NDC ASPECTS

Policy Brief

Decarbonising the Buildings Sector

Investments and possible rebound effects

Issue #13 / September 2024

Faidra Filippidou, E3Modelling

NDC ASPECTS has received funding from the European Union's Horizon 2020 Research and Innovation programme under grant agreement No 101003866

Introduction to buildings decarbonisation

What does successful decarbonisation for the buildings sector mean?

A key reason behind the buildings sector's persistently high emissions is its diversity and complexity. Identifying viable socio-technical strategies for buildings transformation is vital to achieve the sector's decarbonisation. To do so, we performed modelling of the evolution of the sector for the European Union (EU27) with PRIMES BuiMo[1], where detailed analyses of potentials and boundary conditions for the implementation of various technological options such as electrification of heating, energy efficiency improvements including deep building retrofits, the changing role of gas, and integration of renewable energy technologies are examined and included. Many of these options are still novel or have not been sufficiently reflected in existing NDCs.

Model-based scenario development is an essential tool previously used to examine the feasibility and mitigation potential of various decarbonisation strategies and sectors – including energy supply and demand sectors – in line with the EU's objective to reach climate-neutrality by 2050 (Capros et al. (2019), Tsiropoulos et., (2022), Costa et al, (2021))[2]. In-depth sectoral assessments of decarbonisation targets and strategies are, on the other hand, rare in the literature. More specifically, while there is a recognition that buildings will play an important role in reaching overall decarbonisation objectives (Camarasa et al. (2022), Wang et al. (2018)), given their high contribution to total GHG emissions and mitigation potential (e.g., up to 85% reduction in GHG emissions from buildings in Europe compared to baseline projections in 2050 according to Cabeza et al. (2022)), less is known about the impacts of different policy mixes and fuel price assumptions on energy and emissions in the EU's buildings sector[2].

For this work, except for the quantitative outputs pertaining to the energy consumption and CO_2 emissions reduction, our main research question was "What are the investments needed to decarbonise the buildings sector?" and "What are possible rebound effects?", to be followed up by "What is the impact when a shock in energy prices materialises?"

The research began with a quantitative modelling study[2] that moves the literature forward by asking whether there is a preferred set of policy options for achieving long-term decarbonisation goals in buildings, based on the pace and magnitude of achieved energy and emissions savings to update the upcoming EU NDC and if there are lessons to be learned from different policy options towards buildings decarbonisation. When referring to mitigation pathways, the focus lies largely on policy implementation to harness "no regret" mitigation options in buildings, including energy efficiency and electrification of heating.

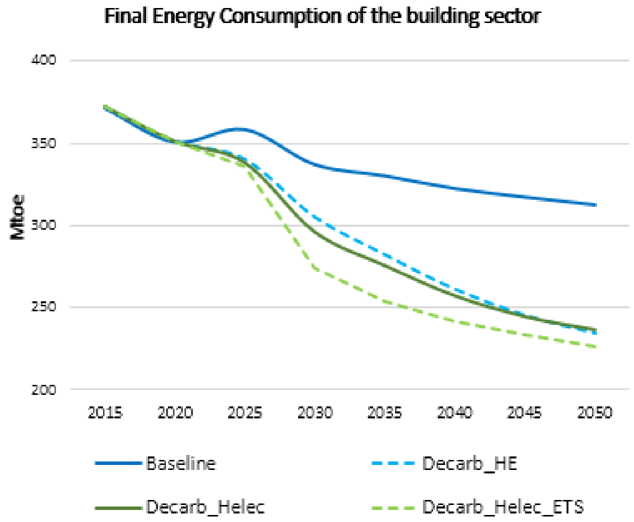
To that end, we implemented 4 scenarios - one baseline and 3 decarbonisation scenarios with distinct priorities:

- High energy efficiency (Decarb_HE), which translates to ambitious renovation rates
- Electrification of heating (Decarb_Helec), which translates to ambitious uptake of heat pumps
- Electrification of heating and ETS II application to Buildings (Decarb_Helec_ETS)

[1] PRIMES Model Description and PRIMES BuiMo can be found in the following: a) https://e3modelling.com/modelling-tools/primes/ and b) Fotiou, T., de Vita, A., & Capros, P. (2019). Economic-engineering modelling of the buildings sector to study the transition towards deep decarbonisation in the EU. Energies, 12(14), 2745.

[2] Deliverable D3.1-B.2 Report of WP3 of NDC Aspects «Decarbonisation pathways for the buildings sector»

NDC ASPECTS has received funding from the European Union's Horizon 2020 Research and Innovation programme under grant agreement No 101003866



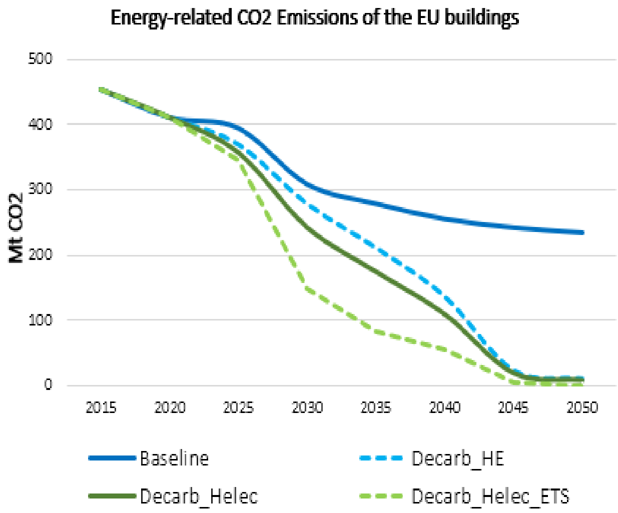


Figure 1 Final energy consumption and energy-related CO_2 emissions of the EU27 buildings sector

Figure 1 shows the ambition level in terms of final energy consumption and CO_2 emission reductions for all scenarios. One of the main conclusions from the study is that – in order to achieve carbon neutrality in 2050 – EU27 countries should base their updated energy policies and NDCs on measures that prioritize building envelope renovations as well as heating equipment replacements. In essence, all decarbonisation scenarios reach net-zero emissions for the buildings sector in 2050 albeit at different paces through the decades and encompassing distinct policy priorities. More specifically, with respect to the buildings sector, at least 1.9% of dwellings should be renovated annually and a minimum of 2.6%-3.1% of the total building stock (including both residential and commercial buildings) should replace the heating equipment on an annual basis until 2030 and 2050, respectively.

EU energy policy measures should be further developed focusing on energy demand reduction, establishing strategies that promote energy efficiency renovations, and on both electrification and high energy efficiency of the buildings technical equipment, along with the extension of carbon pricing in the buildings sector. In other words, despite the rapid development of clean and sustainable solutions of technical building equipment – for all end uses – the principle of 'energy efficiency first' is of great importance to achieve demand reduction. This is important not only to achieve the GHG and final energy consumption reduction goals of the EU, but to also ensure a just energy transition along with the multiple co-benefits of buildings renovation – among them those of health and well-being (MacNaughton, P. et.al. 2018 and Gillingham, K. T. et.al. 2021).

NDC ASPECTS has received funding from the European Union's Horizon 2020 Research and Innovation programme under grant agreement No 101003866

How much does it cost to decarbonise the buildings sector?

In the buildings sector and even more so in its largest subset, the residential sector, materialising the decarbonisation potential bears a high dependency on investment decisions of individual citizens. These alone exhibit a large variety of socio-economic conditions (i.e. purchasing power ability) and personal preferences. Not only that, but often citizens decide under uncertainty, incomplete information and cash flow constraints (Fotiou et.a. 2019).

Research performed with PRIMES BuiMo affirms that market and non-market barriers play a major role in understanding the eventual lack of energy efficiency investment and the poor response of consumers to energy efficiency policies, which is currently observed in many EU countries (Fotiou et.a. 2019). This means that financial and regulatory measures are needed to remove those barriers.

In this current study, in an effort to assist policy makers when designing mitigation pathways for the buildings sector, we present in Figures 2 & 3 the investment expenditure needed to reach the energy and CO_2 savings of the buildings sector in the three decarbonisation scenarios studied, where the focus varies in terms of the investments – renovation of buildings or energy equipment replacement.

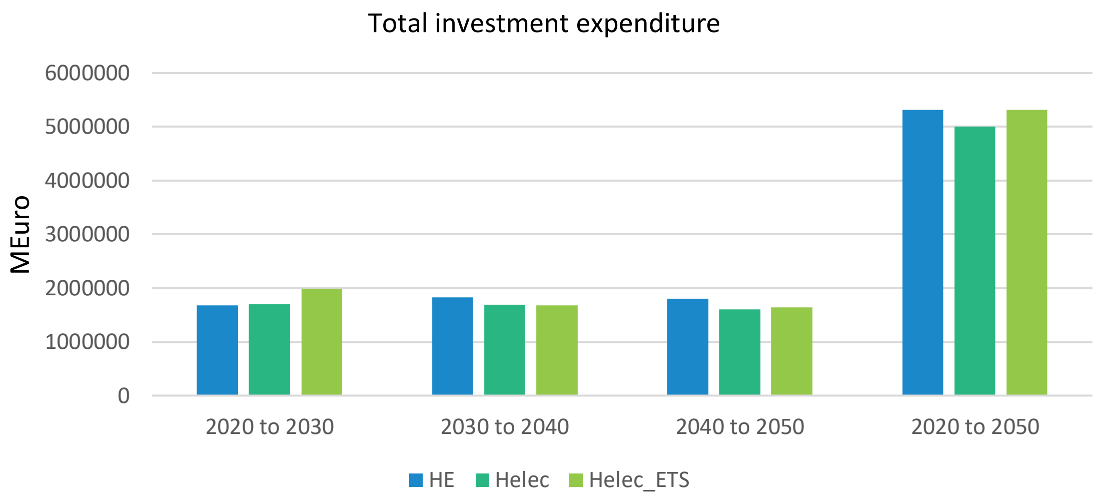


Figure 2 Total investment expenditure per decate of investigated period of the EU27 building stock (renovation, energy equipment replacement and new construction)

What we observe is that investment expenditure needed for HE & Helec_ETS scenarios are very close, while the Helec scenario is slighlty lower in terms of investments needs. Greater total investment expenditure for the Helec_ETS scenario from 2020 to 2030 (mainly esulting from the introduction of ETSII from 2025 to 2030), whereas from 2030 to 2050, the HE scenario investment expenditure is higher.

NDC ASPECTS has received funding from the European Union's Horizon 2020 Research and Innovation programme under grant agreement No 101003866

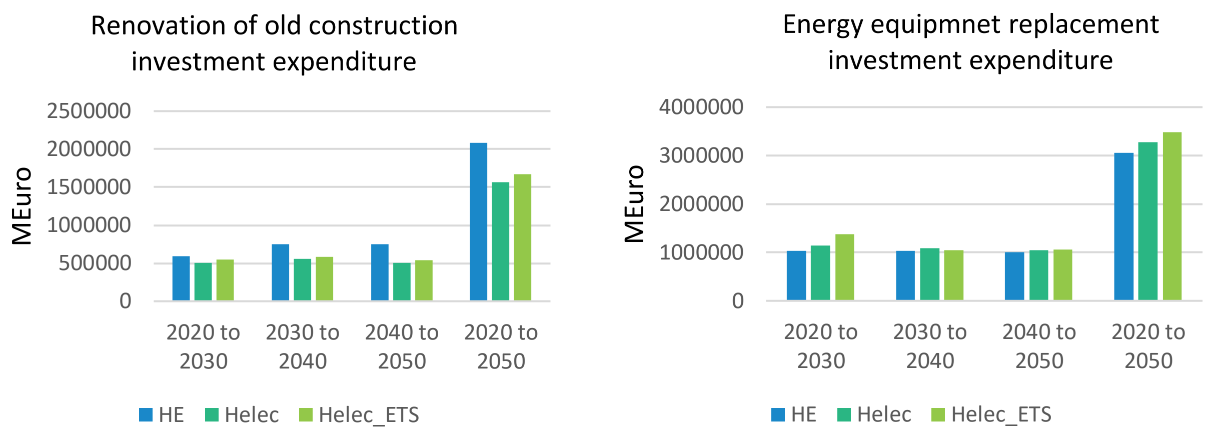


Figure 3 Breakdown of total investment expenditure into renovation and equipment replacement

However, it is not only the total investment expenditure that can inform decision making, but also the split between the main decarbonisation activities – renovation of envelope, sustainable heating, and cooling solutions.

What we observe in Figure 3 is that the renovation investment expenditure is higher in terms of the HE scenario (during the whole 30-year period). This scenario prioritises envelope renovation and depth[3] resulting in almost 60% of the building stock being renovated in 2050. It is worth noting that more than 40% of total investment expenditure is given for the renovation of the building envelope in the HE scenario – prioritizing the improvement of the building stock in terms of energy demand reduction that in the end results in the reduction of final energy consumption.

On the other hand, the energy equipment replacement investment expenditure is exceedingly greater for the Helec_ETS scenario from 2020 to 2030. In total, the Helec_ETS scenario represents the highest investment expenditure in terms of equipment replacement highlighting the effect of the extension of carbon pricing in the buildings sector. In the Helec and the Helec_ETS scenarios, more than 65% of the total investment expenditure is given for the replacement of the building technical equipment. Overall, equipment replacement investment expenditure is dominant for all the scenarios throughout the 30-year period.

What is the impact of a shock in energy prices?

The "high energy prices" variants reflect the current energy crisis and the drastic reduction of Russian gas imports to the EU as a consequence of the Russia-Ukraine war. As shown in **Error! Reference source not found.**, the international energy prices increase drastically in 2025 by about 53% and 40% in oil and coal compared to 2020, respectively, while the gas price is more than double the 2020 price. Then, they are still higher, but to a lower extent until 2035. In 2035 and onwards, previously assumed prices as on the Reference 2020 scenario (European Commission, 2020) are projected regarding oil and coal, whereas the gas price never gets back to previously assumed prices until 2050.

[3] Renovation depth is defined based on modelling of the envelope renovation actions (see Fotiou, T., de Vita, A., & Capros, P. (2019)). and their resulting energy savings in terms of final energy consumption. In example, replacing the windows is consindered a "shallow" renovation with average energy savings of 10% whereas a "deep "renovation including insulation of walls, floor and windows could result in energy savings of 50%

NDC ASPECTS has received funding from the European Union's Horizon 2020 Research and Innovation programme under grant agreement No 101003866

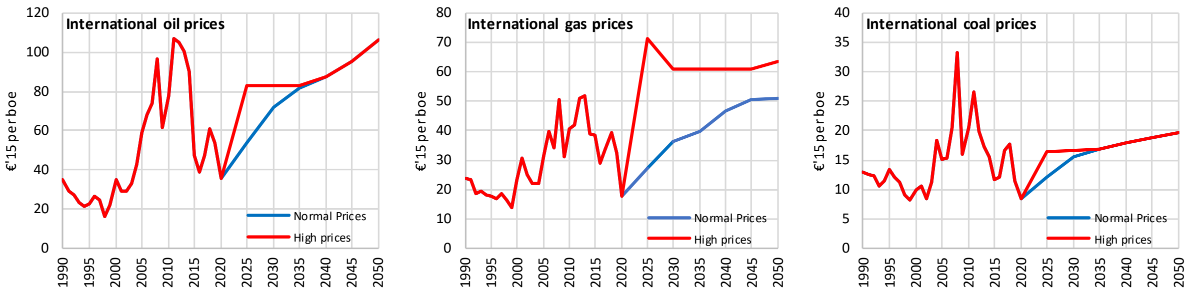


Figure 4 International oil, gas and coal prices projections in different scenarios

The high energy prices act on top of the assumptions in the four main scenarios. Accordingly, four more scenario variants are developed and investigated: The "Baseline_HP", the "Decarb_HE_HP", the "Decarb_Helec_HP" and the "Decarb_Helec_ETS_HP" scenario.

Within the "decarbonization" framework, high energy prices resulting from the war in Ukraine lead to significantly greater equipment replacement rates and higher buildings envelope renovation rates already in 2025. The increase in fuel prices, as a result, led to higher investment expenditures throughout the projected period – roughly 2% higher investments compared to the initial scenarios. This investment expenditure growth is mainly driven by the increase in energy equipment replacement investments, during the first investigated decade, indicating an increase equal to 8% for the HE_HP and the Helec_HP scenarios, and a raise of 4% in terms of the Helec_ETS_HP scenario.

Especially from 2020 to 2025, the increase in energy equipment replacement expenditures is equal to 17%, 22% and 25% in terms of the HE_HP, the Helec_HP and the Helec_ETS_HP scenario, compared to the initial scenarios, respectively.

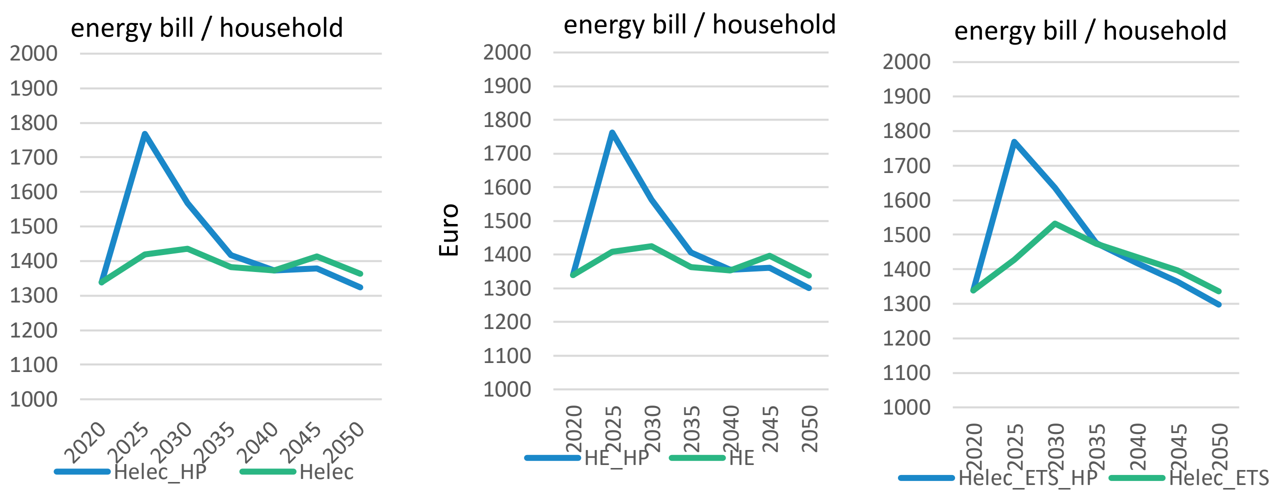


Figure 5 Energy crisis impact: energy bill per household

Next, we investigated what the impact on the fuel expenditure is when this price shock materialises. Despite the decrease in final energy consumption per household in the short-term revealing a shift towards more efficient heating & cooling equipment, the high prices scenarios show a remarkable increase in the energy bill compared to the initial scenarios until 2035. For the investigated scenarios, this increase is equal to 25% compared to the initial scenarios, indicating a 350 Euro increase in household energy bills in 2025. In 2030, this increase is slightly lower

NDC ASPECTS has received funding from the European Union's Horizon 2020 Research and Innovation programme under grant agreement No 101003866

(approximately 130 Euro), while until 2035 the high prices and the initial scenarios show the same energy bill per household.

The high renovation and energy equipment replacement rates drive a considerable EU buildings final energy consumption reduction, demand electrification and CO_2 emissions decrease earlier in time compared to the normal fuel prices variants. Yet, it is vital to note that these positive effects shown in the results require a remarkable increase (of 11%) in the capital expenditures, while a significant raise (of 24%) in the operating expenditures that is of even greater importance, as shown in Figure 5.

The high energy prices scenario variants show different effects in terms of both the "existing" and the "decarbonization" framework after 2030. Since the high renovation and equipment replacement rates until 2025 succeed in confronting the energy crisis and fuel prices are getting back to normal, there is no need for further higher investments. Therefore, results reflect a remarkable decrease in both the renovation and the equipment replacement rates regarding the high prices scenario variants, which are even slightly lower than the initial scenarios ones.

Policy alternatives and recommendations

This work examined different transformation pathways for the EU buildings sector in the 2020-2050 period inducing mitigation options like ambitious energy efficiency improvements in buildings and electrification of their energy demand to attain the EU targets – related to both CO_2 emissions and final energy consumption, as well as renewable energy shares. On top of this initial modelling exercise, a deep dive into investments needed and the impact on households relating to their energy expentiture especially when shocks in energy prices materialise.

With the adoption of the European Green Deal, the Fit for 55 policy packages, and most recently the REPowerEU plan, the EU targets, in terms of the final energy consumption, use of renewables and CO_2 emissions, are updated, indicating both binding medium term for 2030 and 2050 carbon neutrality goals. Accordingly, the energy demand sectors energy policy frameworks should be revised in order for the EU's updated NDC submission to be complemented in light of the adoption of these upgraded targets, while integrating the specific sector contribution to them.

Results drawn from our study show that EU energy policy measures should be further developed focusing on energy demand reduction, establishing strategies promoting energy efficiency renovations via, for example, financing and awareness campaigns, and on both electrification and high energy efficiency of the buildings technical equipment, along with the extension of carbon pricing in the buildings sector. In other words, despite the rapid development of clean and sustainable solutions of technical building equipment – for all end uses – the principle of energy efficiency first is of great importance to achieve demand reduction.

One of the main conclusions from the study is that in order to achieve carbon neutrality in 2050, EU27 countries should base their updated energy policies and NDCs on measures that prioritize building envelope renovations as well as heating equipment replacements. This is especially important for two main reasons, first due to the fact that the buildings sector is one of the hardest to abate while collective decisions are hard to implement. Second, decarbonizing the sector while maintaining the pillars of the just energy transition. Meaning that possible rebound effects relating to energy poverty and the energy equity gap need further attention in policy making - these bear upon both financial enablers/barriers and socio-economic dynamics.

NDC ASPECTS has received funding from the European Union's Horizon 2020 Research and Innovation programme under grant agreement No 101003866

References

Cabeza, L.F. et al. (2022) 'Buildings', in IPCC, 2022: Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK and New York, NY, USA: Cambridge University Press.

Camarasa, C., Mata, É., Navarro, J. P. J., Reyna, J., Bezerra, P., Angelkorte, G. B., Feng, W., Filippidou, F., Forthuber, S., Harris, C., Sandberg, N. H., Ignatiadou, S., Kranzl, L., Langevin, J., Liu, X., Müller, A., Soria, R., Villamar, D., Dias, G. P., … Yaramenka, K. (2022). A global comparison of building decarbonization scenarios by 2050 towards 1.5–2 °C targets. Nature Communications, 13(1). https://doi.org/10.1038/s41467-022-29890-5

Capros, P., Zazias, G., Evangelopoulou, S., Kannavou, M., Fotiou, T., Siskos, P., De Vita, A., & Sakellaris, K. (2019). Energy-system modelling of the EU strategy towards climate-neutrality. Energy Policy, 134. https://doi.org/10.1016/j.enpol.2019.110960

Costa, L., Moreau, V., Thurm, B., Yu, W., Clora, F., Baudry, G., Warmuth, H., Hezel, B., Seydewitz, T., Ranković, A., Kelly, G., & Kropp, J. P. (2021). The decarbonisation of Europe powered by lifestyle changes. Environmental Research Letters, 16(4). https://doi.org/10.1088/1748-9326/abe890

Filippidou, F. et.al., (2023) Deliverable D3.1-B.2 Report of WP3 of NDC Aspects H2020 project «Decarbonisation pathways for the buildings sector»

Fotiou, T., de Vita, A., & Capros, P. (2019). Economic-engineering modelling of the buildings sector to study the transition towards deep decarbonisation in the EU. Energies, 12(14), 2745.

Gillingham, K. T., Huang, P., Buehler, C., Peccia, J., & Gentner, D. R. (2021). The climate and health benefits from intensive building energy efficiency improvements. Science Advances, 7(34), eabg0947.

MacNaughton, P., Cao, X., Buonocore, J., Cedeno-Laurent, J., Spengler, J., Bernstein, A., & Allen, J. (2018). Energy savings, emission reductions, and health co-benefits of the green building movement. J. Expo. Sci. Environ. Epidemiol, 28(4), 307-318.

Tsiropoulos, I., Siskos, P., De Vita, A., Tasios, N., & Capros, P. (2022). Assessing the implications of bioenergy deployment in the EU in deep decarbonization and climate-neutrality context: a scenario-based analysis. In Biofuels, Bioproducts and Biorefining (Vol. 16, Issue 5, pp. 1196–1213). John Wiley and Sons Ltd. https://doi.org/10.1002/bbb.2366

Wang, H., Chen, W. and Shi, J. (2018) 'Low carbon transition of global building sector under 2- and 1.5-degree targets', Applied Energy, 222, pp. 148–157. Available at: https://doi.org/10.1016/j.apenergy.2018.03.090.

NDC ASPECTS has received funding from the European Union's Horizon 2020 Research and Innovation programme under grant agreement No 101003866

NDC ASPECTS

POLICY BRIEF

Decarbonising the Buildings Sector

Investments and rebound effects

Corresponding Author

Faidra Filippidou
filippidou@e3modelling.com

Project Coordination

Wolfgang Obergassel
wolfgang.obergassel@wupperinst.org

PARTICIPANTS

Wuppertal Institut; VUB Brussels School of Governance; IDDRI; Deutsches Zentrum für Luft- und Raumfahrt DLR German Aerospace Center; E3Modelling Energy Economy Environment; bc3 Basque Centre for Climate Change Klima Aldaketa Ikergai Sustainability, that's it!; University of Eastern Finland; Higher School of Economics National Research University; IIM Ahmedabad; University of Cape Town; ИГКЭ; 清華大學 Tsinghua University; IPB University Bogor Indonesia; University of Maryland School of Public Policy Center for Global Sustainability; HOLISTIC

NDC ASPECTS has received funding from the European Union's Horizon 2020 Research and Innovation programme under grant agreement No 101003866

www.ndc-aspects.eu

@ndcaspects

@ndcaspects