Maastricht University

MAASTRICHT CENTER FOR REAL ESTATE

Inaugural lecture

Prof. dr. Nils Kok

School of Business and Economics

People Planet Property

How Buildings Shape the Environment, Your Health, and Your Wealth

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How Buildings Shape the Environment, Your Health, and Your Wealth

Nils Kok is Professor in Real Estate Finance at Maastricht University, the Netherlands, where he also directs the Maastricht Center for Real Estate. His research interests range from urban economics to institutional real estate investments, with a strong focus on the economics of energy efficiency and sustainability in the real estate sector.

Previously, he was a non-executive board member and Chief Economist at GeoPhy, which was sold to Walker & Dunlop in 2022. Nils was also the founder and CEO of GRESB, a global ESG rating company for real estate and infrastructure investments, which was sold to GBCI in 2014 and subsequently sold to Summit Partners in 2021.

Nils' research has appeared in leading academic journals, including the American Economic Review, Review of Economic and Statistics, the RAND Journal and the Journal of Public Economics, and is frequently cited in newspapers and industry publications.

Nils received his PhD from Maastricht University (Netherlands) and, after a 4-year stint in Westport, Connecticut, currently lives in Maastricht, the Netherlands, with his wife, Lian, and his three kids.

More information at www.maastrichtrealestate.com

Design & Print: Canon The Creative Hub (UM-230008)
Design illustration: Chiara Schiatti

ISBN: 978-90-5681-495-3
NUR: 793

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How Buildings Shape the Environment, Your Health, and Your Wealth

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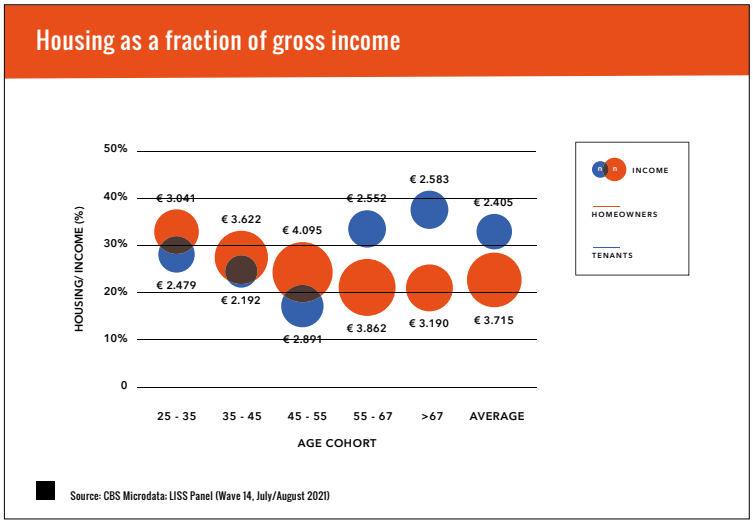
Inaugural lecture
given in shortened form upon the public acceptance of the appointment as professor of Real Estate Finance at Maastricht University on Friday February 10, 2023, by Nils Kok.

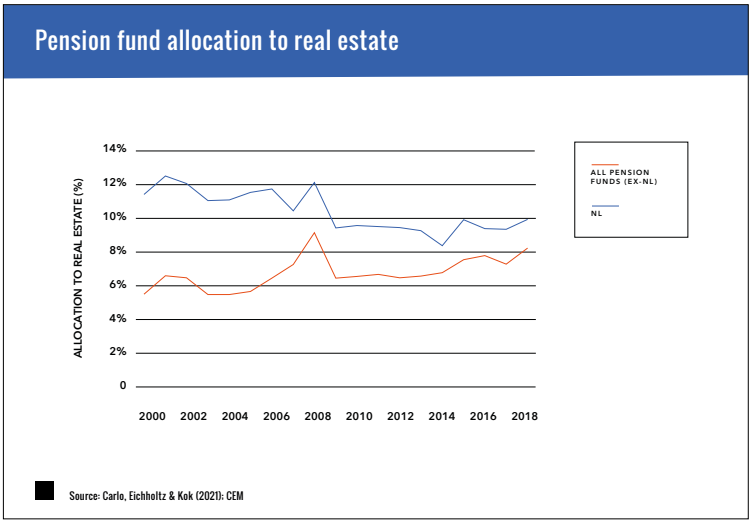
"Research, like travel, is about the journey, not the destination."

Real estate is a big part of your life, you live in an *apartment or house*, you likely work in an *office*, maybe you bring your kids to a school, you sometimes eat in a *restaurant* and perhaps you go to the *gym*. Real estate is also a big part of your financial life: you're spending a large percentage of your income on housing. If you own your own house, you spend on average 23% of your gross income on your monthly mortgage payment, varying between 28% for youngsters and 21% for older people. If you rent a home or an apartment, like the other 3.2 million households in the Netherlands that are tenants, you're spending on average 33% percent of your gross income on rent (varying between 17% and 38%).



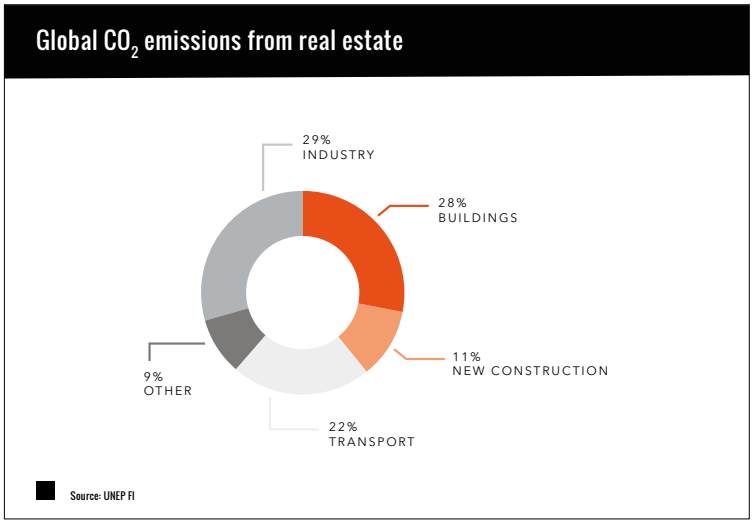
The impact of real estate on your financial situation goes beyond your own home. For example, think about the pension fund, to which you, knowingly or unknowingly, contribute on a monthly basis. ABP for teachers, policemen, firemen, etc. PfZW for doctors and nurses. PMT for metalworkers, but also for the ASML'ers out there. You may not think about it right now, while you are in your 20's, 30,'s, 40's or even 50's, but the monthly check from your pension fund makes up a large fraction of your income once you retire. On average in the Netherlands, that fraction is 68% of gross income for folks that are 65 years or older (and own their

own home)! Importantly, your pension fund invests in real estate as well: Alexander Carlo, Piet Eichholtz and I show that, across the globe, pension funds allocate about 8% to real estate, on average, and in the Netherlands that's even more, at about 10% (Carlo, Eichholtz and Kok, 2021). Dutch pension funds such as ABP or PfzW are even at allocations of 11% and 12%, respectively.



But, real estate doesn't just affect you through a mortgage, rent or pension. **Real estate and the environment are also closely related:** about 40% of total energy consumption in the United States (and that number is similar in Europe) is consumed by the built environment, including both residential homes and commercial buildings (EIA, 2022). If you purely look at electricity, that number is even higher, at 71%, going up from 50% about 70 years ago as the economy changed from agriculture to factories, and from factories to offices. You're probably pretty aware of the fact that real estate consumes a lot of energy, with energy costs rising rapidly during 2022. For many households, the monthly energy bill has doubled or even trebled. Indeed, energy expenditures, after rent and mortgage payments, are the second largest fixed cost for most households. In 2021, energy made up about 4.5% of gross income if you were an owner, or 4.6% if you were a tenant. Assuming an average increase in energy prices of 400%, the percentage of monthly gross income spent on energy is now 18% for both owners and tenants!

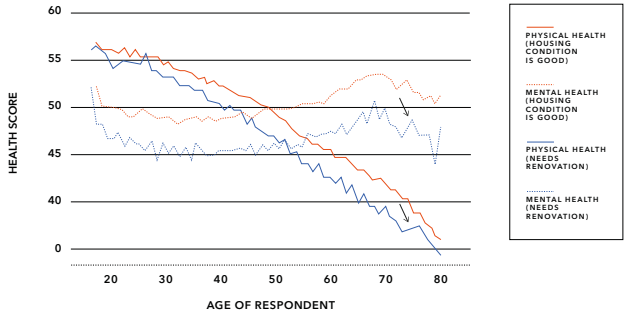
The environmental impact of real estate is not just about energy. Real estate's consumption of electricity, gas and other natural resources leads to 39% of global carbon emissions - 28% of global carbon emissions stem from the operation of buildings, like heating (maybe cooling) of your own home, lighting, etc. Another 11% of emissions stem from new construction - emissions generated through the production of concrete, steel and all other materials that are needed to build new buildings. You may wonder how carbon missions are related you? Well, carbon missions are irrevocably linked to global warming, and subsequently, climate change. The devastating effects of a changing climate include, for example, flooding and wildfires, but also extreme heat and pollution.



Real estate may also affect you in a different way: through your health. "The great indoors" is where you're sleeping, eating and, increasingly, working. Indeed, the National Human Activity Pattern Survey shows that you're spending about 86.9% of your time indoors, that's the equivalent of about 21 hours per day (Klepeis et al., 2001)! Now that wouldn't be a problem if the quality of "indoors" would be perfect, but that's sadly not the case. The state of maintenance of for example homes in Europe is actually not as great as you would expect it to be (EU SILC, 2015). In the Netherlands, about 15% of homes are considered deficient, with a leaking roof, damaged walls, or some form of rot in windows and doors. That percentage is even higher in Belgium, Denmark, France and many other

European countries. Such bad maintenance of homes has a direct effect on your physical health. In research together with Juan Palacios, Piet Eichholtz and Erdal Aydin, we study the causal effect of home maintenance on health outcomes. We document that in homes that are not so well-maintained, the physical health of occupants is significantly lower as compared to the physical health of people living in well-maintained homes. Importantly, it's not just self-reported health, but also actual doctor visits that are influenced. The difference holds throughout the lifecycle, but is particularly strong for elderly, who spent most time at home and in that sense are exposed to the highest "dose" (Palacios, Eichholtz, Kok and Aydin, 2020). The same picture emerges if you look at mental health. The good news is that your mental health typically goes up until the age of about 70, after which it slowly starts to go down. But throughout your life, your mental health is much better if you live in a home that is well-maintained as compared to a home that has deficiencies in maintenance.

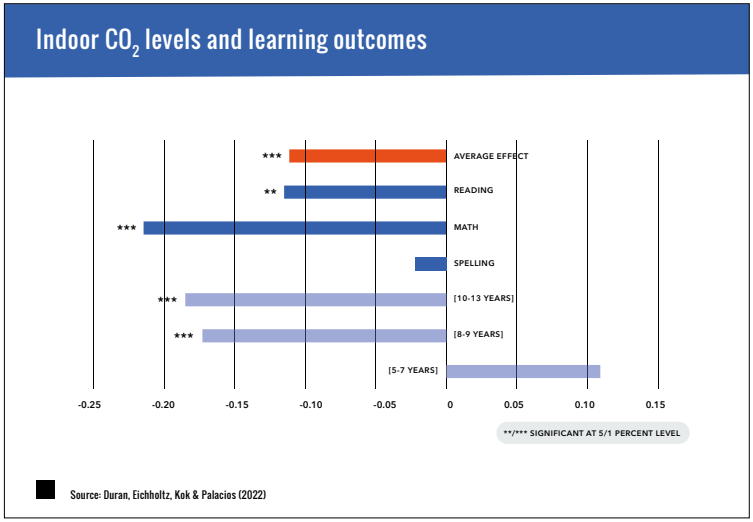
Housing quality and physical/mental health



Source: Palacios, Eichholtz, Kok & Aydin (2020)

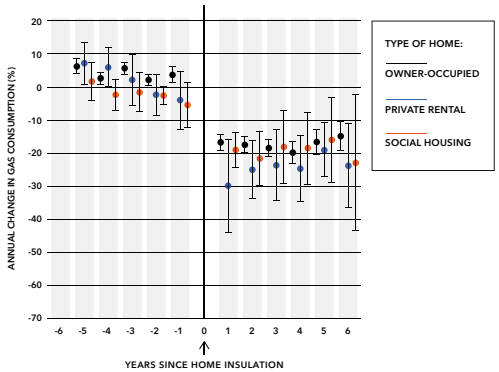
If we dive deeper into a building, it's not just maintenance that matters, but also air quality within buildings. And that air quality can be pretty bad. In a long-running study on 300 classrooms across 30 schools, we continuously measured the indoor air quality, over a period of five years. What we found is that daily peak CO_2 levels were almost always above the legally prescribed level, which is 1,200 parts per million (ppm). And if you wonder what that does to the brain of the young child, the results are

pretty stunning (in a bad way). If you double the CO_2 emissions in the air in the period during which kids are learning, say from September until November, learning outcomes go down with 20% at their subsequent test, in December. The effects are strongest for reading and mathematics, and for kids from 8 to 13 years old. Importantly if we look at high school recommendations, we find that the likelihood of getting high school advice for HAVO/VWO, which subsequently gives access to university and the university of applied science, is about 30% lower when you double the CO_2 level in the period preceeding to the final test (Duran, Eichholtz, Kok and Palacios, 2022).



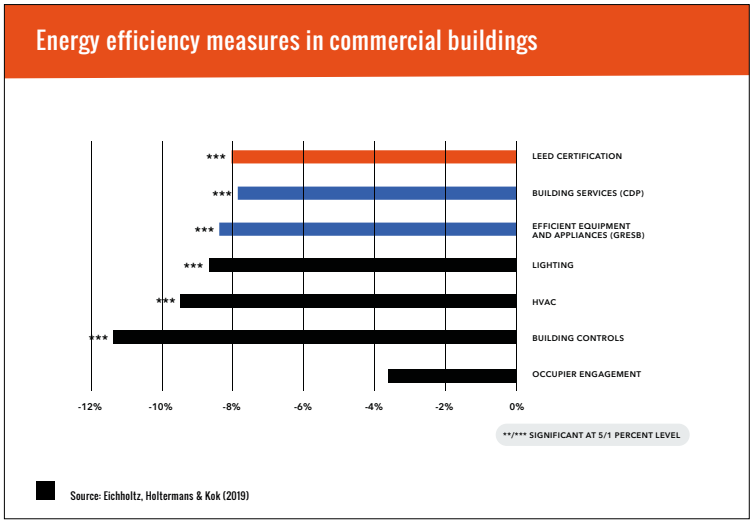
But, real estate can also be a force for good. Let's start with the environment. In recent research, Linde Kattenberg, Piet Eichholtz and I study the impact of home insulation on actual energy consumption, using data from Bameco BV, an insulation company in the Maastricht area (Eichholtz, Kok and Kattenberg, 2022b). We have data on insulation interventions for both homeowners and for tenants (who likely have less influence on the insulation decision), and construct a control sample of comparable homes that were not insulated. Once you install home insulation, which is relatively cheap, the average gas consumption goes down with about 20%, whether you're a homeowner or a tenant in a rental home. That effect is persistent and lasts for a period of at least 10 years.

Insulation measures and energy consumption in housing

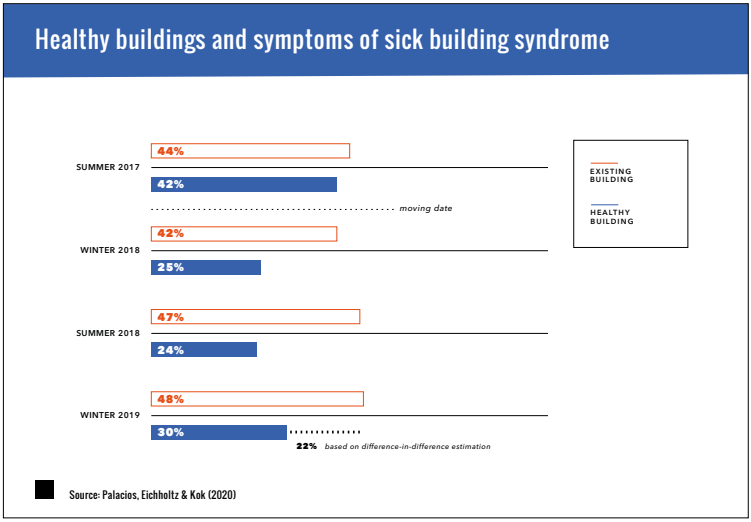


Source: Kattenberg, Eichholtz & Kok (2022)

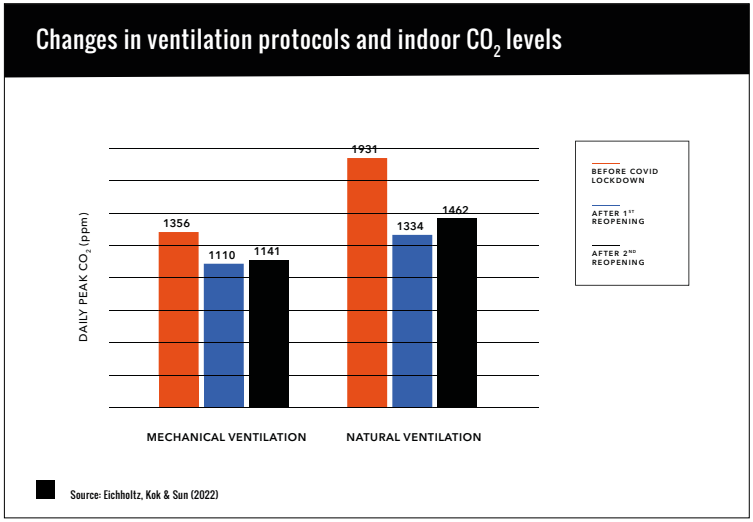
And it's not just homes where energy efficiency measures can have large effects. Piet Eichholtz, Rogier Holtermans and I looked at the effect of investments in energy efficiency in commercial buildings, in a study using data from Measurabl, which provides a platform for collection of environmental, social, and governance (ESG) data. We document that relatively simple interventions, such as lighting replacement programs, from conventional lighting to LED lighting, leads to a reduction in whole building energy consumption of 9%. Changing the HVAC system can yield a real estate investor savings of about 10%. Certification by a green building label, LEED, also reduces consumption, by 6-12%. Only behavioral interventions, such as information provision to tenants, did not lead to significant reductions in energy consumption (Eichholtz, Holtermans and Kok, 2019).



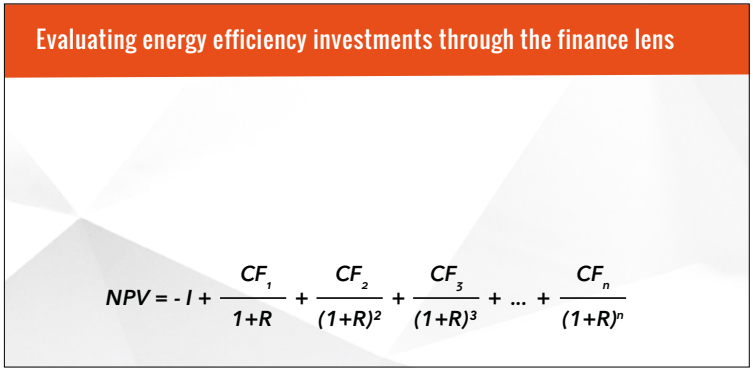
And the positive effects of green building go beyond energy savings alone. In 2016, part of the workforce of the city of Venlo moved into a new healthy and green building. The building has natural ventilation only, to save on energy expenditures, but also to provide an indoor environment that more resembles the outdoor environment. Part of the workforce of the municipality stayed in the existing building, while some teams were (randomly) assigned to move to the new building. Juan Palacios, Piet Eichholtz and I surveyed the entire workforce both before a part of them moved, and then surveyed the entire workforce multiple times after the move. What we found is that reported symptoms of the so-called "sick building syndrome," such as headache and dry eyes, were reduced significantly for those employees that moved into the healthy building. Based on a formal difference-in-difference estimation, the change was 22% (Palacios, Eichholtz and Kok, 2020). Importantly, those employees also reported in sick less often, with sick leave falling by 2% - a seemingly small number, but it had a big effect on the organization.



Interestingly, it's not needed to build a completely new building to improve the indoor environment - simple interventions in existing buildings can also change air quality for the better. The recent COVID crisis, as bad as it was, offers an interesting experimental setting. We again studied the 300 classrooms where we had already put sensors, comparing the period before the COVID-induced lockdowns (when children had to stay at home) with the periods right after. We found that changes in school ventilation protocols - teachers had to open windows and the mechanics in schools had to crank up the ventilation system to the maximum - lead to significant improvements in CO_2 levels in classrooms. These levels went from 1,930ppm in naturally-ventilated rooms, to levels that were 600ppm lower in the new situation (remember, that's an improvement in learning outcomes of 6%). In mechanically ventilated classrooms, the CO_2 levels decreased with 200ppm, on average (Eichholtz, Kok and Sun, 2022).



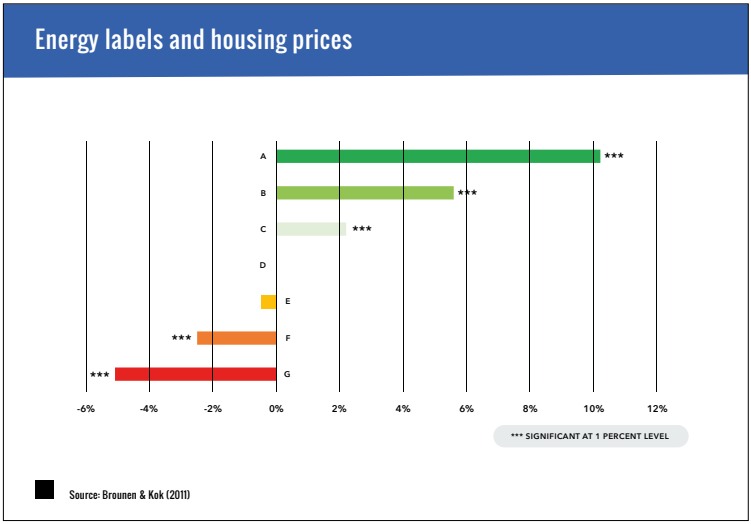
Importantly you can do "well" by doing "good." If you put green and healthy investment decisions into a finance framework, using the simple, Finance 101, discounted cash flow (DCF) model, you can compare the initial investment in energy efficiency and/or health with its subsequent cash flow, divided by one plus a required rate of return. Or, simply compare the return on an energy efficiency investment with the return on a "conventional" investment.



If you go back to the insulation study on homes in the greater Maastricht area (see Kattenberg, Eichholtz and Kok, 2022b), the initial investment, at the price level when the insulation measure was taken, ranges from

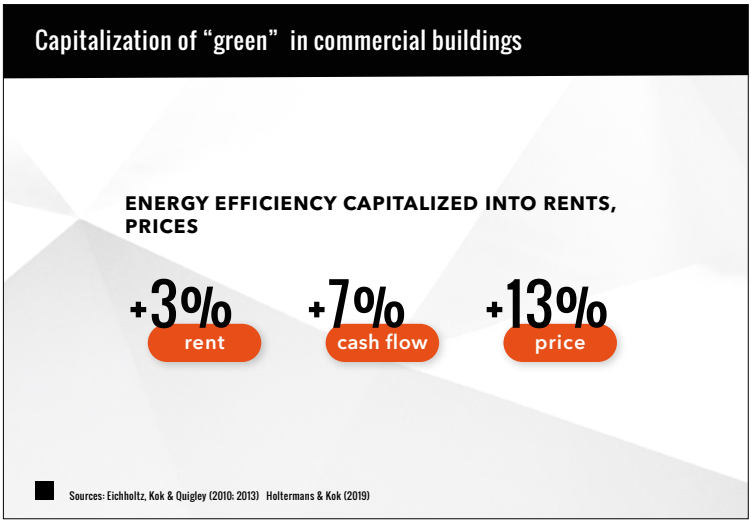
€1,400 for floor insulation to €2,000 for roof insulation. The yearly savings on those investments are €164 to €300 - assuming perpetuity, that's an annual return of about 11% to 15%. The return on wall insulation is even higher, at 18%. Now if you use 2022 prices, you find that the annual return has gone up to about 25% for floor insulation to 41% for wall insulation. Compare those very simple return calculations with the average annual return on, for example, stocks (8%), bonds (5%) or real estate (7.7%) and the picture is clear: the return to home insulation basically beats...anything.

What about energy efficiency in homes more broadly? As early as 2011, Dirk Brounen and I documented that homes deemed energy efficient, as measured by the Dutch energy label (the EPC), were selling at a premium relative to inefficient homes, or looking at the other side of the coin, inefficient homes were trading at a discount relative to efficient homes (Brounen and Kok, 2011). The marginal cost of improving a home is a popular item of discussion, but the Economisch Instituut voor de Bouw (EIB) and the award-winning consultancy firm Finance Ideas estimate the investment to improve a home by one notch on the energy label (EPC) scheme at about €4,000. An improvement of a home with label G to label C would thus cost about €16,000. At the average house price in the Netherlands (which admittedly is inflated), that compares to a premium of €29,000 - this more than compensates for the initial investment (and some).



The return on investment for green building is a little harder to quantify, mostly because cost estimates on the marginal cost of green building are scant. In early research with Andrea Chegut and Piet Eichholtz, we documented that the average construction costs of green building were just about 7% higher as compared to the construction costs of a conventional building. Of course, if you wanted to build a deep green, BREEAM Outstanding building, the marginal cost would be higher, in this case by about 30% (Chegut, Eichholtz and Kok, 2019). Note this data is now about 10 years old, and the cost of green building has likely compressed as green technology has become more commonplace. We also showed that much of the higher cost for green building is reflected in the cost at the design stage rather than the "hard" costs that are actually incurred to construct a building. This is an impediment for developers, who bear the brunt of costs at the design stage themselves.

When you look at the capitalization of green or energy efficiency into market prices, we have ample evidence. In research first started during my PhD, with John Quigley and Piet Eichholtz, and later repeated together with Rogier Holtermans, we have consistently documented that green, energy-efficient buildings have rents that are about 3% higher as compared to non-green buildings, cash flows that are about 7% higher, and ultimately, green buildings have prices that are higher by 13%, on average. What that means is that the initial (marginal) investment in green building is more than recouped by the developer, or throughout the economic life of the asset by the investor (Eichholtz, Kok and Quigley, 2010, 2013; Holtermans and Kok, 2019).

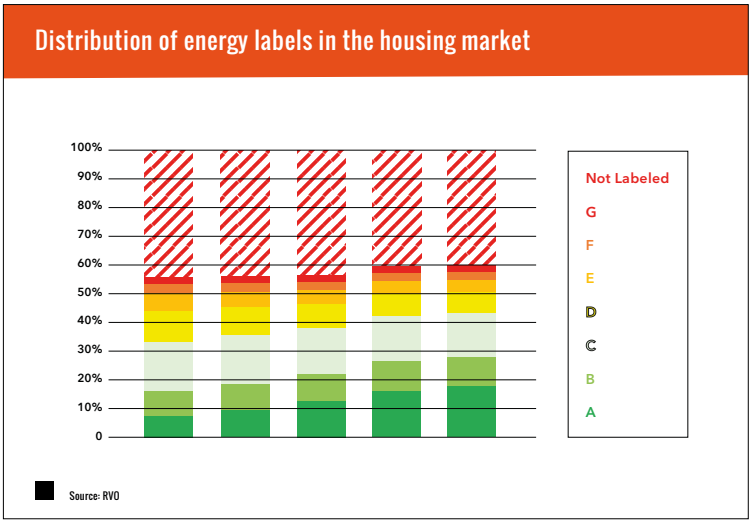


Of course, it's not just about energy. Investing for health also yields a return. Back to Venlo, where the marginal investment to make the building from a rather boring, conventional asset into a healthy, green building was €3.4 million of hard-earned taxpayer money. The marginal benefit in building management and exploitation, such as savings in energy consumption already amounted to €17 million. But as documented in our research, there's another marginal benefit: the reduction of sick leave. The wages of the 800FTE working at the city of Venlo are estimated to be about €54 million per year. 43% of employees are sick at least once a year, with an average sick leave of 5 days. A simple back-of-the-envelop calculation shows that a 2% reduction in sick leave leads to a capitalized benefit of another €2.5 million - that's almost the same as the marginal investment needed to make this building into a healthy, green building in the first place. And mind you, we didn't even consider the beneficial effects of potentially enhanced productivity of employees in the healthy building here.

One more thing on the return on health. Let's go back to Germany, where about 29% of the housing stock needs some form of improvement. Imagine that you indeed renovate 29% of the total stock, which stands at 41 million homes and apartments. At a renovation cost of €50,000 per home and €25,000 per apartment, the total cost of this massive renovation wave would be €446 billion - a lot of money (about one-tenth

of the German GDP). The marginal benefit of that renovation wave would obviously be reflected in energy savings, but let's forget about that for now. We purely focus on the marginal benefits of reduced demand for healthcare. We estimate that the present value of savings of reduced doctor visits (and subsequent demand for healthcare), capitalized under the assumption of perpetuity, would lead to savings of about €600 billion. Given these number, there is clearly an NPV-positive business case for renovation of deficient homes, from the perspective of demand for healthcare alone. Or vice versa, the current renovation wave, prompted by the energy crisis, also has other positive externalities, such as health improvement and healthcare savings.

So, if the business case is so good, why aren't all buildings green and healthy? Well, it's important to realize that a large chunk of the building stock is old. Indeed, if you look at the distribution of the building stock by year of construction, what you observe is that about 50% of the Dutch stock of homes is more than 50 years old. Given that we aim construct 70,000 to 80,000 homes per year, we only add about 1% of new, efficient and healthy buildings per yeae. This is also reflected in the energy efficiency of the stock - less than 50% of homes are labeled with a label C or better (and about 42% of the stock isn't even labeled). How to convert all these homes, as well as all inefficient commercial buildings, to higher levels of energy efficiency and health? Given that buildings are long-lasting, durable goods, and given that both the residential and commercial real estate markets are full of frictions and failures, the market may need some help.

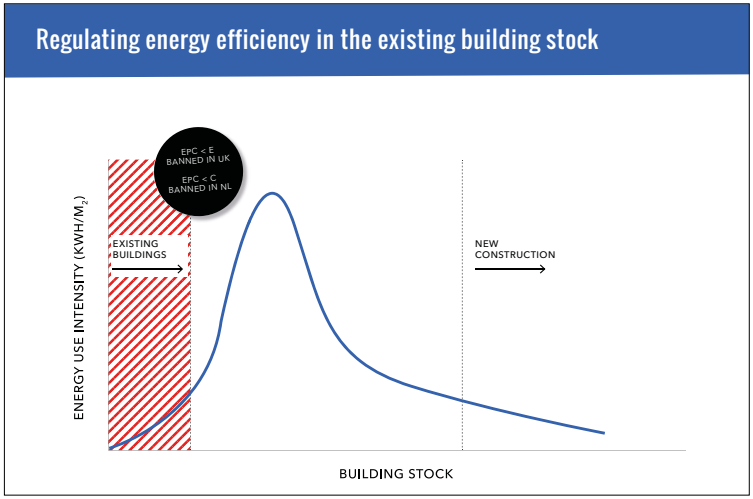


First of all, households, tenants, and investors need clear information in combination with forward-looking regulation. In the Netherlands, and Europe more broadly, we use the energy label for information provision. This label measures how the building should perform, given an "average" user. Ideally, the energy label is not based on theoretical assessments of energy consumption, but on how the building actually performs. That's much harder to achieve, but at the same time it's much more fair. As an analogy: it's not about how efficient your car is, but how you're driving it. There are examples of successful performance-based benchmarking tools, both in the US with Energy Star as well as in Australia and the UK with NABERS. The same holds for indoor air quality: we currently work with design-based regulation rather than performance-based regulation. We prescribe that a building should have a certain level of ventilation, but after completion, we never measure how well the building is actually ventilated!

Based on clear information and clean measures of performance, the government could then decided to further regulate the minimum energy performance of buildings, or their maximum energy or carbon-use intensity (EUI). We are indeed moving toward regulation of the built environment, but on the basis of energy labels. In the Netherlands (and in Britain, for that matter), office buildings with label D or lower may no longer be leased, financed or sold. However, this regulation is based on

model-based performance, not actual energy consumption of buildings. The jury is out on whether the regulation has had an effect on actual improvements in the energy efficiency of office buildings, because under the minimum performance standards, tenants don't have to change their behavior - but it's those occupying the building that ultimately are the consumers of energy.

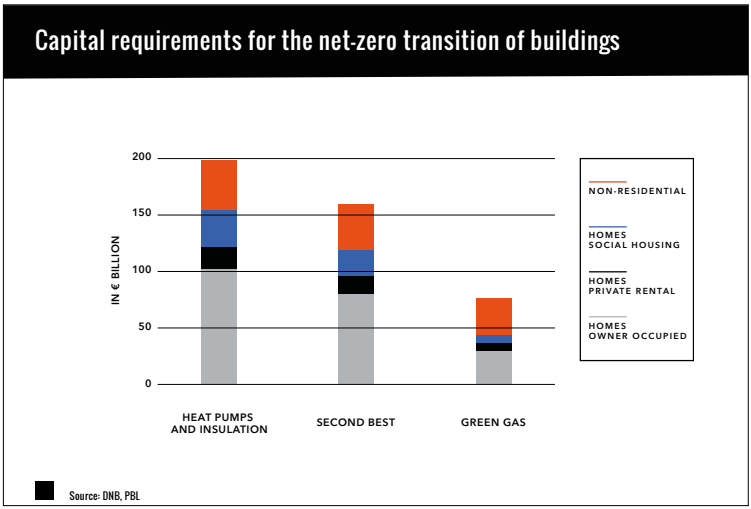
In New York, recently introduced Local Law 97 simply caps the carbon intensity of every commercial real estate asset, based on its observable characteristics (such as construction year, size, stories, etc.). That cap decreases over time, requiring the landlord to invest in the building *and* work with tenants on reduction programs, or to pay a fine. Further research is needed here, but the market is likely to benefit from such energy performance regulations, but applied more broadly. One might wonder why in the Netherlands only the office market is subject to regulation, rather than all types of real estate, including retail, logistics, etc.



Of course, information provision and regulation don't solve all problems. **At the end of the day, we also need capital to improve the building stock.** It is estimated that in the Netherlands alone, we need €200 billion for heat pumps and insulation to get the residential building stock to net zero (DNB, 2022), and I would say that is a narrow definition of a green and healthy building. Importantly, the capital is not just needed for owner-occupied homes, where decision-making is relatively straightforward, but

the money is also needed for both private rental homes and rental homes owned by social housing institutions. Let's zoom in here.

In owner-occupied homes, most energy efficiency measures are return-generating and therefore budget neutral, that means energy savings exceed financing cost. In addition, investments in energy efficiency are capitalized into home values. For consumers that are credit-constrained, the easiest thing to do would be a mortgage top-up with an energy efficiency allowance, where existing lenders extend additional capital to improve the home. Now, that's of course more challenging for low-income household or those with past payment issues (i.e. "bad credit"). A simple solution would be a regional or national debt fund with government support (where the government provides the first-loss piece to the fund). The Duurzaam Thuis scheme in Limburg is a good step into this direction, but needs to be modified such that those households with a BKR registration (i.e. a negative credit indication) are not excluded, but rather included. It's exactly those households that need financing! And of course, you want to track the actual investment in energy efficiency with ex-post energy efficiency (EPC) assessments and ideally program evaluations on actual energy savings.



For rental homes or apartment buildings, the situation is a bit more complicated. In apartment buildings, or rental homes more generally, there's a clear split incentive, where the owner invests and the tenant

benefits from reduced energy expenses. That's why regulation for the owner is not sufficient. If the savings-to-cost ratio on energy efficiency improvements is larger than one, a landlord should be allowed to be amortize the investment through the service charge. Alternatively, the rent in the regulated market should be allowed to be more strongly tied to the energy efficiency of the asset, as I recently discussed in Nieuwsuur (2022). To reassure tenants that measures have an actual effect on energy consumption, you could track the investment with ex-post energy-efficiency assessments, plus smart metering to assess actual savings (and to engage the tenant). Financing is typically less of a concern for residential investors, but alternatively, for commercial investors a mortgage top-up, comparable to single-family home owners, seems to be a simple, straightforward concept. Most banks require commercial real estate clients to have a business plan to reach energy label C and will finance such business plan as part of the existing mortgage (sometimes even with preferential rates). Over the years I've been impressed by some of the Dutch banks, including ING Real Estate Finance, in implementing such simple solutions.

From an investment and financing perspective, the big issue here is the so-called VVE (or coop), where individual owners jointly form a building board that is responsible for maintenance and energy efficiency investments. Interests in such VVE's are generally hard to align, which may require regulating VVE's like commercial real estate (with minimum energy performance standards). Importantly, VVE's typically don't have collateral and as such are hard to finance. New products are clearly needed to finance VVE's to invest into the energy efficiency of their buildings - this could be a debt fund financed by the major banks, with a first-loss piece provided by the government, the Bank Nederlandse Gemeenten (BNG), or the European Investment Bank (EIB). Housing corporations, owning almost 2.3 million apartments and homes in the Netherlands, need support as well. On the hand, support in their ability to increase the service charge when making investments in energy efficiency, but also from a financing perspective, given that housing corporations are increasingly cash-constrained (you can thank the government for that). Here again, there's a clear place for a debt fund with government support or with involvement from the EIB or the BNG.

But capital doesn't just come from banks. The equity market (i.e. the same pension funds that I wrote about earlier) is also eager to get in.

What the capital market needs though is both clarity and product. If you think about clarity, we've come a long way since we started the Global Real Estate Sustainability Benchmark (now known as GRESB) in 2009. We first initiated GRESB, with a number of large pension funds, to better understand ESG initiatives by listed property companies and private equity real estate firms (Bauer, Eichholtz, Kok and Quigley, 2011). But more than 10 years onwards, it's important that we move from policies and programs to actual energy consumption and reductions in energy consumption (and other KPIs, of course). And equally, we need well-defined metrics on healthy buildings and other social indicators. Investors are looking for impact, not just the buzz of ESG.

For capital to flow into products, we also need clear regulatory definitions. The EU, in it's recent Sustainable Finance Disclosure Regulation (SFDR) has defined Article 8 and Article 9 products - those can be considered "sustainable investments". Article 9 is the holy grail for many institutional investors, but the issue is that Article 9, at this point, can only contain buildings that are already green, rather than buildings that will be moved from "brown" to "green." Such seemingly simple omissions can have large implications for capital flows that are needed to improve the efficiency of the building stock!

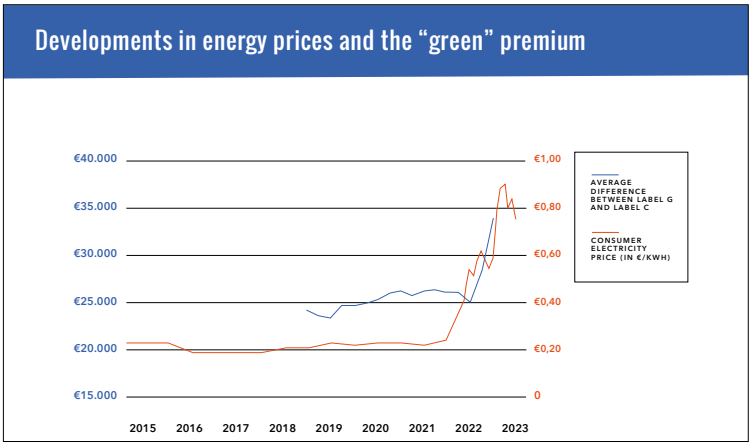
And what about subsidies? Currently, the Dutch government provides subsidies for energy efficiency, but in a scattered manner both in depth and breadth. For example, insulation is subsidized. But the results of our research clearly show that insulation doesn't need to be subsidized. What we should subsidize is the bleeding edge of energy efficiency and healthy building - we should subsidize battery storage, heat pumps, and perhaps the less economically viable energy efficiency investments such as window replacements. There's currently a heated debate about the ability of solar panel owners to deliver electricity back into the grid, and what the compensation for that should be. But that's the wrong discussion: of course we should phase out net metering, but at the same time we should subsidize battery storage (like our Belgium neighbors), such that homeowners and investors that currently deploy solar PV are at the same time also installing batteries. So, we need a holistic, forward-looking perspective on subsidies for investments in energy efficiency and renewable energy, rather than looking at single measures in isolation.

Energy efficiency subsidies and the innovation adoption curve

So, what will the future bring? What we know from 2022 is that the fundamentals for energy efficiency have shifted, dramatically. Electricity prices, which had been pretty much constant for a long period of time, increased from about €0.20 per kilowatt hour, to almost one euro per kilowatt hour. For the average Dutch household, the energy bill went from €1,610 per year to an estimated €2,694 in 2023. Based on the increased salience of energy efficiency among households, and the higher cost of energy, we already observe an increased premium for energy-efficient homes. As the housing market cools, and the market shifts from a seller's market to a buyer's market, expect further bifurcation based on those homes that are efficient, and those that are not. Further tightening of regulation, new construction of healthy and green homes, and the desire to become independent from natural gas will further reinforce that trend.

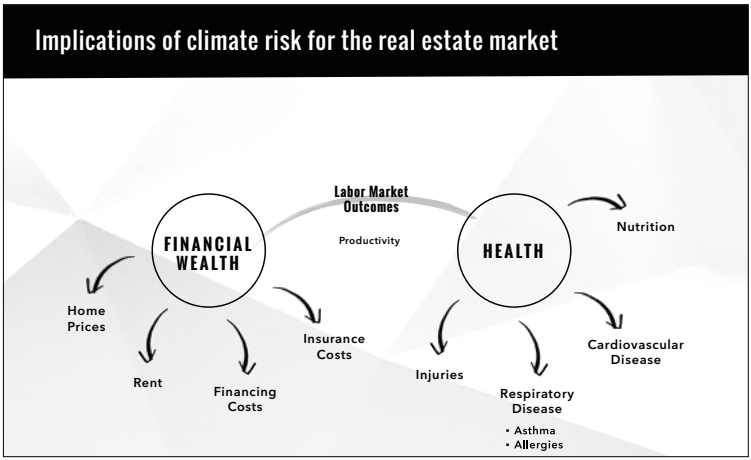
The future of commercial real estate poses another big question. The demand for commercial space, including, for example, the office, has changed dramatically since COVID-19. As the Kastle Back-to-Work Barometer shows, offices are just about half full since the pandemic, and that of course has significant consequences for space demand. When you think about the type of offices for which there's still demand, quite clearly you can imagine that tenants want to be in healthy and green buildings (as already noted in Eichholtz, Kok and Quigley, 2016). Such shift in demand, at both the extensive margin (i.e. the amount of space) and the intensive margin (i.e. the quality of space) has direct implications for

the office market, reinforcing the "green premium" for offices documented as early as 2010. Indeed, it is nice to see that both practitioners and press are finally catching up - recently on CNBC it was noted that green offices in London are 25% more expensive as compared to a regular office building. And, tantalizingly close to actually being *in* The Economist is it least the topic being mentioned in there: "...green building are increasingly popular" (The Economist, Jan 20, 2023). Not unlike the residential market, high energy prices, increasingly strict regulation (e.g. minimum energy performance standards), and lower demand for office space will further increase the split between the "green" and "healthy," and the "brown," also known as the "have-nots."



All of this ignores physical climate risk. Going back to the effect of carbon emissions on the environment, think about the implications of flooding, drought, extreme heat, and other stressors on both your home and the place where you work. While we already know some things about the impact of climate risk on the real estate market (see, for example, Holtermans, Kahn and Kok, 2022), we're interested to explore the extent to which both current climate risks and forward-looking measures of such risks are being capitalized into the value of real estate. Beyond that, we want to understand the impact of climate risk on financial markets and their products, such as insurance for homes and commercial buildings, as well as the pricing of mortgages and mortgage-backed securities. But it doesn't stop there: the building can also be a shelter. A shelter against energy price shocks, against climate risks, against pollution. In future research, we want to learn how individuals make choices for buildings and

in buildings relative to climate-related shocks and events. And of course, while the building is a shelter, that's not always a good thing, as we learned from our work in schools. We will continue our research on the impact of indoor environmental quality on cognitive performance, productivity, and health outcomes, together with our colleagues at the medical faculty (FHML).

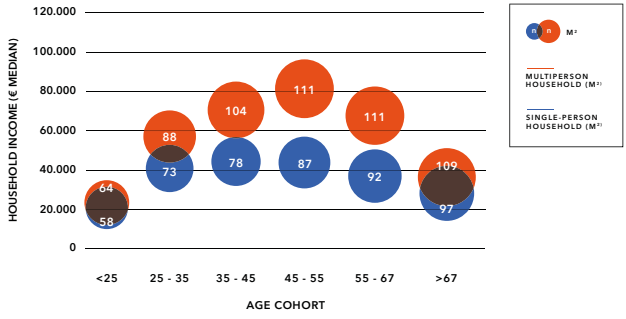


Finally, I want to address the elephant in the room. I've been discussing green buildings and healthy buildings, but at the same time we have a massive housing shortage (which is about to get worse) and there's a big question around how to solve this housing crisis. We construct less than 100,000 homes per year and very soon I expect it will just be 50,000 homes per year. The current housing shortage is estimated to be 500,000 homes and we don't even build enough for current demand, let alone to solve the housing deficit. Academics are not necessarily in the construction business or in the business of laying bricks, but, we can think about solutions. One of is the solutions that we've come up with last year is to stimulate home sharing (Eichholtz, Kattenberg and Kok, 2022).

If you look at the square meters that single-person households have at their disposal, for example 87 m^2 for single households between 45 and 55, and even 97 m^2 for single households that are 67 and older, the solution seems quite obvious. And before you think that I want to force my mom to live together with a 20-year old student in the name of science, think about many of the side benefits of sharing a house: additional income,

higher efficiency from an energy consumption perspective, and fewer people living alone. The latter is not trivial; loneliness is the biggest source of death, even bigger than smoking. So, mom can we finally start to reduce our housing demand?

Housing demand and income across the lifecycle



Source: Eichholtz, Kok & Kattenberg (2022)

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