock. Section 4 consists of an empirical international analysis to determine the added value of green bonds on the use of renewable energy. This will be done by multiple regression models and also determines whether spatial differences between countries play a part in the adoptability of renewable energy. Then, the impact on the real estate sector specifically is assessed. Furthermore, in Section 5 the current policy regarding green bonds is analysed and recommendations for improvement will be made in order to stimulate the energy transition by the use of green bonds as best as possible. Limitations and suggestions for further research will be given in Section 6. Section 6 will also include an advice for a policy design specifically for the Netherlands. Section 7 will conclude. Finally, Section 8 states all data sources of the data used for the empirical international analysis in Section 4.

2 LITERATURE REVIEW: DRIVERS AND BARRIERS

There are enablers and also obstacles in the sustainable transition in residential housing[1]. Understanding the main enablers and obstacles provides insight into the type of policy that is necessary. In this Section, the most important drivers and barriers are therefore discussed. A distinction can be made between intrinsic and extrinsic factors regarding drivers and barriers. Intrinsic factors are consequences of an interaction between an individual's internal wishes, ambitions and preferences with their individual situation. Extrinsic factors on the other hand can be rules, financial costs and incentives (Jacob, 2007).

2.1 DRIVERS

Households are eager to perform renovations when there are expected potential benefits. According to a paper by Martin Jacob in 2007, this means that the assumption is made that an individual does not get involved in an action, either when high risks are incurred and/or the expected benefits are not favourable (Jacob, 2007). In other words, an agent acts rational. In the decision-making process of whether to renovate several factors can be considered. Bounded rationality plays a part, meaning the cognitive burden in gathering and also processing information. Thereafter, the expected time and financial support in order to accomplish the renovations is of importance. Finally, the expected fast return on investment (ROI) plays a role. Delayed gains is seen as a barrier, even though these gains will have long-term effects (Frederiks, Stenner, & Hobman, 2015; Wilson, Crane, & Chryssochoidis, 2015). In the following paragraphs of this Section these factors will be elaborated on. First, bounded rationality will be discussed in section 2.1.1 Cognitive drivers. Then the latter two named factors will be discussed in 2.1.2 Financial benefits.

2.1.1 Cognitive drivers

Bounded rationality is referring to the information component part of the renovation process. This can be seen as a driver towards sustainable energy when information is easy accessible (Ebrahimigharehbaghi, Qian, Meijer, & Visscher, 2019). Other intrinsic factors that stimulate the energy transition are environmental concerns. Moreover, in general enhancing life quality by performing renovation is often mentioned. This concerns reducing noise, replacing or repairing equipment and increasing comfort (Ebrahimigharehbaghi et al., 2019). These findings correspond with other literature as well. Higher comfort levels and better expected living conditions were found by Klöckner and Nayum as the most crucial drivers when household are starting to decide to engage in renovation (Klöckner & Nayum, 2016).

Renovations are usually a periodic or an ongoing feature more than a one-time event (Fawcett, 2014). It is a process where decisions taken and perceived barriers influence and may also change during the renovation process (Novikova, Vieider, Neuhoff, & Amecke, 2011). This in turn means that research findings are influenced by in what the specific stage in the renovation process a household is. In the paper by Klöckner and Nayum and also the paper by Ebrahimigharehbaghi et al., they incorporate the entire decision-making process in their research to find drivers and barriers in each of the different stages. Klöckner and Nayum are, however, more explict in defining what drivers and barriers belong to what stage in the decision-making process compared to the paper by Ebrahimigharehbaghi et al. Nevertheless, the paper by Klöckner and Nayum could be subject to hypothesis bias. This might slightly bias the results, since people behave differently than they say they would. There is cognitive incongruity with actual behaviour. To overcome this, future studies might observe people longer after the *decision* to do a renovation. The paper by Ebrahimigharehbaghi et al. does in fact overcome this issue. Namely, besides potential renovators, they also incorporate people who already have renovated.

[1] This Section is based on a literature review done for another course

This is an important aspect, since the effect in the renovation process seems especially big when comparing expectation pre-renovation with experiences post-renovation (Tweed, 2013). So, by incorporating this into the research more reliable results are obtained.

2.1.2 Financial benefits

Aside from the cognitive drivers, also financial drivers contribute a great deal in the decision-making process. Throughout literature there is consensus that cost-saving counts as the main driver in the energy transition (Ebrahimigharehbaghi et al., 2019; Klöckner & Nayum, 2016). In the majority of the stages in the decision-making process this holds as the main driver (Klöckner & Nayum, 2016). In the research conducted by Ebrahimigharehbaghi et al. it is found that the importance of an expected reduction in energy costs is more than twice as big compared to the reason to protect the environment (Ebrahimigharehbaghi et al., 2019). Furthermore, in the final stage of deciding how to perform the upgrades to planning implementation, an expected payoff within a reasonable timeframe is shown as one of the main drivers in that stage (Klöckner & Nayum, 2016). The timeframe is relevant, since delayed gains are not seen as favourable. Even though there will be gains on the long-term (Wilson et al., 2015). Another extrinsic factor is the increase in house value. This also ensures that the house will be easier to sell in the future. A critical note on the research conducted is the fact that most surveys being held have closed-end form answers. This can bias results, since people are influenced by the line of questioning (Wilson et al., 2015). In Section 4 Discussion this will be elaborated on and on how to overcome this kind of bias.

2.2 BARRIERS

In the previous section 2.1 the drivers in the energy transition were discussed. In this section the barriers will be analysed. In subsection 2.2.1 Financial investment, the costs of renovating and the ‘split incentive’ between owner-occupiers and renters will be discussed. Thereafter in subsection 2.2.2 Transaction costs, transaction costs will be considered.

2.2.1 Financial investment

Energy renovation usually inclines high upfront costs compared to repairing or improving the energy efficiency measures (Wilson et al., 2015). These monetary costs may be covered by savings or loans from the bank. Interest rates determine the feasibility of renovations. A high interest rate can negatively affect the decision to renovate (Jakob, 2007). Moreover, the payback period is of interest. As mentioned previously, if the payback is short, it is seen as a driver (Klöckner & Nayum, 2016). However, when the gains are delayed this is shown to be an obstacle to renovation (Wilson et al., 2015). Furthermore, according to Klöckner and Nayum one of the most common barriers throughout the decision-making process is the feeling that the right time has not come yet (Klöckner & Nayum, 2016). This can be tackled by focussing on creating awareness and informing residents. In addition, supervising contractors is also perceived as an obstacle. It takes time to find a reliable contractor and intermediars. In the paper by Decuypere et al., they discuss the specific case of heat pumps. When switching of natural gas, heat pumps will be necessary to heat the house. It is found that the cost of electricity is a significant barrier to the installation of such heat pumps. Fluctuating electricity prices complicate the guarantee of the timeframe for the return on investment and the profit. Price fluctuations in the past can influence the decision of home-owners in the present (Decuypere R. , Robaeyst, Hudders, Baccarne, & Sompel, 2022). Additionally, as said before, the renovation requires high upfront costs. The incomes of households play a crucial part in this barrier. Heat pumps specifically have a high financial cost. According to the architects in the research of Decuypere et al., the installation is very pricy. It accounts for one of the most expensive features in a renovation. Whereas a gas boiler is still much cheaper.

In the papers mentioned in the previous section 2.1 Drivers, most of the drivers are referring to home-owners. However, it is likely that home-owners might benefit more from renovations and retrofitting (Nejat et al., 2015). Therefore, there is an extra barrier in the decision-making regarding renters. The principle-agent problem, where the agent (landlord) who makes the investment decision is different from the one bearing a great deal of the costs, namely the principle (tenant), arises in this case. In the energy efficient technology case this is often referred to as the ‘split incentive’ effect (Krishnamurthy & Kriström, 2015). In a paper by Klöckner and Nayum, they consider private homes. They conducted their own research where 3787 Norwegian households were questioned. They found that one of the most important factors in deciding not to implement energy efficiencies is the fact that they do not own the dwelling (Klöckner & Nayum, 2016).

2.2.2 Transaction costs

Aside from the monetary costs mentioned in the subsection above, also non-monetary costs are highly relevant. According to the literature review by Wilson et al., this domain in energy investments is systematically understudied (Wilson, Crane, & Chryssochoidis, 2013). Later this has been studied more. In the research of Ebrahimigharehbaghi et al., they capture the non-monetary costs as so called transaction costs. According to Mundaca et al., transaction costs are some kind of hidden costs which adds to the existing costs that cannot be used for other purposes (Mundaca, Mansoz, Neij, & Timilsina, 2013). Examples of transaction costs are asset uncertainty and time and effort to gain knowledge and information. These transaction costs are essential in the considering and planning phases. Households need to evaluate the benefits of renovation. Asset uncertainty arises when there is uncertainty about the expected benefits.

Uncertainty in economic benefits, costs and payback times is regarded as a considerable barrier (Decuypere et al., 2022; Ebrahimigharehbaghi et al., 2019). Asset uncertainty can also occur when there is uncertainty about opportunistic behaviour. This occurs when for example there is a lack of trust between parties. This includes the professional contractors that execute the renovations (Ebrahimigharehbaghi et al., 2019). When households have experienced similar renovations before, the uncertainties reduce.

Furthermore, time and effort to gain insight and information is another transaction cost. This kind of transaction cost is inevitable, since acquiring information on energy renovations usually takes time. Imperfect and asymmetric information complicate the energy renovation even more, because high costs are encountered to find reliable information (Mundaca L. , 2007). If households do not obtain information regarding nature and costs of energy renovations, this might cause households to not invest. Another transaction cost is the complexity in the decision-making process itself. Making decisions that are complex and irreversible cause a cognitive burden. In addition, renovations can cause ‘hassle’ in day-to-day life during the renovations (Wilson et al., 2015).

2.2.3 Socioeconomic variables

Socioeconomic variables determine to a great amount the decision to renovate. Income plays a key role in this decision. As said in subsection 2.2.1 financial investment, energy renovation has a high cost. Other socioeconomic factors have a large influence too, such as the age of home-owners. Older home-owners might hesitate since their return on investment may not be on time (Decuypere et al., 2022). They benefit less from energy renovations because the timeframe of breaking even and making profit is a lot shorter. Therefore the older generation is harder to motivate (Mortensen, Heiselberg, & Knudstrup, 2016). Furthermore, the construction period of the house determines to an extent the choice to renovate as well. The newer the house, the more likely households are to renovate. This could be due to the complexity of renovation in older houses. Even though the age of the house explains a large part of the energy consumption (Ebrahimigharehbaghi et al., 2019). There could be a lot to gain when performing an energy renovation in an older house.

3 LITERATURE REVIEW: POLICY INSTRUMENTS

In Section 2 drivers and barriers are analysed. These drivers and barriers shape the kind of policy measures that are useful in motivating households towards sustainable energy. In this Section policy implications in energy renovation will be discussed as presented in peer-reviewed literature.[2] An overview will be given of the different policy mechanisms reviewed. In general policy instruments can be divided into 3 types of incentives: normative incentives, economic incentives and communication (Blok, de Groot, & Rietbergen, 2004). First normative incentives will be discussed, followed by economic incentives. Economic incentives will be split into subsidies, taxes and green bonds. Finally, communication is discussed.

3.1 OVERVIEW POLICY INSTRUMENTS

3.1.1 Mandating energy renovation by law

Making sustainable renovation mandatory for everybody is easy to implement. Nonetheless, there are differences in personal characteristics, which relate to age, income and owning versus renting. If renovation were to be made mandatory, these differences will be nullified. Older home-owners might not benefit fully from the renovation. The return on investment might not be on time (Decuypere R. , Robaeyst, Hudders, Baccarne, & Sompel, 2022). The timeframe for older home-owners is relatively short in comparison with the younger generation. Therefore, the investment might not pay out. Second, energy renovations require significant costs. Households have different income, the associated costs might be too high for households with lower income. Third, the situation of owning versus renting creates unfair situations. Owner-occupiers benefit more from renovations than renters do (Nejat et al., 2015).

3.1.2 Financial instruments

3.1.2.1 Subsidies

Financial incentives can trigger energy renovation, whereas a disincentive can demotivate certain behaviour. Financial subsidies provide an incentive towards renovation. In the paper by Ebrahimigharehbaghi et al., they find that limited or no subsidies at all is one of the major barriers in the decision-making process (Ebrahimigharehbaghi et al., 2019). However, similar to mandating energy renovation by law, differences in personal characteristics play a role in this financial instrument. If subsidies are based on the investment, free-riding could occur. Residents who have sufficient amount of financial resources still receive similar compensation as residents with low income.

3.1.2.2 Taxes

Another financial instrument which can be used is taxation. In the paper by Vringer et al., the authors propose a tax that is connected to the energy label of the house. They argue that this tax differentiation can be done with already existing taxes as such that the average tax burden does not increase. They stress the importance of autonomy in this matter. Residents still have the choice to opt for renovation or not (Vringer, Middelkoop, & Hoogervorst, 2016). The authors explicitly mention that the price of electricity and natural gas is an important factor for the energy saving policy. The energy tax is about one third of the energy price paid by households. This energy tax provides clear efficiency standards and residents directly encounter the cost. This means that the energy tax impacts the energy saving measures by residents (Vringer et al., 2016). The effect of a carbon tax for the Swiss market has been analysed in the paper by Amstalden et al.

[2] This Section is partly based on research conducted in another course.

They find that only a carbon tax does not affect the profitability of retrofitting significantly, unless the tax results in a substantial energy price. In Switzerland, expenses made for energy conserving measures can be deducted from the income tax. The authors find that in combination with income tax deductibility and subsidies, the carbon tax would be of use. Their research was conducted by using a discounted cash flow model to calculate the profit for residents. The research thereby does not incorporate the effect on the decision made by residents (Amstalden, Kost, Nathani, & Imboden, 2007). It can only conclude on the basis of the attentiveness to residents in terms of financial gains.

3.1.2.3 Green bonds

Another financial instrument that can be used are green bonds. In this section, the definition of green bonds will be discussed and their relation to conventional bonds. Furthermore, the advantages as well as the disadvantages of green bonds will be reviewed. In addition, the green bond market will be analysed.

What are green bonds?

Green bonds use the funds raised by financing or refinancing green projects. Green projects are defined as activities and projects that promote progress on environmentally sustainable activities. These funds can be used in the real estate sector to, for example, isolate rental housing. A green bond is a fixed-income financial instrument in the debt capital market. So, the issuer of the bond raises capital, which is a fixed amount, over a period of time. The issuer of the bond repays the capital, called the principal, plus a before determined amount of interest (coupon value). Green bonds should follow four main guidelines (ICMA, Green Bond Principles: Voluntary Process Guidelines for issuing Green Bond, 2015). These are:

1. Use of Proceeds: the proceeds must be used for green projects.
2. Process for Project Evaluation and Selection: the issuer of a green bond should state clearly the sustainable objective, the selection procedure of a green project and how risks are managed.
3. Management of Proceeds: the net proceeds raised by the green bond should be held in an external manner and be credited on a sub-account. Preferably, the use of proceeds is checked by an independent auditor. The auditor should verify the allocation of funds from the green bond proceeds and the internal tracking method in order to increase transparency.
4. Reporting: Issuers must report current information on the use of the proceeds. The annual report should include a list of the designated green projects, the amounts that have been allocated and their expected environmentally sustainable impact.

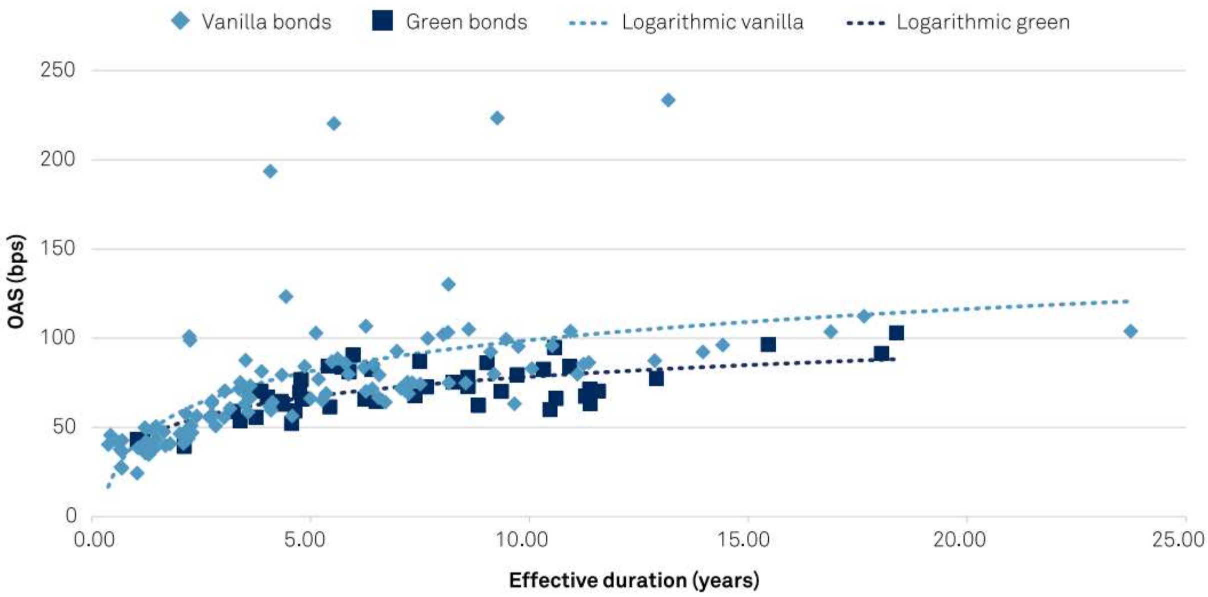
The guidelines will be elaborated on in Section 5.

Relation to conventional bonds

What makes a green bond fundamentally different from a conventional bond is its ‘label’. This shows that the funds raised by green bonds will be used to finance or refinance only green projects (ICMA, Green Bond Principles: Voluntary Process Guidelines for issuing Green Bond, 2015). In principle, conventional bonds and green bonds should price at equal yield-to-majority when they are issued by the same issuer and have similar characteristics, such as majority, coupon and structure. However, it is found that investors pay a higher price for green bonds compared to conventional bonds. Investors pay a green premium. This means that green bonds have a lower yield compared to outstanding debt. So, the difference in yields between a conventional bond and a green bond with similar characteristics is defined as a so called ‘greenium’ (Ehlers & Packer, 2017; Harrison, 2021; MacAskill, Roca, Liu, Stewart, & Sahin, 2021). This greenium shows that an investor is willing to accept a lower yield to obtain a ‘green’ asset. These price differentials are represented as a higher price for a green bonds compared to a conventional bond in the primary market. In the primary market new bond issuances are offered to the market. After the bonds are issued, they can be traded freely on the open market, which is the secundary market. On the secundary market bonds are subject to price movements.

Therefore, a negative 'greenium' in either primary or secundary markets implies that a green bond is trading at a lower yield, or higher price, compared to a conventional bond with similar characteristics. This 'greenium' thus entails that for investors there is a nonfinancial benefit when obtaining a green bond. For issuers, the implemenation of green projects are supported by a lower cost of finance (MacAskill et al., 2021). So it costs an issuer less to fund its green bond in comparison with its 'conventional' debt (ICMA, Green Bond Principles: Voluntary Process Guidelines for issuing Green Bond, 2015). Figure 1 shows that green bonds have a lower yield than conventional bonds. Further, green bonds have a smaller spread than conventional bonds.

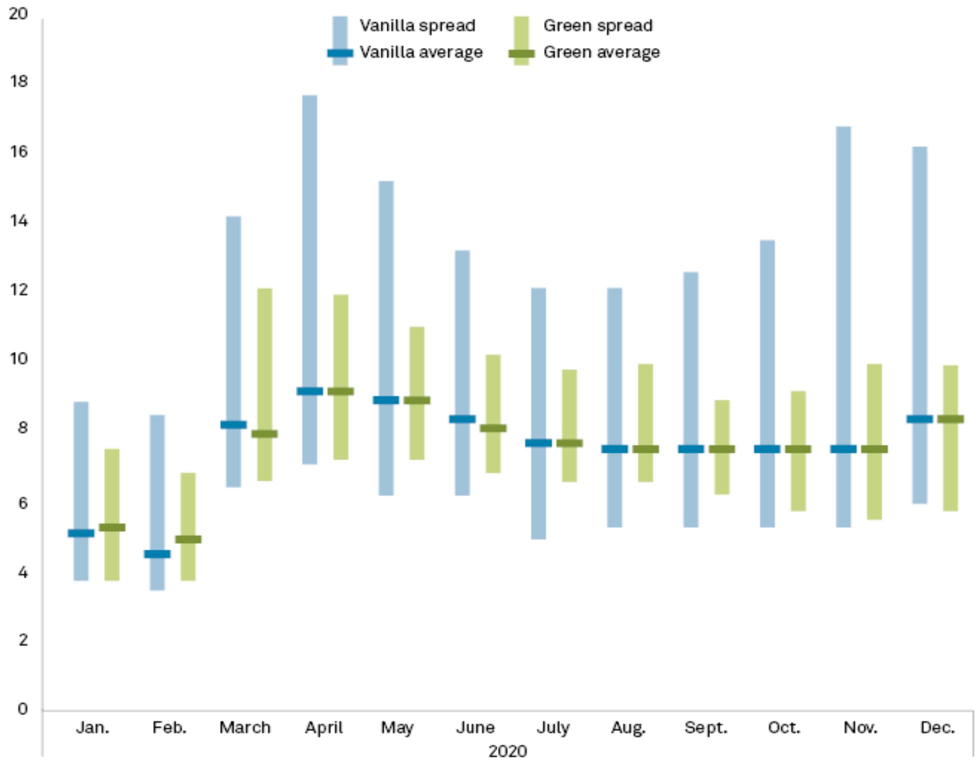
Figure 1: Utilities credit curve



Sources: S&P Dow Jones Indices, S&P Eurozone investment Grade Corporate Bond Index and S&P Green Bond Index.
Data included 100 European vanilla utility bonds and 46 green bonds.
Illustration: Standard & Poor's Financial Services LLC. (S&P Global Ratings, 2021)

Aside from pricing, another fundamental concept in finance is market liquidity. Market liquidity can be defined as the ability to buy or sell an asset quickly and without having to reduce the price significantly (CFA Institute, 2016). The stability and health of financial markets can be measured by means of liquidity (Guo & Zhang, 2020). Illiquidity impedes efficient price discovery, namely the speed and accuracy with which transaction prices incorporate information available to market participants. Also, it hampers access to funding from those financial markets by issuers. In case of financial distress, low liquidity can massively amplify disturbances in the financial system. This happened during the outbreak of Covid-19. These effects caused by low liquidity represent a big risk for investors, issuers and regulators (Guo & Zhang, 2020). Market liquidity can be measured by bid/offer spread. This is the difference between the highest price a buyer is willing to offer and the lowest price a seller is willing to accept. In 2020 the bid/offer spread for green bonds was smaller for every month compared to the spread of conventional bonds, which are also referred to as vanilla bonds (Harrison, 2021). This shows that green bonds are more liquid compared to vanilla bonds. Febi et al. come to the same conclusion when using also the LOT liquidity measure. The LOT liquidity measure is the difference in the buying and the selling cost in percentage (Febi, Schäfer, Stephan, & Sun, 2018). Furthermore, Figure 2 shows that bid-offer spread range is consistently tighter for green bonds compared to vanilla bonds. The bid-offer spread range shows the dispersion of the bid/offer spread. So, it represents the difference between the largest and the smallest bid/offer spread. Predictability is high when this range is tight, whereas uncertainty increases when this range is broad.

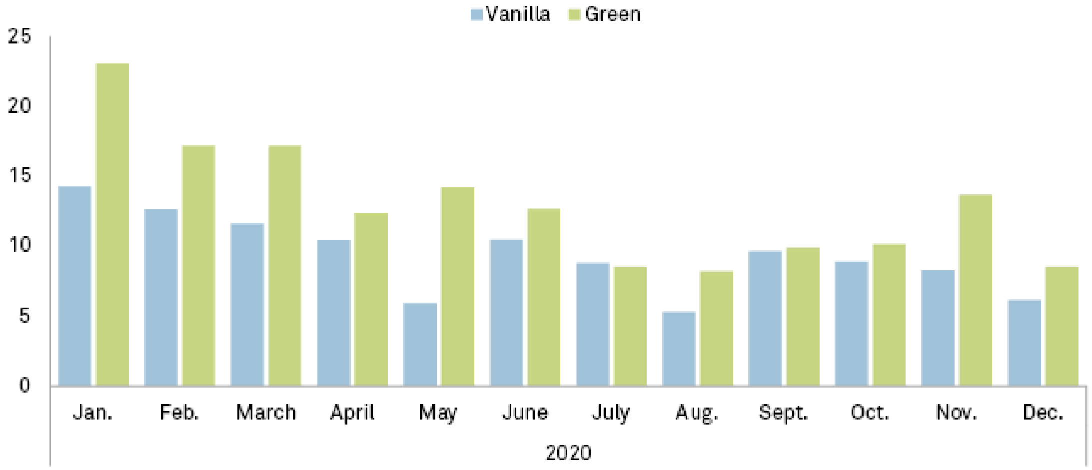
Figure 2: Bid/offer spread range of vanilla and green bonds (in basispoints)



Data included 29 vanilla utility bonds and 17 green bonds sold in 2019
Source: Climate Bonds Initiative (Harrison, 2021)

Moreover, green bonds are traded more frequently than vanilla equivalents on average in 2020 (see Figure 3). Even in March 2020, when the Covid-pandemic hit the capital markets, green bonds were traded 48% more. In cases of crisis, it is important to have liquid assets in the investment portfolio. This is due to the fact that investors need to be able to fund redemptions. It is likely that people pull out money from their funds in case of crisis. Therefore, green bonds provide flexibility to investors. Additionally, the monthly turnover for green bonds in 2020 is higher for green bonds compared to the vanilla equivalents. The monthly turnover is defined as the volume traded in each month divided by the outstanding debt of each bond (Harrison, 2021). Green bonds are trading actively in the secondary market. This support the argument of green bonds providing more flexibility. Thus, green bonds have a smaller bid/offer spread and a narrower bid/offer spread range (See Figure 2). Besides this, green bonds are traded more frequently and have a higher turnover on average. All of the above suggests that green bonds offer more liquidity compared to their vanilla equivalents in the secondary market. Hence, although green bond are trading with a premium on average in the primary market, the flexibility of green bonds in the secondary market could justify the presence of a greenium. The fact that a buyer for a green bond is easy to find is due to high demand for green bonds. There is a lack of supply of green bonds, which likely results in the premium paid and the higher level of flexibility (Harrison, 2021; MacAskill, 2021).

Figure 3: Average number of trades per bond



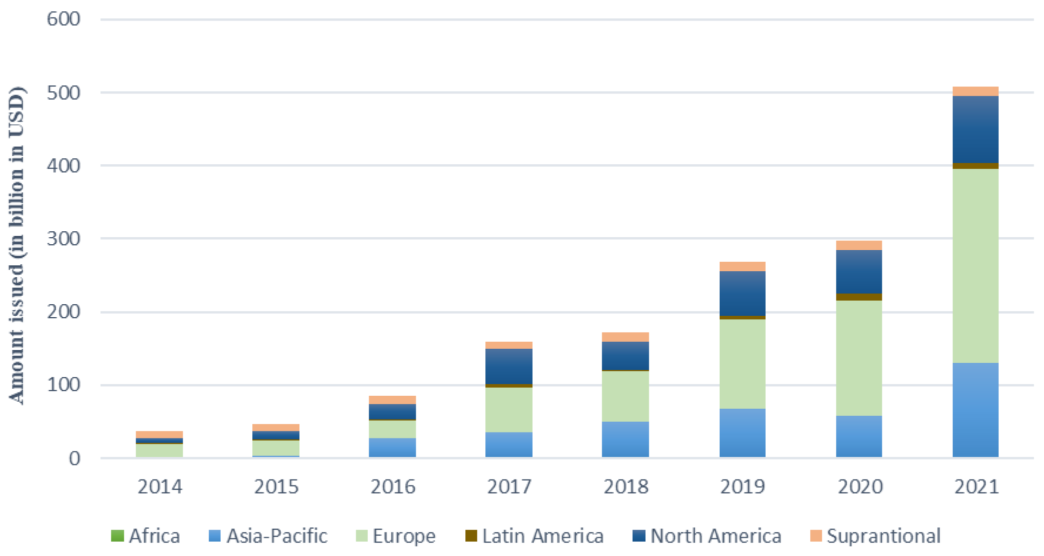
Data included 29 vanilla utility bonds and 17 green bonds sold in 2019
Source: Climate Bonds Initiative

Market

The green bond market has experienced exponential growth over time. This growth can be explained by that on the one hand investors would like to make their portfolio sustainable as soon as possible, where on the other hand issuers are looking for appropriate financing of their sustainable targets (Rabobank, 2019).

Green bonds can be issued by banks, financial institutions, corporations, and (municipal) governments, regions or cities. The first green bonds were issued by the European Investment Bank in 2007 (OECD, Green bonds: Mobilising the debt capital markets for a low-carbon transition, 2015). Since then the market has expanded and reached 500 billion annual green investment in 2021. Europe is the biggest issuance region. See Figure 4. When looking at countries, the USA and China are the biggest issuers, with a total of 303.9 billion and 199.1 billion respectively (CBI, Dataplatform, 2021).

Figure 4: Volume of issuances by region



Source: Data from Climate Bonds Initiative
Illustration: author's own

Advantages

The main component that separates green bonds from any other financial instrument is the commitment to financing *only* sustainable projects. It provides financing for issuers for their sustainable projects. As discussed in the section regarding the relation to conventional, vanilla bonds, green bonds provide benefits over holding vanilla equivalents. Green bonds provide liquidity benefits and flexibility in the secondary market probably due to the combination of scarcity of green bonds and high demand. Green bonds are effective in positively affecting the climate (EPRA, 2021; Flammer, 2020; OECD, 2015).

Renewable energy infrastructure requires high upfront costs and frequently income-streams that are related to inflation (OECD, Green bonds: Mobilising the debt capital markets for a low-carbon transition, 2015). Bond financing is a natural fit considering these factors. Bonds could potentially provide long-term sources of debt capital. Bonds provide diversification and therefore take up a large part of investment portfolios. Mostly pension funds and insurance companies invest the vast majority of their portfolio in bonds (OECD, Green bonds: Mobilising the debt capital markets for a low-carbon transition, 2015). Green bonds show low correlations with other types of bonds, equities and commodity prices (Horsch & Richter, 2017). Green bonds can reconcile the high demand for ESG-screened investments (Environment, Social and Governance). Moreover, bonds with long tenors, time-to-majority, can be a good fit for investors holding long-term liabilities. This is because bonds allow for asset-liability matching. Additionally, diversity for investors is especially important when holding emission-intensive assets as well in the portfolio. Green bonds then lower climate policy risks, which can make pollutant alternatives less profitable. Also, green bonds are a safe asset against the volatility of fossil fuel alternatives, like oil price fluctuations (Braga, 2020). Furthermore, investment is less risky due to use-of-proceeds reporting in an otherwise relatively untransparent fixed-income market. When looking from the point of view of issuers of green bonds themselves, other advantages arise. Firstly, strong demand can lead to oversubscription and thereby driving up price or increasing issuance size. In addition, high demand decrease bond demand fluctuations in the market. It is also shown that quite some buyers are buy-to-hold investors in the green bond market. This results in lower bond volatility in secondary markets (OECD, 2015). In addition, issuing green bonds gives access to new investors. There are more and more investors that focus on the sustainable profile of their investments (Rabobank, 2019). Furthermore, the research by Alonso-Conde and Rojo-Suárez finds that green bond financing is more profitable than a bank loan, because it provides higher returns. Also, they suggest that green bonds constitute a financial incentive for issuers to really invest according to use-to-proceeds approach. In the investment decision-making process bondholders play a passive role. Due to the financial incentive, green bonds can help align the financial objectives with national authorities (Alonso-Conde & Rojo-Suárez, 2020). Finally, issuers can improve their reputation by issuing green bonds and showing their interest in green investments publicly (OECD, 2015).

Disadvantages

A considerable drawback is green washing. Issuers of green bonds are not obliged to comply with these guidelines. Therefore, it is possible that green bonds are issued and the proceeds are not used to finance green projects. There is currently limited scope for legal enforcement to ensure the green commitment. Besides that it is not obliged to comply with the guidelines, it is also unclear what counts as a green investment. This means that funds raised by green bonds are invested in projects that have little environmental value (Weber & Saravade, 2019). There are no universal standards and definitions of green projects (Blakstad & Allen, 2018). So, unclarity of what counts as a green investment and guidelines that are not mandatory to be followed contribute to the problem of green washing. Issuers of green bonds may solely use this for good publicity. The lack of accountability and transparency adds to the problem of green washing (Neves & Prata, 2018). Policy needs to target these elements in order to prevent green washing. Section 5 will discuss the improvements that the policy for green bonds requires.

Bonds do not compensate for inflation (except for inflation-linked bonds). This is a drawback for investors like pension funds and insurance companies. These type of investors have long-term liabilities usually stated in nominal terms, however expected to be honoured in real terms. For this reason, assets that increase in value with inflation are appealing long-term assets. So, even though bonds are a good match for nominal liabilities, they do not provide a hedge against inflation.

There are upfront and also ongoing transactions costs associated with labelling green bonds. In order to fulfil the guidelines, there are monitoring, administrative, reporting and verification costs. Nonetheless, economies of scale may arise as the majority of the issuance costs are in the beginning where processes are being set up (OECD, Green bonds: Mobilising the debt capital markets for a low-carbon transition, 2015).

3.1.3 Informing/communicating

Throughout literature, a lot has been written about the importance of informing residents. In the paper by Klöckner and Nayum they found that most people feel as though the right moment in time to renovate has not yet presented itself. They recommend to make people aware of this moment and to inform people in the planning phase (Klöckner & Nayum, 2016). In this phase realising the benefits can persuade people to renovate (Wilson et al., 2015). Likewise, in the paper by Ebrahimigharehbaghi et al., they stress the importance of information in also the planning and implementing phase. Most policies focus on minimizing financial barriers, but also minimizing information barriers is a key tool. Homeowners should receive reliable information and tailor-made to their situation (Ebrahimigharehbaghi et al., 2019). Drivers and barriers are related to personal characteristics. Age can for example play a role in the decision to renovate, because older home-owners might not benefit fully form the renovation (Decuypere R. , Robaeyst, Hudders, Baccarne, & Sompel, 2022). These older home-owners are harder to motivate compared to younger ones. Nevertheless, it is shown that with the right instrument it is possible (Mortensen, Heiselberg, & Knudstrup, 2016). Also the living situation affects the incentive to renovate. According to Klöckner and Nayum, renters can be taken out of the marketing campaigns, since their incentive is a lot lower than owner-occupiers. Furthermore, transaction costs play a large part in information barriers. Searching and finding reliable information consumes time and effort. They suggest that the government could focus more on the provision of information. Additionally, connecting information hubs and agencies with households (Ebrahimigharehbaghi et al., 2019). Although, they do not argue how this would potentially look like and on what factors households are matched with certain information hubs and agencies. In addition, the authors state the importance of providing information regarding applying for loans or subsidies and reducing the complexity in assessing these.

Ebrahimigharehbaghi et al., also mention the importance of contractors and installers. Reliable energy experts is a critical influencing factor in the decision-making process. This is stated as well in the paper by Decuypere et al. There the authors claim that intermediars have a signifcant impact on the renovation decision. They propose that the government supports intermediars in advising and installing heatpumps. Heat audits and checking before installation whether heat pumps are a feasable option will reduce workload for intermediars. Thereby there is more time for intermediars to advise residents. Second, the knowlegde of installers should be kept up-to-date. There is an information overload in technical but also legislative changes in heat pumps. Such as the heat pumps installation depends on the physical context of a building. Thus, the authors propose to inform, guide and sensitize architects and installers in a systematic manner. As a third proposition in general, complex information should be accessible and user-friendly in a centralized place. Fourthly, there should be a shared vision between different intermediars. Presently, interaction between architects and installers is not optimal as if yet. So, a transfer of knowledge between intermediars should be facilitated.
Moreover, socioeconomic factors, like income play a role in the information barrier as well. Low income could lead to social housing. Even though the social housing organization can inform their residents, this needs to be done under the right circumstances. According to Bal et al., the motivation of residents in social housing is present, however informing residents should be done properly.

The authors claim that clear instructions should be provided and the environmental impact of their behaviour should be emphasized. Behaviour impacts the energy consumption. In their study, they find that social norms play a large part. So policy-makers should focus on creating social norms that support the energy transition (Bal, Stok, Van Hemel, & De Wit, 2021). In Table 1 below all discussed policy instruments are mentioned.

Table 1: Overview policy instruments

Policy Instrument	**Pro**	**Con**
Mandatory by law	Easy to implement	Provides inequality[3]
Financial support[4] (e.g. subsidies)	Removes financial barriers	Costs money Takes time Possible pure income transfer
Carbon tax[5]	Stimulates renovation and/or towards green energy	
Taxes linked to energy label[6]	Stimulates renovation	
Green bonds	Removes financial barriers[7] and Stimulates renovation[8]	Greenwashing
Informing residents[9]	Removes information barriers and Transaction costs	
Informing by expert/intermediars[10]	Removes information barriers and Transaction costs	
Reducing complexities by applying for loans/subsidies[11]	Removes work/process barriers and Transaction costs	

3.2 EVALUATION POLICY INSTRUMENTS

3.2.1 Mandatory by law

In my view, the disadvantages outweigh the advantage of easy implementation. As stated in Section 3.1 (Overview policy instruments), differences in personal characteristics and living situations will create extreme inequality.

3.2.2 Financial instruments

3.2.2.1 Subsidies

Financial subsidies provide incentives to renovate. Therefore, governments should provide more financial support to residents and more should be invested in making people aware of available subsidies and how to assess them. This is an important factor that should be incorporated in policy in my opinion. A study by Jaffe and Stavins studies the impact on technological diffusion of several policy instruments. The authors find that a subsidy has a significantly greater effect on the efficiency of dwellings than an equivalent tax (Jaffe & Stavins, 1995).

[3] Inequality regarding age: (Decuypere et al., 2022; Mortensen et al., 2016); inequality regarding financial resources: (Decuypere et al., 2022; Ebrahimimigharehbagh et al., 2019); inequality regarding owning or renting 'split incentive': (Nejat et al., 2015)
[4] (Ebrahimimigharehbagh et al., 2019)
[5] (Amstalden et al., 2007)
[6] (Vringer et al., 2016)
[7] (Alonso-Conde & Rojo-Suárez, 2020; Braga, 2020; Horsch & Richter, 2017; OECD, 2015)
[8] (EPRA, 2021; Flammer, 2020; OECD, 2015)
[9] Informing about advantages: (Ebrahimimigharehbagh et al., 2019; Klöckner & Nayum, 2016)
[10] Informing by experts/intermediars: (Decuypere et al., 2022; Ebrahimimigharehbagh et al., 2019; Mortensen et al., 2016)
[11] (Ebrahimimigharehbagh et al., 2019)

However, it must be pointed out that a subsidy may be a pure income transfer (Baumol & Oates, 1988). The subsidy may not be used for the intended purpose. Moreover, if the subsidy is indeed used for the intended purpose, money is saved in the investment budget. This money could then be used for polluting activities, while the original purpose was to minimize such activities. In this case, polluting activities are being subsidized so to speak. There is a rebound effect, improvements in energy efficiency lead to smaller reductions in energy than expected due to secondary effects (Freeman, 2018). This caveat is difficult to eliminate.

Policy needs to focus on energy poverty. Low income households are running behind in the energy transition due to their lack of financial resources to afford retrofitting and other sustainable investments. It is seen that high income households indeed make substantially more use of current financial tools. Therefore, it is advised to target policy specific to low- and mid-income households. Currently, most subsidies require upfront payment before receiving the subsidy. This stimulates mostly the households with higher incomes. In addition, it can be considered to whether or not to make subsidies income-dependent in order to avoid free-riding. Moreover, an interest-only mortgage for retrofitting and other sustainable investments can support low income households. Treating these mortgages tax-friendly results in lower monthly costs. The risk on remaining outstanding debt is low, since dwellings with a low energy label gain the most in value when performing sustainable measures (Arends, Heijna, & Vlielander, 2022).

3.2.2.2 Taxes

A carbon tax will could potentially create unfair situations. Since people who cannot afford a sustainable renovation due to the high costs, will then be forced to pay a higher price for their energy use. Therefore, this measure must only be implemented when accompanied by financial support. Taxes linked to the energy label is more pragmatic, since it regards price differentiation in an already existing tax. Moreover, it could work more stimulating towards an energy renovation than carbon tax. With carbon taxation there is a risk that households consume less energy, but they do not switch of natural gas. Preferably, households switch off natural gas completely. Renovation is necessary to obtain to higher energy label.

3.2.2.3 Green bonds

In general, the current pace of making dwellings natural gas free may not be sufficient to achieve the climate goals. Additional and more effective measures are necessary. Green bonds have a lot of benefits for investors as well as issuers. Green bonds can be seen as a combination of an implicit subsidy and a loan. It provides a financial advantage for issuers, compared to issuing vanilla bonds due to the greenium. Also, green bonds give incentives to invest properly, since the issuer must pay back the principal plus interest to the investor. Furthermore, green bonds provide incentives to invest according to the green label. In behavioural economics, this is known as the warm glow effect. It motivates pro-environmental behaviour, since individuals may experience a good feeling from their contribution (Hartmann, Eisend, Apaolaza, & D'Souza, 2017). Due to its green label, it contributes to activities that are of societal importance that would otherwise not have taken place at regular market forces. There is a more disciplinary functioning in green bonds for the issuer in comparison with subsidies for instance. Green bonds can therefore contribute to the existing financial instruments. Subsidies can potentially target energy poverty in a more substantial way than green bonds. Although, a research by Zhau et al. find that green finance can effectively facilitate energy poverty eradication. Their sample considers China, which is the most populous country and largest energy consumer. Also, China is a front-runner in issuing green bonds. The authors do find spatial differences regarding the effectiveness of green finance on reducing energy poverty (Zhao, Wang, & Dong, 2022). A significant drawback of green bonds, however, is the presence of green washing. In reality investments are not that green as they were presented. There are several ways to deal with this problem. Standardization of reporting, verification and taxonomies are of importance. Additionality tests, certification of green bonds, public governance and the role of technological advancement also enhance the current policy.

Policy needs to ensure that green bonds can fulfil their potential in order to stimulate the energy transition in real estate. In Section 5: Policy implications, this will be elaborated on.

3.2.3 Informing households on their specific needs

Knowledge of the different decision-making phases allows for designing specific interventions in this process. Designing the policy instruments as such that it incorporates the phase which the consumer is in. This could be especially helpful in the policy instrument of informing. In my view, this is a very strong tool influencing the renovation decision. In the early stages of the decision-making process, informing about comfort levels and better life quality can trigger the decision of renovating. Whereas later in the process, information about subsidy-schemes and other cost-related information would be efficient (Klöckner & Nayum, 2016). It is best to make complex information accessible and user-friendly in a centralized place (Decuypere et al., 2022). This reduces transaction costs.

Moreover, home-owners should be approached as individuals. The older generation's main concern is the improvement in comfort when undertaking an energy renovation rather than cost-saving. (Mortensen et al., 2016) The timeframe for older home-owners is relatively short in comparison with the younger generation. Therefore, the investment might not pay out. Focussing on pointing out the most important benefit custom to the needs of individuals will have a considerable impact.

The importance of intermediars as pointed out by Decuypere et al. should be adopted in the informing process as well. Decuypere et al., suggest several propositions. First, they argue that the government should support intermediars by heat audit and checks before the installation in order to reduce workload of intermediars. In my perception, this is not a feasible option. Simply because nothing is being said about who should perform these activities. This requires more trained staff, while the intention was to reduce workload. Their second proposition is to inform, guide and sensitize intermediars about the current heat pump installations. This is a positive matter in my regard. This also ensures that homeowners receive reliable and up-to-date information. This is also advised by Mortensen et al. (Mortensen et al., 2016). The final suggestion of Decuypere et al. regarding intermediars is that intermediars should have a shared vision mutually. This could potentially be achieved during the information sessions described above.

As mentioned in the section 2.1 Barriers, owning a dwelling can have a significant effect on whether or not implementing renovations. Klöckner and Nayum point out that people who do not own the dwelling could be excluded from the marketing campaign. In my view, this is not a correct decision. Landlords depend on their tenants. In order to apply sustainable renovation cooperation of tenants may in same countries be necessary due to legal requirements. In the study on social rental housing it shows that residents want to be part of the energy transition. According to Bal et al., it is best to provide clear instructions and the impact of their behaviour on the environment (Bal et al., 2021). Thus marketing campaigns and the provision of information should also be done towards renters.

4 INTERNATIONAL COMPARISON ANALYSIS

In this Section, the role of green bonds will be explored by means of an international empirical comparison analysis. In the previous sections policy instruments with respect to the housing stock have been discussed. Ideally, the specific effect of green bonds on the greening of the housing stock is measured. Unfortunately, no detailed data is available yet of green bonds issued by real estate firms and where the funds raised are also used for increasing energy efficiency and retrofitting of dwellings. For this reason, the international empirical comparison analysis will estimate the associated effect of green bonds on the percentage renewable energy generated per country. This will still provide insight into the impact that green bonds have on the transition to sustainability. First, the dataset will be explained, consisting of the dependent variable the percentage of renewable energy, the share of green bonds and a set of control variables. Subsequently, several regression models will be used and explained. These regression models are a pooled OLS regression, a fixed effects regression and a standard OLS regression.

4.1 DATASET

The dataset which is constructed includes 18 countries for the year 2014 until 2020. The dependent variable, the percentage renewable energy generated per country is from the International Energy Agency (IEA) (IEA, Data and statistics, 2020). Renewable energy consists of solar PV, hydro, wind and biofuels. The percentage renewable energy is calculated by the four energy sources mentioned above combined divided by the total production. Table 2 below shows the average share of renewable energy of total production in the time period 2014 until 2020 per country in the dataset. The countries are ordered by the highest average percentage of renewables to the lowest average percentage of renewables.

Table 2: Average share renewable energy per country (in percentages)

Country	Percentage renewables
NORWAY	97.7
AUSTRIA	78.7
CANADA	65.5
NEW ZEALAND	63.6
SWEDEN	58.4
PERU	57.0
ITALY	36.8
SPAIN	36.3
GERMANY	33.7
UK	29.9
CHINA	25.4
FRANCE	18.9
AUSTRALIA	16.8
USA	15.9
JAPAN	15.6
NETHERLANDS	14.4
SOUTH AFRICA	4.9
TAIWAN	4.6

The data on green bond issuances in US dollars per country is from Initiative Climate Bonds (CBI) (CBI, Dataplatform, 2021). The 18 countries in the dataset were the only countries to issue green bonds already in 2014. There is data available on other countries as well that issued green bonds later than 2014, however the effects of the green bonds will then also be capitalized later. Therefore, due to the relatively short time period, the effects are best captured when using the countries of 2014. The green bonds issuance is divided by total investments per country to obtain the share of green bonds. Total investments are measured by the gross fixed capital formation. The share of green bonds shows the importance a country puts on investing through green bonds. The gross fixed capital formation is obtained from the OECD (OECD, Investment (GFCF), 2022). Table 3 shows the descriptive statistics regarding the green bond share per year. The table presents the average share of green bonds of the total 18 countries. There is quite some variation seen in the share of green bonds between the countries, when looking at the minimum and maximum share of green bonds. Over time the share of green bonds increases. Besides green bonds, there are other factors that influence the percentage of renewable energy. Therefore, control variables are included. These will be explained in the next section.

Table 3: Descriptive statistics green bonds share

GB share *(in percentages)*				
Year	N	Mean	Min	Max
2014	18	.453	.002	1.653
2015	18	.455	0	2.228
2016	18	.593	0	3.158
2017	18	1.128	0	3.779
2018	18	1.32	.064	4.626
2019	18	2.069	.313	7.724
2020	18	2.673	.232	9.441

4.1.1 Control variables

The control variables, which may affect the percentage of renewable energy are included in the dataset. The willingness to pay for renewable energy is included in the model. Countries with a higher willingness to pay, may make more investments beneficial to the environment. According to the Environmental Kuznet's-curve, the willingness to pay for clean energy increases with income. The Environmental Kuznet's-curve states that first as income rises, the environment degrades. However, once income reaches a certain threshold, the degradation begins to subside (Shahbaz & Sinha, 2019). So, at a certain threshold the environmental pressure decreases. The Environmental Kuznet's curve hypothesises an inverted U-shaped relation between pollutants and income per capita. A dominant explanation for this Environmental Kuznet's curve is the tendency of having a higher preference for environmental quality as income per capita rises (Dinda, 2004). So, the proxy used for the willingness to pay is the mean income per capita. The data of income per capita is retrieved from the OECD (OECD, Average wages (indicator), 2022). Income per capita does not grow exponentially over time, therefore it is decided not to log-transform this variable. In addition, histograms have been made to compare a normal distribution with the distribution of the variable income per capita. Also, the square root transformation has been taken into account. Normality tests, such as the Shapiro-Wilk test, Shapiro-Francia test and Skewness and Kurtosis test have been conducted to ensure that indeed the visualisation of the data in histograms draws to same conclusion. It is seen that no log transformation is the best option. Furthermore, GDP growth per country from the Worldbank is included (Worldbank, 2020). This variable is included due to vintage capital models. Equipment from different vintages differ in their efficiency. This results from technological progress or non-exponential depreciation (Benhabib & Rustichini, 1991). So, new capital is usually more productive.

If there is high GDP growth which adds a relatively large amount of new capital, there will be a composition effect. This effect captures that the share of relatively young capital is relatively large in a growing economy. When adopting new capital and discarding older capital, it represents a source of technical change (Färe & Grosskopf, 1997). So, advanced technical characteristics are embodied in newer capital (Fallah-Fini, Triantis, & Johnson, 2014; Jorgenson, 1974). GDP growth stimulates the introduction of new capital, which results in more energy efficient technology. Moreover, fossil fuel subsidies are included due to lack of data over time per country on renewables energy subsidies. A higher fossil fuel subsidy is likely to result in a lower percentage of renewable energy generation. It is a financial barrier to switch to renewable energy sources. Fossil fuel subsidies are measured in the percentage share of GDP. The database of the fossil fuels is constructed by The Organisation for Economic Co-operation and Development (OECD) and The International Institute for Sustainable Development (IISD) (OECD & IISD, 2020). In addition, knowledge regarding energy technology and innovation is likely to play a role. It is found that the fields of knowledge regarding the topics building energy efficiency and building energy retrofitting are still far from the maturity phase (Cristino, Neto, Wurtz, & Delinchant, 2022). Thus, there are still research opportunities for gaining knowledge in this field. Investment in research addressing these themes is still needed. Therefore, to measure the amount of knowledge per country, the energy technology Research, Design and Development budget per country per year is included. These budgets per year are available through the IEA (IEA, 2020). Finally, the spatial differences per country can affect the speed of adoptability of renewable energy. To account for those, the availability of sun, water and wind are included. The availability of sun is measured by the average yearly sunlight (Climate data, 2020). The availability of water is measured by the water stress score per country (WRI, 2020). The higher the score, the more water stress a country has. Lastly, wind is measured by the average wind speed (Global Wind Atlas 3.0, 2022). Table 4 shows the descriptive statistics of all control variables in the dataset. An overview of all the data that has been gathered and the additional sources are in the final Section.

Hence, the panel data consists of the dependent variable: percentage renewable energy, measured by the percentage of biofuel, solar PV, wind and hydro in the energy generation of the total energy sources from 2014 until 2020. This will be explained by:

i. Share of green bond issuance of total investment, measured by the total value of green bonds issuance divided by total investments. Total investments are measured by means of the gross fixed capital formation

Controls:

ii. Willingness to pay, measured by income per capita.
iii. Economic growth, measured by GDP growth.
iv. Subsidies measured by fossil fuel subsidies percentage share of GDP.
v. Knowledge, measured by the energy technology Research, Design and Development budget per million unit of GDP in US dollars.
vi. Availability of sun, measured by average yearly sun hours (time-invariant)
vii. Availability of wind, measured by average wind speed (time-invariant)
viii. Availability of water, measured by water stress scores, the higher the score, the less available water a country has. (time-invariant)

Table 4: Descriptive statistics control variables

VARIABLES	(1) N	(2) mean	(3) sd	(4) min	(5) max
Income_per_capita *(in US dollars)*	126	41,165	16,896	4,680	69,392
Electricity_generation_solarPV *(in GWh)*	126	20,485	40,067	0	269,718
Electricity_generation_hydro *(in GWh)*	126	138,936	280,841	46	1.3 million
Electricity_generation_wind *(in GWh)*	126	50,120	89,946	257	471,175
Electricity_generation_biofuel *(in GWh)*	126	16,154	23,121	29	113,961
Total_electricity_generation_renewables *(in GWh)*	126	225,695	407,491	6,452	2.2 million
Total_electricity_production *(in GWh)*	126	901,482	1.7 million	43,678	7.8 million
GDP_growth *(in %)*	126	1.370	3.166	-11.10	7.400
Fossil_fuel_subsidies_perc_GDP *(in percentage share of GDP)*	126	0.315	0.431	0	2.564
RDD_energy_budget *(per million unit of GDP in US dollars)*	93	397.8	273.9	56	1,685
Sun_hours *(in hours)*	126	2,640	351.9	2,074	3,346
Water_stress_score *(between 0-5)*	126	2.216	1.057	0.440	3.770
Wind_speed *(in m/s)*	126	7.184	1.203	3.960	9.100

4.2 REGRESSION MODELS

4.2.1 Pooled OLS regression model

First a pooled OLS regression is performed. In this case all units are pooled and the same effect is assumed on the dependent variable for all countries. Equation 1 shows the equation that will be estimated. The dependent variable Y_{it} represents the share of renewables in the total energy production in percentages for country ***i*** in year ***t***.

$$Y_{it} = \beta_0 + \beta_1 GB\_share_{it} + \beta_2 Income\_per\_capita_{it} + \beta_3 GDP\_growth_{it} + \beta_4 Fossil\_fuel\_subsidies\_share\_GDP\_perc_{it} + \beta_5 RDD\_energy\_budget_{it} + \beta_6 Sun\_hours_{it} + \beta_7 Water\_stress\_score_{it} + \beta_8 Wind\_speed_{it} + \varepsilon_{it} \quad (1)$$

The table below shows the results of the pooled regression with robust standard errors. The robust standard errors are robust to heteroscedasticity of the error term. This means that it allows for the fact that variance of the error term might not be constant. The share of green bonds of total investment has a coefficient of 2.19 significant at a 1% level. This means that if the share of green bonds of total investment increases by 1%, the share of renewables of total energy production goes up by 2.19%. Norway has the highest average percentage of renewables with a value of 97.7% and Taiwan has the lowest average percentage of renewables of 4.6%. This results in a difference of 93.1 percentage point in renewables. The pooled regression model predicts a coefficient of the share of green bonds of 2.19. When multiplying the green bonds share of Norway of 2.56% and of Taiwan of 0.28% with the estimated coefficient, a difference of 4.99 percentage point arises. So, green bonds contribute by 5.4% in the explaining the total difference in renewables between these two countries. This decomposition shows that the estimated coefficient is not only statistically significant, but also has economic significance.

The control variables are all significant at the 1% level, except for income per capita and GDP growth. Besides these two control variables, all variables have the expected sign, except for the fossil fuel subsidies. This is probably due to the omitted variable subsidies for renewable energy. If the subsidy for renewable energy is significantly higher than the subsidy for the fossil fuel alternative, the variable might pick up this positive effect on renewable energy. The pooled regression has a relatively high r-squared. In column 2 of Table 5 time fixed effects are included by means of including year dummy variables in the regression model. This controls for time variance between the countries. It controls for time-trends that are common to all countries, like business cycles. The coefficient for the share of green bonds increases with about one tenth to 2.28 at a 5% significance level compared to the pooled model in column 1.

Table 5: Pooled regression

Dependent variable: Percentage of renewables		
	(1)	(2)
VARIABLES	Pooled Regression	Pooled regression Year fixed effects
GB_share *(in %)*	2.188***	2.283**
	(0.720)	(0.886)
Income_per_capita *(in US dollars)*	-0.000174	-0.000173
	(0.000176)	(0.000184)
GDP_growth *(in %)*	-0.0960	-0.259
	(0.685)	(1.304)
Fossil_fuel_subsidies_perc_GDP *(in percentage share of GDP*	52.40***	52.82***
	(8.554)	(8.891)
RDD_energy_budget *(per million unit of GDP in US dollars)*	0.0280***	0.0283***
	(0.00552)	(0.00584)
Sun_hours *(in hours)*	0.0610***	0.0617***
	(0.00608)	(0.00694)
Water_stress_score *(between 0-5)*	-22.91***	-22.92***
	(1.523)	(1.574)
Wind_speed *(in m/s)*	8.998***	9.241***
	(1.958)	(2.261)
Constant	-160.8***	-165.8***
	(30.28)	(34.60)
Observations	98	98
R-squared	0.786	0.787
Time fixed effects	NO	YES

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

4.2.2 Fixed effects regression model

The pooled regression does not use all the data available in the dataset. When pooling the units, the information that there are multiple observations for the same country is not used. The dataset includes multiple observations for multiple countries which is defined as panel data. The most basic panel data models are a fixed effects model and a random effects model. The latter requires very strong assumptions that are not likely to hold. It assumes a stochastic structure, which implies that all unobserved variables are statistically independent of all observed variables.

A fixed effects model assumes less strict assumptions. Therefore, in this section a fixed effects model will be estimated. A fixed effects model controls for unobserved time-invariant heterogeneity. It is a one-way error component model. There are three ways in fixed effects models to deal with individual-specific time-constant n-variables that cause the error term to be correlated with the regressors. The methods are a within-estimator, first difference estimator and least squares dummy variables. The latter implies including a dummy variable for each cross-sectional unit and using OLS. For big datasets this is not suitable. The within estimator is the quickest way to estimate a fixed effects model. The disadvantage of a fixed effects model is that time-invariant regressors cannot be included. These will be captured by the fixed effects. Therefore, the independent variables that measure the availability of sun, wind and water are not included. See equation 2.

$$\begin{aligned} Y_{it} = \beta_0 + \beta_1 GB\_share_{it} + \beta_2 Income\_per\_capita_{it} + \beta_3 GDP\_growth_{it} \\ + \beta_4 Fossil\_fuel\_subsidies\_share\_GDP\_perc_{it} + \beta_5 RDD\_energy\_budget_{it} \\ + v_{it} \text{ with } v_{it} = \eta_i + u_{it} \end{aligned} \tag{2}$$

The results of the fixed effects model are shown in column 1 of Table 6 on the next page. The standard errors are clustered. This is a type of heteroscedasticity- and autocorrelation-consistent standard errors. This allows for heteroscedasticity and any correlation within the country over time. The coefficient of the share of green bonds of total investment is 0.55, however is statistically insignificant. To interpret this coefficient, again a decomposition analysis will be done comparing the countries with the highest and lowest average percentage of renewables. When multiplying the green bonds share of Norway of 2.56% and of Taiwan of 0.28% with the estimated coefficient of 0.55, the model predicts a difference of 1.24 percentage point due to the difference in the share of green bonds. This results in green bonds explaining 1.33% of the total difference in renewables between Norway and Taiwan. In column 2 of Table 6, time fixed effects are included as well. The time fixed effects control for time trends that are common to all countries. The coefficient of GB_share decreases, but is again not statistically different from zero. The time dummies show an increase in the percentage of renewables per year compared to the base-year 2014. The t-values are not within the rejection region of a 10% significance level and are thereby declared as insignificant.

Table 6: Fixed effects model, within estimator

Dependent variable: Percentage of renewables		
VARIABLES	(1) Fixed effects model with within-estimator	(2) Country and Time fixed effects model
GB_share	0.545	0.268
	(0.381)	(0.473)
Income_per_capita	0.000819*	0.000499
	(0.000421)	(0.000603)
GDP_growth	-0.587***	-0.533
	(0.113)	(0.315)
Fossil_fuel_subsidies_perc_GDP	-11.60	-9.503
	(14.23)	(12.18)
RDD_energy_budget	0.000814	0.00155
	(0.00422)	(0.00477)
2015.Year		0.135
		(1.103)
2016.Year		0.461
		(0.991)
2017.Year		0.619
		(1.638)
2018.Year		1.873
		(1.514)
2019.Year		2.112
		(2.340)
2020.Year		1.929
		(4.348)
Constant	3.367	17.70
	(20.32)	(28.06)
Observations	98	98
R-squared	0.501	0.526
Number of countryID	14	14
Time fixed effects	NO	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

4.2.3 Explaining fixed effects by standard OLS regression

There might be spatial variation in countries that cause differences in the use of renewables. For this reason, the control variables measuring the availability of sun, wind and water were included. The drawback of a fixed effects model is that time-invariant regressors cannot be included, as mentioned before. In this section, first a fixed effects model will be estimated by means of the least square dummy variables estimation as shown in Table 7. The standard errors are clustered which allows for heteroscedasticity and any correlation within the country over time. This model shows the fixed effects per country. Subsequently, these fixed effects will be explained by spatial differences regarding the availability of sun, wind and water. The table below shows the fixed effects per country, they are all significant at the 1% level. The reference country is Australia.

Table 7: Fixed effects, LSDV estimation

Dependent variable: Percentage of renewables	
	(1)
VARIABLES	Fixed effects model LSDV estimation
GB_share	0.545
	(0.412)
Income_per_capita	0.000819*
	(0.000454)
GDP_growth	-0.587***
	(0.122)
Fossil_fuel_subsidies_perc_GDP	-11.60
	(15.36)
RDD_energy_budget	0.000814
	(0.00455)
Austria	57.97***
	(5.129)
Canada	44.26***
	(5.725)
France	3.373
	(6.196)
Germany	14.35***
	(3.909)
Italy	31.01***
	(6.606)
Japan	5.520
	(10.57)
The Netherlands	-13.44*
	(7.527)
New Zealand	50.48***
	(8.869)
Norway	73.28***
	(8.265)
Spain	26.39***
	(8.417)
Sweden	43.64***
	(6.089)
UK	18.99***
	(3.563)
USA	-15.74*
	(8.672)
Constant	-20.92
	(25.23)
Observations	98
R-squared	0.991

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

In order to explain the fixed effects, a standard robust OLS will be estimated per country. This will be done for the spatial differences between countries regarding the availability of sun, wind and water. First sun will be analysed.

4.2.3.1 *Spatial variation: sun*

The dependent variable is the percentage of electricity generated by solar PV of the total production. The regressor of interest will be the availability of sun, measured by the average yearly sunhours. Including too many control variables can lead to imprecise estimates as it can overfit the model. In that case it introduces noise and leads to problems with inference. (Zhang, 2014) Therefore, not all control variables will be added at once. If the amount of sunlight is the decisive factor of whether or not investing in solar panels, then the budget of RDD has no input. A country may decide to not use that money for researching to solar further. It is found that this variable does not change the coefficient of sun hours by a significant amount. So the finding is robust against a specific set of controls. In the table below, the regressions which have the percentage of solarPV as the dependent variable are shown. Column 1 shows a standard cross-sectional OLS estimation with robust standard errors, whereas in column 2 controls are included. In both cases the coefficient of yearly sun hours in the capital of each country is positive and is around 0.002. It is highly significant. In column 3, country dummies are added to control for variation across countries. In column 4, controls are included again. The sign of the coefficient changes and is in both cases significant. This could be due to the fact that sunhours of capitals are used. The sunhours per capital might not be a representative average for a country as a whole. Thus, the spatial variation of the availability of sun cannot be linked to a higher percentage of solarPV due to lack of representative data. There is scope for further research to investigate this relation and to create a trustworthy database regarding the sunhours per country with a weighted average.

Table 8: Regression table percentage solarPV

Dependent variable: Percentage of solarPV				
	(1)	(2)	(3)	(4)
VARIABLES	Standard	Incl controls	Country specific	Country specific incl controls
Sun_hours	0.00235***	0.00221***	-0.00962**	-0.0198***
	(0.000630)	(0.000580)	(0.00384)	(0.00734)
GB_share		-0.0151		0.205*
		(0.163)		(0.110)
Austria			33.41***	-25.18
			(0.696)	(0.849)
Canada			-3.978***	-4.344**
			(1.136)	(1.668)
China			-4.292**	
			(1.819)	
France			-5.979**	-8.211**
			(2.406)	(3.506)
Germany			0.374	-2.037
			(1.912)	(2.739)
Italy			10.06***	19.40***
			(1.522)	(4.977)
Japan			2.098**	7.184***
			(0.895)	(2.279)
The Netherlands			-4.897*	-10.52**
			(2.494)	(4.339)
New Zealand			-3.354***	-0.615
			(0.763)	(1.826)
Norway			-6.611***	-8.770***

			(1.957)	(3.300)
Peru			-7.226***	
			(2.555)	
South Africa			0.541	
			(0.587)	
Spain			3.865***	11.25***
			(1.007)	(3.494)
Sweden			-6.135***	-7.316***
			(1.860)	(2.573)
Taiwan			-9.377***	
			(3.418)	
UK			-6.818**	-11.53**
			(3.299)	(4.755)
USAo.			-	-
Income_per_capita		-2.43e-05		0.000234**
		(2.54e-05)		(9.90e-05)
GDP_growth		-0.306***		-0.150***
		(0.0841)		(0.0393)
Fossil_fuel_subsidies_perc_GDP		5.003***		-0.262
		(1.072)		(2.757)
RDD_energy_budget		-0.00121**		-0.00166
		(0.000599)		(0.00108)
Constant	-3.772**	-2.287	30.21***	46.02**
	(1.622)	(2.326)	(11.36)	(19.18)
Observations	126	98	126	98
R-squared	0.115	0.429	0.834	0.898
Controls	NO	YES	NO	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

4.2.3.2 *Spatial variation: water*

Now, the spatial variation regarding water is analysed. The dependent variable is the percentage of hydro of the total production. The variable of interest is the water stress score. The expected sign of this regressor is negative. The higher the score, the more water stress a country has. This indicates that the percentage of hydro decreases, as there is not a lot water present in the country. The table below shows the regression explaining the spatial variation of water. In the first column a standard cross-sectional OLS estimation is performed. In the second column controls are added. The coefficient has indeed the negative hypothesised sign. Both coefficients a highly significant at a 1% level. When adding country dummies in column 3, the coefficient decreases. It remains negative and highly significant. Australia in the reference category and has a water stress score of 3.3. All the countries that have a positive coefficient, have a intercept that is higher than Australia. The intercept represents the average percentage of hydro when the water stress score is zero.
In column 4, control variables are added and shows again a negative sign. It is significant at a 10% level. Therefore, it can be concluded that the spatial variation regarding the availability of water has a positive correlation with the percentage of hydro.

Table 9: Regression table percentage hydro

	Dependent variable: Percentage of hydro			
	(1)	(2)	(3)	(4)
VARIABLES	Standard	Incl controls	Country specific	Country specific incl controls
Water_stress_score	-16.45***	-18.09***	-7.870***	-28.71*
	(1.853)	(1.558)	(2.842)	(16.01)
GB_share		-1.131		-0.329*
		(1.043)		(0.172)
Austria			33.41***	-25.18
			(8.061)	(45.02)
Canada			34.89***	-10.88
			(6.267)	(35.71)
China			11.06***	
			(0.413)	
France			-5.175	-32.31
			(3.611)	(21.82)
Germany			-14.23***	-45.33*
			(4.216)	(24.41)
Italy			12.27***	14.88***
			(1.263)	(2.525)
Japan			-5.602**	-25.42
			(2.656)	(17.06)
The Netherlands			-17.64***	-44.70**
			(4.016)	(22.23)
New Zealand			29.38***	-23.86
			(7.521)	(43.33)
Norway			66.84***	9.858
			(7.761)	(44.26)
Peru			46.81***	
			(1.669)	
South Africa			-6.724***	
			(0.778)	
Spain			9.688***	21.13***

			(1.834)	(7.167)
Sweden			21.72***	-12.06
			(4.812)	(27.85)
Taiwan			-13.61***	
			(3.623)	
UK			-9.371***	-26.16**
			(1.918)	(12.62)
USAo.			-	-
Income_per_capita		-0.000329		-3.76e-05
		(0.000228)		(0.000143)
GDP_growth		0.347		-0.152***
		(0.711)		(0.0461)
Fossil_fuel_subsidies_perc_GDP		2.417		6.277**
		(10.05)		(3.061)
RDD_energy_budget		0.0261***		0.00190
		(0.00825)		(0.00253)
Constant	61.88***	70.98***	32.11***	100.2*
	(4.765)	(11.12)	(9.216)	(57.66)
Observations	126	98	126	98
R-squared	0.400	0.634	0.996	0.997
Controls	NO	YES	NO	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

4.2.3.3 Spatial variation: wind

In this subsection, the availability of wind is analysed. The table below shows the regressions performed with as dependent variable the percentage of wind of the total energy production. In column 1 a standard cross-sectional OLS is performed and shows a positive coefficient. It is significant at a 1% level. Column 2, where controls are included, also shows a positive sign. Nevertheless, it is insignificant. In the third column, country dummies are included. Again a positive sign, but insignificant. The final column included country dummies and control variables. Here a negative sign is seen that is highly significant. Thus, there is no strong connection between the availability of wind and the percentage energy generated by wind.

Table 10: Regression table percentage wind

Dependent variable: Percentage of wind				
	(1)	(2)	(3)	(4)
VARIABLES	Standard	Incl controls	Country specific	Country specific incl controls
Wind_speed	1.287***	0.682	1.141	-38.35***
	(0.335)	(0.680)	(2.258)	(10.51)
GB_share		0.868***		0.623***
		(0.197)		(0.108)
Austria			3.564*	-25.51***
			(1.899)	(8.094)
Canada			-1.258*	8.795***

			(0.665)	(2.977)
China			-1.012	
			(0.792)	
France			-0.670	-2.133
			(0.806)	(2.397)
Germany			10.10***	15.97***
			(1.850)	(2.040)
Italy			2.297	-49.78***
			(3.819)	(14.48)
Japan			-3.751	-39.60***
			(2.578)	(10.81)
The Netherlands			1.935	29.83***
			(2.070)	(7.965)
New Zealand			-2.431	65.00***
			(3.540)	(17.70)
Norway			-3.695**	24.18***
			(1.842)	(7.978)
Peru			0.543	
			(8.103)	
South Africa			-2.932	
			(1.979)	
Spain			14.44***	-19.25*
			(2.528)	(9.926)
Sweden			5.685***	-1.947
			(1.386)	(2.879)
Taiwan			-3.296	
			(3.453)	
UK			7.994*	80.37***
			(4.066)	(19.24)
USAo.			-	-
Income_per_capita		-2.25e-05		0.000556***
		(6.25e-05)		(0.000202)
GDP_growth		-0.434*		-0.242***
		(0.251)		(0.0869)
Fossil_fuel_subsidies_perc_GDP		4.597*		-12.92***
		(2.598)		(4.607)
RDD_energy_budget		-0.00920***		0.000404
		(0.00181)		(0.00148)
Constant	-2.443	5.696	-2.927	265.2***
	(2.400)	(5.863)	(17.03)	(73.26)
Observations	126	98	126	98
R-squared	0.077	0.331	0.873	0.940
Controls	NO	YES	NO	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

This Section investigated the effect of green bonds on the use of clean energy by means of an international comparison analysis. The panel dataset included in total 18 countries from 2014 until 2020. The dependent variable was the percentage of renewables used in the energy production per country over time. The variable of interest was the share of green bonds, which has been calculated by the green bond issuances and the total investments per country over time. Furthermore, control variables were also included. These were income per capita, based on the Environmental Kuznet's-curve and GDP growth because of vintage capital theory. Additionally, fossil fuel subsidies were included, since these provide a financial barrier in the transition to clean energy. Moreover, knowledge about energy technology could play a role. This has been captured by the energy technology Research, Design and Development budget. Finally, spatial differences between countries can cause differences in the speed of adoptability of clean energy. Due to this reason, the availability of sun, water and water were included, measured by yearly sun hours, the water stress score and wind speed respectively.

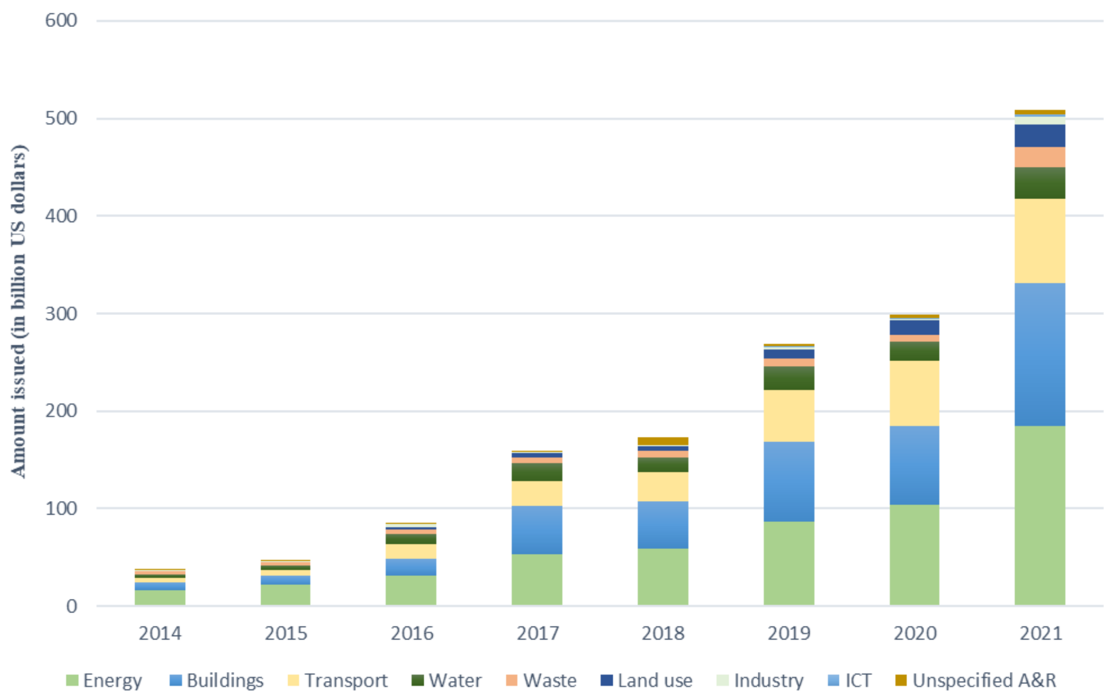
The pooled regression showed a positive correlation with a value around 2.2 with and without time fixed effects of green bonds on the percentage of renewables. The coefficient was highly significant at a 1% level. The fixed effects model controls for unobserved time-invariant heterogeneity. This means that time-invariant variables are captured in the fixed effects and can therefore not be included in the regression model. The share of green bonds showed a positive coefficient with the within estimation of 0.55. When including time fixed effects as well to control for time trend that are common for all countries, the coefficient remained positive and has a value of 0.27. Nonetheless, the fixed effects model had no significant result.

Subsequently, cross-sectional OLS estimations have been performed regarding the availability of sun, water and wind. The differences in fixed effects between countries could namely be due to spatial differences. Therefore, a division was made of the percentage of renewables into the percentage of solarPV, hydro and wind. The availability of sun was analysed first. The dependent variable was the percentage of solarPV of the total energy production. The variable of interest was sun hours. The analysis provided inconclusive results, since adding country dummies turned the sign of the coefficient negative. This would mean that the more sun hours in a year, the lower the percentage of generating energy by sun. A possible explanation for this could be due to that the sun hours per capital are not representative for the country as a whole. Further research can focus on calculating a weighted average of sun hours per country. Then, the availability of water was analysed. The dependent variable was the percentage of hydro of the total energy production. The variable of interest was the water stress score. The higher the water stress score, the lower the availability of water. All the different regressions provided a negative coefficient which were all significant. Thus, it can be concluded that the availability of water and energy generated by of hydro are positively correlated. Finally, the availability of wind was analysed measured by the average wind speed. The dependent variable was the percentage of wind of the total energy production. There is no strong positive correlation seen between wind speed and the percentage of wind energy generated.

The empirical analysis shows that green bonds are likely to have a positive impact of the share of renewable energy in general. This paragraph investigates the positive impact on the real estate sector specifically. According to the European Public Real Estate Association (EPRA) four sectors directly involve real estate or their value chain. These sectors are renewable energy, energy efficiency, green buildings and clean transportation. Renewable energy involves solar panels and wind turbines. Energy efficiency are investments in insulation, double/triple glass windows and combined heat and power plants (CHP). The category green buildings concerns new development and retrofitting of existing buildings. Lastly clean transportation involves EV charging stations, pedestrian walkways, bicycle lanes and garages. Transportation is part of the value chain, since sustainable transporting connects buildings (EPRA, 2021). According to the Global Real Estate Sustainability Benchmark (GRESB) also the other five sectors of the Green Bond Principles are linked to real estate. Sustainable waste management can involve building that show waste management metrics that are above prevailing building codes.

Also, sustainable land use can be linked to real estate. Investments in sustainable land use attributes can be regarded as conservation and preservation. Similar to sustainable waste management, sustainable land use can be rated by building rating systems, such as BREEAM, Green star or LEED. Real estate investment that preserves habitat biodiversity is regarded as an eligible green project. Minimizing potable water consumption and disposal in buildings are also of importance. This could involve green roofing and making sure that there is no potable water in landscaping. The last two sectors are climate change adaption, which is being rated in all real estate rating systems, and health and well-being. Health and well-being is about the air quality, so sufficient ventilation should be present. Also, thermal control, sound insulation and indoor ambiance connects the real estate. These factors can also be rated by several building rating systems. The first four sectors mentioned are probably most linked to the real estate and therefore contribute the most to the energy transition in real estate. The use of proceeds accounts for over 80% in these categories and remains the biggest over time. See Figure 5.

Figure 5: Use of Proceeds



Source: Data from Climate Bonds Initiative
Illustration: author's own
Note: A&R stands for climate change adaptation and resilience

The empirical analysis showed that green bonds are likely to have a positive impact on the use of renewable energy. Due to the fact that the vast majority of the use of proceeds is in categories directly linked to real estate and its value chain, it can be concluded that green bonds have a positive impact on the energy transition in real estate. The majority of the funds raised for real estate, namely 66%, is used for existing buildings. It shows that the focus of funds for real estate is on upgrading and renovating the existing building stock and thereby achieving the decarbonisation targets (EPRA, 2021). In the next Section, the improvements necessary for the policy targeting green bonds will be discussed.

5 POLICY IMPLICATIONS

In the previous Section, it is shown that green bonds have a positive influence on the share of renewable energy. Green bonds can complement the existing subsidies and taxes in order to speed up the energy transition in housing. In this Section, the current policy frameworks for green bonds are discussed. Then, with a special focus on the existing guidelines for the real estate sector. The global bond market is valued around 100 trillion USD, while the cumulative issuances of green bonds are just over 1.5 trillion (IRENA, 2020). So, in order to let green bonds flourish and contribute to the energy transition this policy will need to be enhanced. The improvements necessary will be discussed, consisting of standardization of reporting and verification, additionality tests, standardization of taxonomies, certification of green bonds, public governance and the role of technological advancement.

5.1 GREEN BOND FRAMEWORKS

There are several green bond frameworks and standards that try to promote transparency and disclosure. Also, it encourages integrity in the development by stating the wanted approach in issuing green bonds (AFME, 2022). The most common one are the Green Bond Principles by ICMA, as discussed in Section 3. The guidelines consist of Use-of-Proceeds, Process for Project Evaluation and Selection, Management of Proceeds and Reporting (ICMA, Green Bond Principles: Voluntary Process Guidelines for issuing Green Bond, 2015). However, in the Green Bond Principles, no definition is given what constitutes as green. The Climate Bonds Standard is another framework that does includes sector-specific green definitions. These are in line with the Climate Bonds Taxonomy. The sector-specific standards are used for certification (CBI, Climate Bonds Standard Version 3.0, 2019). The EU has also made their own standard: EU Green Bond Standard. This framework includes a taxonomy as well. Similar to the other frameworks, it highlights the importance of transparency. Furthermore, external checking must take place and these reviewers should be registered by the European Securities Markets Authorities (ESMA). The reviewers should also be supervised by the ESMA, to ensure quality, reliability and market integrity (European Commission, 2021).

5.1.1 Green bonds real estate sector framework

The Global Real Estate Sustainability Benchmark (GRESB) is a global standard in the real estate sector for portfolio-level ESG reporting framework. In the light of the Green Bond Principles, there are real estate guidelines issued by GRESB. The guidelines provide sector-specific guidance on identifying green buildings, implementing and managing proceeds and communicating green bond outcomes to stakeholders (Zurko, 2017). The first principle, use-of-proceeds, involves all kind of eligible green projects. It can range from construction to real estate investment activities. Real estate investment activities include land preservation easement, retrofitting and refinancing of existing high performance buildings (GRESB, Green Bond Guidelines for the Real Estate Sector, 2016). High performance buildings have a high level of energy efficiency (UNECE, 2017). For a project to qualify as a green project, the overall building certification level is suitable to use. It can serve as a minimum threshold to identify eligible green projects. To obtain certification green building rating systems should be used. These rating systems use performance-based measurements along impact categories to assess the validation of potential certification. In addition, documentation is required detailing specific environmental measures against a baseline set. There are several rating systems that can be used, such as BREEAM, LEED, DGNB, CASBEE or Green star. Furthermore, locally defined energy efficient levels need to incorporated as well (GRESB, Green Bond Guidelines for the Real Estate Sector, 2016). So, green projects should be assessed by means of using minimum threshold levels and the local requirements regarding energy efficiency. Per property types these criteria may differ.

The second principle is project evaluation and selection. As stated above, the funds raised by a green bond should be used for green projects. To assess the eligibility of green projects thresholds can be used. According to the second principle, the criteria to identify the greenness of a project should be communicated. This includes the overall project evaluation and the decision-making process. Moreover, in order to provide investors broader guidance and context, green property bond issuers should emphasis the alignment between ESG-ratings and the sustainability objectives of the entity itself. This provides insight into the history of the entity with green property investments, where ESG-ratings are based upon. Next, the third principle, namely management of proceeds, should track the funds used. The funds should be earmarked and issuers should direct capital to the green project until the proceeds are fully allocated. Periodic reporting during the life-to-maturity of the bond is a necessary component. Issuers should communicate the allocation of the funds, actions undertaken during at the project approval stage and the final project assessment fund. The evaluation processes should be disclosed as well.

The last principle regards reporting. When issuers are reporting in a periodic manner, this ensures transparency and disclosure for green bond investors. The three other principles mentioned above already discuss the importance of reporting. The fourth principle summarizes the aspects that require reporting in greater detail. Issuers should provide information regarding the use-of-proceeds and the actions taken related to the proceeds. GRESB stresses that in order to maintain market credibility, data accuracy and integrity are key. Investors should receive aggregated portfolio level disclosures upon bond origination as well as throughout the holding period (GRESB, Green Bond Guidelines for the Real Estate Sector, 2016). Green bonds can namely be sold in the secondary market before the bond matures. Annual reporting should incorporate three aspects. First, information about the use-of-proceeds. So, issuers of green bonds should report on the green project, the impact category and the outcome objective. Next, issuers should mention the energy ratings data and the green building certifications. This allows investors to review the investment decisions and to monitor progress made. Additional guidance may be required due to regional differences regarding different standards and norms in a specific region respectively. Finally, investors should be informed on the impact assessment. Here, performance is linked with the objectives set and the targeted impact. Different metrics can be used that are accepted within the industry to determine the performance and impact as long as the metric used is communicated clearly. Moreover, it might be beneficial to utilize ESG-ratings. This provides more context regarding the ESG performance history of the green bond issuer (GRESB, Green Bond Guidelines for the Real Estate Sector, 2016).

5.2 BARRIERS GREEN BOND MARKET GROWTH AND POLICY RECOMMENDATIONS

5.2.1 Green washing

Green washing is one of the biggest barriers that hampers the growth of the green bond market. One of the current voluntary guidelines highlights the importance of reporting. Reporting of green bond activities and their impacts is essential for creating attention and building confidence in green bonds. Torvanger et al. suggest that government should make more requirements on disclosure of activities that are beneficial to the environment. This will raise awareness among corporates and financial actors and will in turn stimulate the green bond market. This is due to the fact that issuing green bonds becomes easier when there is an existing institutional structure already for sustainability disclosures. Additionally, higher quality disclosures increase to credibility of green financial instruments (Torvanger, Maltais, & Marginean, 2021). So, more requirements regarding disclosures for sustainable activities will contribute to overcoming the current barrier of green washing. Furthermore, reporting on green bonds can benefit from standardization. Reporting is seen as a costly and complex process. So, creating standards for reporting and verification contributes to the stimulation of the green bond market (European Commission, 2020).

5.2.2 Impact

Another policy implication is the added value of green bonds in green projects. In order for green bonds to have a positive impact, the projects need to be additional. If these projects were undertaken regardless, green bonds have little effect in speeding up the energy transition. This becomes especially clear when companies simply use green bonds for refinancing their existing conventional bonds. In this case, there is no change in behaviour of companies (Flammer, 2020). The United Nations' Clean Development Mechanism (CDM) has created additionality tests to ensure the additionality of carbon offsets (UNFCCC, 2004). To demonstrate, one of these tests analyses if the project fulfils industry standards, regulations or formal policies. If this is the case, the project does not qualify as additional. Only if the project goes beyond this compliance, has so called regulatory surplus, then the project is seen as additional and may qualify. Therefore, such criteria for additionality tests can also help in case of green bonds. So, having additionality tests to ensure to added value of green bonds in projects helps the credibility of green bonds and most of all, ensures the desired additional impact.

5.2.3 Unclear definitions

A frequently mentioned drawback of the current guidelines is the definition of green. When the definition of green is ambiguous, it complicates as to what counts as a green project. This facilitates green washing and complicates certification. Besides the Green Bond Principles and the Climate Bonds Standard, there are a number of other international as well as national taxonomies that address the definition of green projects (Flammer, 2020). It is important that convergence towards commonly accepted definitions takes place. This will maximize the effectiveness, efficiency and integrity of the green bond market (OECD, Mobilising Bond Markets for a Low-Carbon Transition, 2017). In order to enhance the current guidelines, standardization of taxonomies is necessary.

For the taxonomies specifically regarding real estate, it is found by Benefield et al. that name recognition plays a large part in the value assessed to a property. Price increases are highest for real estate with the most known energy label (Benefield, Hefner, & Hollans, 2019). Therefore, increasing standardization among the taxonomies as to what are equal energy levels will help to contribute to a universal understanding.

5.2.4 Certification

Caroline Flammer finds in her research that certification is a fundamental governance mechanism. Her research shows that green bonds provide an increase in financial performance compared to non-green bond issuers. Furthermore, green bonds impact the environment in a positive manner. A decrease in CO_2-emissions and an increase in environmental ratings are seen. The findings of an increase in financial and environmental performance are only significant when the green bonds were certified by independent third parties (Flammer, 2020). In this respect, it is advisable that green bonds can only receive certification when certified by an independent third party. This will ensure integrity of green bonds, while also limiting the chances on green washing.

Certification is currently binary in nature. Green bonds can be either certified or not certified. However, it is reasonable to assume that green bonds differ in terms of their environmental impact. A similar rating scheme as tiered ratings used by credit rating agencies, like a triple-A rating for a green bond with the strongest environmental impact, can enhance the informativeness of certification. Adding this extra layer in certification contributes to expanding the depth of the green bond market (Flammer, 2020). Furthermore, digitizing green certification and verification processes reduces costs and time spent. This will reduce the barrier perceived by issuers of transaction costs involved by labelling the green bonds and complying with the reporting, verification and certification requirements (OECD, 2015).

It is up for debate whether or not the guidelines should remain voluntary or become mandatory. The European Commission is currently of the opinion that guidelines on a voluntary basis is the most suitable (European Commission, 2020). Mandatory application could lead to the adverse effect of stimulating the green bond market. Financial market participants could use other sustainable financial instruments, such as sustainability-linked bonds, that are not subject to any mandatory standards and are more broadly defined (ICMA, 2020). So, in order to stimulate the green bond market as best as possible, the standards should remain voluntary. Issuers who issue green bonds in accordance with a green bond standard, like the EU green bond standard, Climate Bonds Standard or the Green Bond Principles, benefit from the advantages of such standards. These advantages provided by the standards include recognition, standardized processes, incentives met and understanding the market (Driessen, 2021). Issuers of green bonds who do not wish to comply with any standards may still issue bonds with the label ‘green’. However, these issuers do not receive certification and benefit from the advantages provided by the standard. Also, as mentioned before, certification also provides an increase in financial and environmental performance.

5.2.5 Public governance

As the market will continue to grow, challenges mentioned above like greenwashing are likely to exacerbate. Leaving governance solely to the private market might hinder the potential financial and environmental impact of green bonds. The green bond market could benefit from hybrid governance, where there is both private as well as public governance (Park, 2018). The benefits from private governance are its flexibility and pragmatism. Nonetheless, private governance occasionally lacks transparency, legitimacy and accountability. Public governance can account for these drawbacks that private governance only brings along by providing a unified basis. Then the effectiveness of private governance is improved (Flammer, 2020).

The public sector is found to be of importance when explaining the growth of the green bond market. When the government includes sustainability as a part of their public policy, especially when focussing on financial markets, this boosts the issuance of green bonds. It reduces uncertainty for business when a government clearly supports sustainability for the long-term. This stimulates sustainable investments (Torvanger, Maltais, & Marginean, 2021).

5.2.6 Artificial Intelligence

A specific field that increasingly has been raising attention is artificial intelligence and its potential for green bond policy. The European Commission has published two action plans on these topics. The first is the so called “Fintech action plan for a more competitive and innovative European financial sector” (European Commission, 2018a) and the second is “Action plan for financing sustainable growth” (European Commission, 2018b). Nevertheless, the clear connection between green finance and the contribution of technological advancement is lacking according to CRIC (CRIC, 2018). The Corporate Responsibility Interface Center, CRIC, is a non-profit association for investors that promotes ethical and sustainable investments. There is a need for continue to explore the opportunities that artificial intelligence can offer to enhance green bond policy. For instance, big data analysis could potentially analyse a green building database. With this knowledge, performance of green buildings can be tracked and improved. It would be useful for stimulating green finance (Darko, et al., 2020). The lack of a dataset with credible information is a barrier for green finance (Agyekum, et al., 2020; Hafner, et al., 2020). Tan proposed a model that includes all kind of key financial variables, such as rental growth, discount rate and energy consumption to overcome this barrier. This will provide insight into the real market value by the revenue and expected expenditures for each building (Tan, 2019). Additionally, it will reduce information asymmetry. AI software can make use of this green buildings database and thereby provide real-time data on the performance of the buildings. More research should be conducted on how AI technologies can be incorporated in analysing the data. It must be pointed out that AI also has an important downside. The data will be stored in a secure way by making use of blockchain. Blockchain has a high energy consumption.

However, there are green blockchain applications that are developing to mitigate this problem. Green blockchain applications are built upon the blockchains Ethereum or Stellar. Ethereum requires 12-14 less electricity compared to Bitcoin and Stellar even less (Dorfleitner & Braun, 2019).

So, levering such technologies to green bonds or green finance in general in real estate can be of great asset to investors and developers. It can stimulate the use of green bonds by reducing barriers like, lack of credible information, information asymmetry and transaction costs of issuers. In addition, it can contribute in preventing green washing.

6 DISCUSSION AND FURTHER RESEARCH

This Master Thesis investigated the role of green bonds specifically. There is not much data available on the effectiveness of policy instruments separately, neither as a whole. More could be invested in investigating the effectiveness and providing such information open source. The most suitable policy design for the energy transition in real estate consists of a combination of policy instruments. A combination of policy instruments can reinforce each other. The effectiveness of green bonds can for instance be strengthened by levying a carbon tax on non-green projects.

The empirical international analysis in Section 4 uses data on green bond issuances for a period from 2014 until 2020. It would be appealing to do a similar analysis in the future with longer time series. Moreover, this analysis can be expanded if better data becomes available on the use of proceeds in different sectors, but also on various technologies. This will help to gain more understanding of the evolution of green bond markets and their financial and environmental impact. Incorporating also location factors on a more micro-level, business cycles and industry in an analysis can help explain the differences in performance of green bonds for issuers. A limitation of the empirical international analysis that arises due to lack of available data is the fact that data is lacking for the effect of green bonds on real estate directly. It is currently hard to estimate the issuance of green bonds by real estate companies used for real estate activities. By use of proceeds it is seen that the majority of funds raised by green bonds are invested in sectors related to real estate. Therefore it can be concluded from the empirical research that green bonds contribute in a positive way to the energy transition in real estate. Nonetheless, further research would benefit from reliable data and a more detailed dataset.

Real estate accounts for approximately 40% of the greenhouse gas emissions. Thus, gaining understanding in augmenting the sustainability of the built environment is of vital importance. Yet, the field of green finance in real estate is a heavily understudied area. In recent years, more research is conducted as it gained popularity. Still, the amount of academic literature is very limited. Especially the area of buildings efficiency and retrofits is understudied. The majority of the research is on new development. The International Energy Agency (IEA) highlights the importance of efficiency retrofits to promote green buildings (IEA, Sustainable Recovery, 2020). Furthermore, green finance and green buildings is usually studied in isolation (Debrah, Chan, & Darko, 2022). Further research can focus on studying green finance, such as green bonds, and real estate in combination. More empirical research on the effectiveness of green bonds contributes to the understanding of this new financial tool.

Moreover, due to the expansion of the green bond market, other drivers and barriers may arise. New research can focus on identifying these new drivers and barriers. Policy might need to adapt to those new insights.

6.1 POLICY DESIGN THE NETHERLANDS

This Master Thesis gave a global perspective of green bonds in the energy transition in residential real estate. In this subsection, an advice is given as to where the energy transition in housing stands regarding the Netherlands and how this can be improved with insights from this Master Thesis.

In the Netherlands, seven million dwellings need to undergo an energy transition. This cannot happen overnight and will take time. In my belief, a combination of several policy instruments would be the most beneficial. This way they have a bigger impact and support each other. Making sustainable renovation mandatory for everybody is easy to implement; there are already implemented measures regarding energy policy that are mandatory in the Netherlands. For example, since 2008 it is obligatory that energy labels are provided when a dwelling is sold or rented (Tambach, Hasselaar, & Itard, 2010). This energy label shows how energy efficient a dwelling is.

Since August 2021, the energy label also includes how easy a dwelling can become natural-gas free (Rijksoverheid, 2021). Another example is that new construction since 2018 needs to be natural-gas free (Klimaatberaad, 2019). In this Master Thesis it is argued that making sustainable renovation mandatory for everybody does not lead to the desired outcome. It will create extreme inequality due to differences in personal characteristics and living situations. The Ministry of the Interior and Kingdom Relations has very recently developed a policy program for the acceleration of the sustainability of the building stock (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties, 2022). In this program published on the first of June, normative incentives, financial incentives and informing are incorporated. Firstly, regarding normative incentives, mandating energy renovation is not desired as stated above. This is also seen in the policy program, where emphasis is put on 'natural moments' to perform retrofitting and renovations. These natural moments consist of replacement of equipment, like the boiler, major maintenance, purchase of a new house or connecting a district to a heating network. For the execution of the policy program, adjustments in the law need to be made. These changes consist of requirements for the existing building stock in phasing out low energy labels and stimulating district-oriented approaches. Also, the rent legislation will be changed in order to stimulate the landlords to perform energy renovations. As discussed in this Master Thesis, difficulties arise in stimulating landlords due to the split incentive. Legislation can in this case be helpful. In my perception, the planning of when the legislative plans come into force may be too optimistic. The legislative process will probably take longer than is anticipated.

Secondly, regarding the financial incentives, according to Ebrahimigharehbaghi et al. the Dutch government provides sufficient financial support to residents (Ebrahimigharehbaghi et al., 2019). The existing subsidies could be evaluated on the effectiveness and the possible problem of free-riding. Most important, more should be invested in making people aware of available subsidies and how to assess them, since households perceive a financial barrier. People should thus be well-informed on subsidies. Also, taxes have proven to be effective in terms of affecting behaviour. Taxes linked to the energy label is a practical tool, since it regards price differentiation in an already existing tax. This will be relatively easy to implement. In the Netherlands, the current pace of making dwellings natural gas free will not be sufficient to achieve the climate goals (van der Molen & Zhang, 2022). Already in 2020, the 'Algemene Rekenkamer' pointed out that a previous program called 'Programma Aardgasvrije Wijken' did not accomplish its goals. In the timeframe of a year, 150 million is spent to make over 2,000 dwellings natural-gas free, yet only a couple are in fact natural-gas free (Algemene Rekenkamer, 2020). Additional and more effective measures are necessary. Green bonds can help contribute in the acceleration of the energy transition in housing. The Netherlands have issued an amount of more than 23 billion green bonds in 2021, with a cumulative value of close to 80 billion since 2014 (CBI, Dataplatform, 2021). In the policy program, there is very brief section mentioning the financial resources for the execution of the program. Financial resources will be reserved for the upcoming 5 years. These financial resources include subsidies and taxes. Green bonds remain undiscussed. In addition, it is assumed that the majority of the financial resources can be stopped after the 5 years. Also, there is no discussion on how the size of the figures of the financial resources is estimated. Therefore, there is no clear view of the financial feasibility of the policy program. Moreover, the exclusion of the new financial tool of green bonds is an opportunity missed.

Aside from the financial tools, information tools are also a key determinant in policy. Informing residents should incorporate the stage of the decision-making process the resident is in. The type of information that is useful to a resident depends on the phase in the process. In addition, residents should be approached as individuals. So, differences in age and owning versus renting highlights different needs. The provision of information should address these different needs. Older home-owners have different interests, so information regarding higher comfort levels is more important to them than long-run cost reductions. In the policy program these aspects are addressed as follows. The Dutch government has made a website called 'verbeterjehuis.nl' to inform residents. It is possible to make a custom sustainability plan for a house.

Furthermore, corresponding financing, subsidies and providers are shown. For those that are not digitally proficient, help is offered at the regional 'energieloket'. In order to apply sustainable renovation cooperation of tenants is necessary in the Netherlands. The vast majority of renters, namely 70%, has to agree first to the proposed measures. Only then they can be implemented (Vringer et al., 2016). A consequence of these renovations is a possible higher rent and possibly a decline in the longer-term. Therefore, it is important that renters are well informed of all the benefits. In the study on social rental housing it shows that residents want to be part of the energy transition. According to Bal et al., it is best to provide clear instructions and the impact of their behaviour on the environment (Bal et al., 2021). Thus marketing campaigns and the provision of information should also be done towards renters.

Finally, apart from the normative incentives, financial incentives and informing, there is still a critical issue to be addressed. In the policy program, it is assumed that there is sufficient work force to perform the retrofitting and renovations. However, the 'Economisch Instituut voor de Bouw' has pointed out that there is a possible deficiency in the upcoming years and to minimize this problem, policy ambitions should be executed in phases (Economisch Instituut voor de Bouw, 2022).

7 CONCLUSION

Climate change is a pressing issue on a world-wide scale. Action needs to be taken to ensure a sustainable future. In the Paris Climate Agreement, is therefore agreed that greenhouse gas emissions must be halved by 2030 and that the EU should run entirely on sustainable energy by 2050. The built environment is responsible for approximately 40% of the greenhouse gas emissions (GRESB, Comprehensive Carbon Footprinting in Real Estate, 2018). This Master Thesis therefore focusses on the existing housing stock. There are drivers and also barriers in this energy transition. Understanding the main enablers and obstacles provides insight into the type of policy that is necessary. In this Master Thesis first a literature review is conducted with the most important drivers and barriers in the energy transition. Subsequently, policy instruments addressing these drivers and barriers are discussed and evaluated. A particular focus is given to green bonds, which is a new financial instrument. Thereafter, an empirical international analysis by means of a multivariate regression model is conducted, investigating the influence of green bonds on the share of renewable energy. In addition, the role of spatial differences across countries in the availability in water, wind and sunlight are explored in explaining the share of renewable energy. Next, the impact on the real estate sector specifically is assessed. Then, the current policy design regarding the use of green bonds in real estate is analysed. Finally, recommendations for improvement are made in order to stimulate the energy transition by the use of green bonds as best as possible. The following research question is central: To what extent can green bonds contribute to the energy transition in housing and how should the policy design regarding green bonds should look like in order to stimulate the energy transition as best as possible?

The main drivers can be subdivided into cognitive and financial drivers. The cognitive drivers were environmental concerns, enhancing life quality and easy accessible information. Financial drivers were cost-saving, payoff within reasonable timeframe and increasing house value. Cost-saving is shown to be the most important driver of all. The main barriers on the other hand were split into financial investment, transaction costs and socioeconomic variables. Energy renovation requires high upfront costs. This is seen as a significant barrier. Also, the timeframe of receiving gains counts as a barrier when they are delayed. In addition, renters have a 'split incentive' compared to owner-occupiers, since they benefit less from renovation (Nejat et al., 2015). Transaction costs consider the non-monetary costs associated with the energy renovation. This concerns asset uncertainty about the expected benefits or opportunistic behaviour and time and effort to gain knowledge and information. Complexity in the decision-making process itself is a transaction cost as well. Socioeconomic variables, like income, age and the construction period determine to a great amount the decision to renovate. Energy renovation has a high cost, so for people with low income this will be hard to realize. Additionally, older homeowners have less incentive to renovate, since their return on investment might not be on time. Older houses benefit the most from renovation, but it is seen that older houses are less likely to be renovated compared to newer houses.

After determining the main drivers and barriers in the literature review, another literature review has been done on policy instruments in Section 3. One can opt for making energy renovations mandatory. Other proposed instruments were providing financial incentives, like subsidies (Ebrahimigharehbaghi et al., 2019). Furthermore, carbon tax and taxes linked to energy labels were suggested (Amstalden et al., 2007; Vringer et al., 2016). Green bonds are another financial instrument which can help speed up the energy transition. This is a relatively new instrument and a special focus has been given to green bonds in this Master Thesis. Green bonds are debt instruments that raise capital for projects that have a positive environmental impact. The green bond market is booming and little empirical research is available on the impact of green bonds and its potential for the real estate sector. Usually investors pay a premium for green bonds compared to its vanilla equivalents. Issuers have a lower cost of finance when funding a green project with green bonds. It is seen that green bonds have a smaller bid/offer spread, are traded more frequently and have a higher turnover on average.

This means that green bonds are more liquid than vanilla bonds in the secondary market. Hence, although green bond are trading with a premium on average in the primary market, the flexibility of green bonds in the secondary market could justify the presence of a greenium. The fact that a buyer for a green bond is easy to find is due to high demand for green bonds. There is a lack of supply of green bonds, which likely results in the premium paid and the higher level of flexibility (Harrison, 2021; MacAskill, 2021). Other advantages for investors consist of low correlation with other types of bonds, equities and commodity prices (Horsch & Richter, 2017), asset-liability matching and reconciling the high demand for ESG-screened investments. In addition, green bonds are a safe asset against the volatility of fossil fuel alternatives, like oil price fluctuations (Braga, 2020). Furthermore, investment is less risky due to use-of-proceeds reporting in an otherwise relatively untransparent fixed-income market. When looking from the point of view of issuers of green bonds themselves, other advantages arise. Prices or issuance size can increase due to oversubscription. Fluctuations in the market may decrease due to this high demand. Green bonds give access to new types of investors. Furthermore, green bond financing provides higher returns than a bank loan and this financial incentive may constitute to commit to use-to-proceeds approach (Alonso-Conde & Rojo-Suárez, 2020). Lastly, issuers have a reputational benefit from issuing green bonds (OECD, 2015). The major drawback of green bonds is green washing. It is possible that green bonds are issued and the proceeds are not used to finance green projects Unclarity of what counts as a green investment and guidelines that are not mandatory to be followed contribute to the problem of green washing. The lack of accountability and transparency adds to the problem of green washing (Neves & Prata, 2018). Policy needs to target these elements in order to prevent green washing. Therefore, Section 5 is discussing the improvements that the policy for green bonds requires. Other disadvantages are that bonds do not compensate for inflation (except for inflation-linked bonds) and the ongoing transactions costs associated with labelling green bonds.

Besides normative and financial incentives, informing is another policy instrument that is mentioned frequently. Informing residents about the advantages of renovating, as well as informing intermediars (Ebrahimimigharehbagh et al., 2019; Klöckner & Nayum, 2016). Intermediars play an important part in informing and advising residents (Decuypere et al., 2022; Ebrahimimigharehbagh et al., 2019; Mortensen et al., 2016).

In Section 3.2 these policy instrument were evaluated. Mandating energy renovation will create extreme inequality due to differences in personal characteristics and living situations. Subsidies provide a financial incentive to residents. Limited or no subsidies at all is one of the major barriers in the decision-making process (Ebrahimigharehbaghi et al., 2019). Policy should focus on informing about the availability of subsidies and loans and making the process of assessing these less complex. Additionally, policy should target specific to low- and mid-income households. This can be done by not requiring upfront payment before receiving the subsidy. Also, making subsidies income dependent in order to avoid free-riding and a tax favourable interest-only mortgage supports low-income households. Taxes may be linked to the energy label of the house. It is pragmatic since it regard price differentiation in an already existing tax. The current pace of making dwellings natural gas free will not be sufficient to achieve the climate goals (van der Molen & Zhang, 2022). Additional and more effective measures are necessary besides subsidies, taxes and informing. Green bonds have a lot of benefits for investors as well as issuers. Green bonds can be seen as a combination of an implicit subsidy and a loan. It provides a financial advantage for issuers due to the greenium. Also, green bonds give incentives to invest properly, since the issuer must pay back the principal plus interest to the investor. Furthermore, green bonds provide incentives to invest according to the green label due to the warm glow effect. Due to its green label, it contributes to activities that are of societal importance that would otherwise not have taken place at regular market forces. There is a more disciplinary functioning in green bonds for the issuer in comparison with subsidies for instance. Green bonds can therefore contribute to the existing financial instruments.

Policy does need to address the considerable drawback of green bonds, which is green washing. Therefore, Section 5 discusses the necessary policy implications. Besides providing financial instruments, also information tools need to be part of the policy design. Informing residents should incorporate the stage of the decision-making process the resident is in. Every phase requires different type of information. Additionally, every resident requires specific information custom to their needs. Residents differ in their income, age and whether they own or rent. The provision of information should address these different needs and should be easy accessible in a centralized place. Finally, intermediars should be informed, guided and sensitized about the current heat pump installations systematically. This guarantees that homeowners receive reliable and up-to-date information. Intermediars should have a shared vision mutually. During information sessions among intermediars this could be achieved.

Green bonds can contribute to existing policy instruments and are necessary in speeding up the energy transition. Therefore, in Section 4 the role of green bonds is be explored. This is done by means of an international empirical comparison analysis. A complete dataset is composed for 18 countries in the period of 2014 until 2020. The percentage renewable energy is the dependent variable in the multivariate regression model. Renewable energy consists of solar PV, hydro, wind and biofuels. The variable of interest is the share of green bonds of the total investment per country. This shows the importance a country puts on investing through green bonds. Besides green bonds, there are other factors that influence the percentage of renewable energy. Therefore, control variables are included consisting of willingness to pay, economic growth, fossil fuel subsidies, energy technology budget and the availability of sun, wind and water. These control variables are based on economic theory and spatial differences among countries. The pooled OLS regression showed a positive correlation with a value around 2.2 with and without time fixed effects of green bonds on the percentage of renewables. The coefficient was highly significant at a 1% level. Subsequently, a fixed effects model is conducted. A fixed effects model controls for unobserved time-invariant heterogeneity. The within-estimator showed a positive coefficient of 0.55, however insignificant. The result stayed positive, yet insignificant when including time fixed effects. In a fixed effects model time-invariant variables cannot be estimated. The differences in fixed effects between countries could be due to spatial differences. Therefore, a division was made of the percentage of renewables into the percentage of solarPV, hydro and wind. These dependent variables were separately estimated by means of a standard cross-sectional OLS regression with as regressors of interest average sunlight hours per year, water stress score and wind speed, respectively. The analysis of sun provided inconclusive results. A possible explanation for this could be due to that the sun hours per capital are not representative for the country as a whole. Further research can focus on calculating a weighted average of sun hours per country. Spatial differences regarding the availability of water showed that the availability of water and energy generated by hydro are positively correlated. Whereas the availability of wind showed no strong positive correlation with the percentage of energy generated by wind.

The empirical analysis shows that green bonds are likely to have a positive impact of the share of renewable energy in general. Due to the fact that the vast majority of the use of proceeds is in categories directly linked to real estate and its value chain, it can be concluded that green bonds have a positive impact on the energy transition in real estate. The majority of the funds raised for real estate, namely 66%, is used for existing buildings. It shows that the focus of funds for real estate is on upgrading and renovating the existing building stock and thereby achieving the decarbonisation targets (EPRA, 2021).

Section 5 discussed the current policy framework for green bonds and the guidelines for the real estate sector specifically. These guidelines consist of use-of-proceeds, project evaluation and selection, management of proceeds and reporting. In order to let green bonds flourish and contribute to the energy transition this policy will need to be enhanced. The policy recommendations focus on overcoming the barrier of green washing. Firstly, more requirements regarding disclosures for sustainable activities constitutes to awareness among corporates and financial actors and will in turn stimulate the green bond market.

Issuing green bonds becomes easier when there is an existing institutional structure already for sustainability disclosures. Additionally, higher quality disclosures increase to credibility of green financial instruments (Torvanger, Maltais, & Marginean, 2021). Furthermore, additionality tests should be created to ensure to added value of green bonds in projects. This helps the credibility of green bonds and most of all, ensures the desired additional impact. Thirdly, convergence towards commonly accepted definitions should take place. This will maximize the effectiveness, efficiency and integrity of the green bond market (OECD, 2017). Also, increasing standardization among the taxonomies as to what are equal energy levels will help to contribute to a universal understanding. Moreover, it is advisable that green bonds can only receive certification when certified by an independent third party. This will ensure integrity of green bonds, while also limiting the chances on green washing. Differentiating in the certification between the different impacts that green bonds may have contributes to expanding the depth of the green bond market. In order to stimulate the green bond market as best as possible, the standards should remain voluntary. Mandatory application could lead to the adverse effect of stimulating the green bond market, where market participants seek other sustainable financial instruments that are not subject to any mandatory standards. Fifthly, the green bond market could benefit from hybrid governance, where there is both private as well as public governance (Park, 2018). Transparency, legitimacy and accountability can be improved by public governance by providing a unified base. Governments incorporating sustainability as a part of their public policy long-term stimulate the issuances of green bonds, since it reduces uncertainty for investments. Finally, levering AI and blockchain technologies to green bonds in real estate can be of great asset to investors and developers. It can stimulate the use of green bonds by reducing barriers like, lack of credible information, information asymmetry and transaction costs of issuers. In addition, it can contribute in preventing green washing.

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9 DATA SOURCES

- Percentage renewable energy (dependent variable): available through the International Energy Agency (IEA). Source link: https://www.iea.org/data-and-statistics/data-browser?country=WORLD&fuel=Energy%20supply&indicator=ElecGenByFuel
  Notes: calculated by dividing the total amount of solar PV, hydro, wind and biofuels in energy generation by the sum of ***all*** energy sources (oil, coal, natural gas, biofuels, waste, nuclear, hydro, wind, solar PV, solar thermal, geothermal, tide, and other sources). Energy sources are measured in GWh.
- Green bonds amount issued in US dollars, available through the Initiative Climate Bonds. Link: Market Data | Climate Bonds Initiative Data filters: green bonds only, country specific.
- Gross fixed capital formation in US dollars, available through OECD Data (OECD (2022), Investment (GFCF) (indicator). doi: 10.1787/b6793677-). Link: GDP and spending - Investment (GFCF) - OECD Data Data was unavailable for Peru and Taiwan. Data for Peru US dollars is from the World Bank. Link: Gross fixed capital formation (current US$) - Peru | Data (worldbank.org). Data from Taiwan of 2017-2020 in US dollars is available through Global Data. Link: The Nominal GDP (USD): Gross Fixed Capital Formation of Taiwan (2017 - 2025,Million) - GlobalData. Data from Taiwan of 2014-2016 is available through the National Statistics from Taiwan. Link: National Statistics, Republic of China (Taiwan). Choose 15-1.The Finance of Gross Domestic Capital Formation (At Current Prices). These numbers are in Taiwanese Dollars and these have been converted into US Dollars. The exchange rates of Taiwanese dollars to US dollars per year is available through Exchangerates.org.uk. Link: Taiwan Dollar to US Dollar Spot Exchange Rates for 2016.
- Average income measured by average wages in US dollars yearly from the OECD. Link: OECD (2022), Average wages (indicator). doi: 10.1787/cc3e1387. Median income is only available through Eurostat, so only for European countries. This limits the scope of research, since a lot of non-European countries are in the dataset. Therefore, mean wages are used. For Taiwan, data on monthly basis is used of Statista: • Taiwan: average monthly wage 2021 | Statista These data are multiplied by 12 to obtain a yearly wage and converted into US dollars. For China, yearly average wages are from trading economics, the national bureau of statistics of China. Link: China Average Yearly Wages - 2021 Data - 2022 Forecast - 1952-2020 Historical - Chart (tradingeconomics.com) These have then been converted from CNY into USD. Peru is from trading economics, central bank of Peru. Link: Peru Average Monthly Wages - April 2022 Data - 2001-2021 Historical - May Forecast (tradingeconomics.com) These have then been multiplied by 12 and converted from PEN into USD. South Africa is from trading economics, statistics South Africa. Link: South Africa Average Monthly Gross Wage - 2022 Data - 2023 Forecast (tradingeconomics.com). These have then been multiplied by 12 and converted from ZAR into USD.
- GDP growth in percentages, available through worldbank, link: https://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG. Data from Taiwan is from International Monetary Fund (IMF) Link: Report for Selected Countries and Subjects (imf.org)
  Notes: annual % growth rate of GDP
- Fossil fuel subsidies measured in the percentage share of GDP. The database is constructed by The Organisation for Economic Co-operation and Development (OECD) and The International Institute for Sustainable Development (IISD). Link: Home - Fossil Fuel Subsidies (fossilfuelsubsidytracker.org)
- Energy technology Research, Design and Development budget per million unit of GDP in US dollars. Link: Data & Statistics - IEA
- Availability of sun, measured by the average amount of sun hours in the capital of each country. Link: Klimaat data voor steden wereldwijd - Climate-Data.org Climate-date.org data is based

on ECMWF Data and is collected between 1999 and 2019. China is from the World Weather & Climate Information. Link: Average monthly hours of sunshine in Beijing (Beijing Area), China (weather-and-climate.com) Taiwan: Taipei City climate: Average Temperature, weather by month, Taipei City weather averages - Climate-Data.org

- Availability of water, measured by the water stress score per country in 2020. Data is provided by the World Resources Institute. The score measures the total annual water withdrawals (municipal, industrial and agricultural) expressed as a percentage of the total annual available blue water. (Luo, Young, & Reig, 2015) The score is between 0 and 5, where 5 indicates high water stress (>80%). So, the higher the score, the lower the availability of water. There are 3 scenarios: business as usual, optimistic and pessimistic. The scores used are from the scenario business as usual (BAU). Link: Data: Aqueduct Projected Water Stress Country Rankings | World Resources Institute (wri.org)
- Availability of wind, measured by the average wind speed per country. Mean wind speed at point ranking 50% of windiest areas in meter per second. Data is from the NASA Shuttle Radar Topography Mission (SRTM) elevation data with the digital elevation model (DEM) Link: Global Wind Atlas