Bridging the climate neutrality, energy security and sustainability gap through energy sufficiency, efficiency and renewables

Establishment of energy consumption convergence corridors to 2050

Residential sector

October 2022

***Clever** – a Collaborative Low Energy Vision for the European Region*

Content

This note was written by the negaWatt Association in the build-up of the CLEVER scenario, with a view to constructing coherent decarbonisation pathways for the residential sector in European countries. It proposes convergence corridors for the energy consumption for key indicators towards 2050, together with policy measures to support this transition.

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Introduction

Establishing a common vision on the residential sector

In the context of the development of the CLEVER scenario led by the negaWatt association, convergence corridors for key consumption indicators in the residential sector by 2050 have been established in order to facilitate the bottom-up construction of the scenario. This note presents this construct and the convergence corridors, together with first policy proposal to back-up these corridors.

The CLEVER scenario

Since 2018, a network of around 24 European partners under the leadership of negaWatt have been engaging in a technical dialogue to ensure the collective development of a European energy and climate scenario.

This scenario is being constructed using a bottom-up approach with national trajectories as a starting point. It assesses all decarbonisation potentials through the main prism of energy analyses based on energy demand reduction (sufficiency and efficiency) and renewable energy development.

It aims at being as ambitious as possible: targeting carbon neutrality and a 100%-renewable energy mix at the European level as soon as possible and by 2050 at the latest, in line with 1.5 degrees pathways. Reaching carbon neutrality by then requires an ambitious and coordinated energy transition strategy supported by concrete and bold policies.

Energy consumption corridors concept definition

The CLEVER vision of energy demand reduction is based on an approach of feasibility and equitable sharing of energy services. However, the baseline of each national trajectory might be very different. It can be an obstacle to the establishment of an equitable and convergent European trajectory.

To address this issue, it has been decided to use the concept of "**consumption corridors**" in the construction of CLEVER: for each major indicator in the scenario, a target corridor for energy consumption by 2050 was proposed. The idea behind this is to take into account national circumstances while ensuring that each national trajectory converge towards the common European low-energy vision. The corridors have been built according to a principle of equity and high environmental ambition inspired from the doughnut economy principle of Kate Raworth[1]: the new consumption society defined by these corridors should be bounded between a *social lower bound* corresponding to the satisfaction of all basic individual needs for all and an *environmental higher bound* corresponding to the limitation of impacts below planetary limits.

The convergence corridor approach is a key element of the CLEVER scenario as it frames the way energy sufficiency is defined in this project. In order to explain this approach and share main modelling assumptions, the CLEVER energy consumption corridors and their development process is published in series of publication for the mobility, industrial and residential sectors[2].

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[1] See her book: Raworth, K. (2017). Doughnut economics: seven ways to think like a 21st-century economist. Chelsea Green Publishing.

[2] These different publications are available on this webpage.

Establishment of corridors in the residential sector

To frame the development of national scenarios in the residential sector, indicators have been chosen to define the scale and performance of buildings (floor area and renovation) and answer the energy needs of residents (hot water, space heating and specific electricity).

Four key inputs were used in the process of harmonisation of these indicators:

- *Context elements* following a review of the literature carried out by negaWatt, allowing for each indicator the definition of the social lower bound[3] and the environmental upper bound[4].
- *National statistics*[5] allowing to understand the starting point of each trajectory, its specificities and the stakes to define a harmonised European vision.
- *First trajectories* of evolution to 2050 for each indicator on which the exchanges and the co-construction of hypotheses between partners were based.
- *Other existing European or national scenario assumptions* showing the level of ambition already proposed by other stakeholders[6].

The analysis of these inputs led to a technical dialogue between the project lead and national partners to establish 2050 corridors that are equitable, ambitious and achievable.

Final corridors presented in this note served as a reference for partners to finalise their national trajectories for the residential sector. They came at a pace of transformation and a level of ambition which is feasible and coherent with their national context, if supported by the right policy framework.

Policy proposals to support the level of ambition

Defining an energy and climate trajectory in line with 1.5 degrees pathways requires setting very ambitious convergence corridors. To support this ambition, policy work has been carried out within the network.

The aim of this work was to share and recommend, for each energy consumption indicator, key policies and existing good practices from the EU to the local level. If they would be implemented, these policies would allow to reach the 2050 target defined in these corridors.

[3] Key sources used: Millward-Hopkins et al., 2020 ; Rao et Min, 2018

[4] Brischke et al., 2015.

[5] Data mainly coming from Odyssee and Eurostat databases.

[6] Key sources used: ECF/Climact, 2018 ; EUCalc ; negaWatt, 2017 ; negaWatt, 2022 ; Data from the CACTUS project

Content of the note

Global content

This note is composed of six parts dedicated to each of the six indicators chosen to harmonise the residential sector assumptions in the CLEVER national trajectory.

Each part begins with the definition of the given indicator and its perimeter. It then describes the inputs used to define it within the network: current statistics, context elements and other scenarios. Given these data, the chosen corridor is defined and the current ambition of the CLEVER national partners is detailed.

Each part concludes with the policies exchanged across the network to support the defined level of ambition. The policies are prioritised in order of impact and scale (from EU to local level).

A summary of the definition of these indicators and the final value associated is given in the Table 1 below.

***Disclaimer 1:* the policy proposals presented are the result of an introductory research work and consultation within the project's partners network. They aim at achieving a collaborative vision that strengthens the scenario-building assumptions. By no means can they be referred to as official position of negaWatt or project partners.**

***Disclaimer 2:* the current energy crisis added a new imperative in the definition of CLEVER. Trajectories are currently being revised to speed-up the pace of transformation of the scenario, e.g. with regards to 2030 objectives and the evolution of gas consumption. The following energy consumption corridors for the residential sector, set before the crisis, are likely to be reinforced by the final publication of the scenario, and so the policies backing them up.**

Summary table of the corridors

Indicator	Definition	Unit	Planned 2050 consumption corridor
Floor area	Useful floor space[7] of dwellings permanently occupied divided by the population	m^2/pers.	**For countries above 40 m^2/pers. in 2015**: • Maximum value: **2015 figure** • Minimum value: a **decrease of 0.4%/year (CAGR)** between 2015 and 2050 **For countries below 40m2/pers. in 2015**: • Maximum value: **40m2/pers.** • Minimum value: **32m2/pers.**
Renovation	Share of the floor area (of all permanently occupied dwellings) that has been deeply renovated[8] since 2015.	%	• **2% to 3%** of deep renovation annual rate reached **by 2030** and kept constant on the period 2030-2050 • **25 to 60 kWh/m2** for heating needs of renovated dwellings • A maximum of 1%/year of new buildings
Domestic hot water	Final energy consumption per person for hot water per year.	kWh/pers.	**Target for 2040: 270** to **680 kWh/pers.**
Efficiency of residential space heating	Average efficiency of heating systems in the building stock. Efficiency is defined as heat delivered in the dwelling divided by the final energy consumption (i.e. energy supplied to the heating system based on lower heating value for fuels).	%	Per kind of boilers: ***Solid biomass***: 70-75% ***Gas***: 75-85% ***Electricity***: 94% ***Heating networks***: 75-80% ***Heat pumps***: 3.5-4.5 in 2040
Share of carriers in residential space heating	Final consumption for space heating of the carrier divided by total final energy consumption for space heating including ambient heat (e.g. heat pumps) and solar thermal.	%	Per carriers: ***Oil*** and ***coal***: complete phase out ***District heating***: between the share observable in 2019 and the share of population in non-rural[9] areas. ***Solid biomass***: between 0% and the share observable in 2015. ***Gas***: between 0% and 20% ***Electric heating***: between 0% and 5% ***Heat pumps:*** the remaining share (limited to 80-90% to reflect the inadequacy of heat pumps in some contexts).
Specific electricity	Final energy consumption per person for specific electricity.	kWh/pers.	**400** to **700 kWh/pers.**

[7] Useful floor space: the floor space of dwellings measured inside the outer walls, excluding cellars, non-habitable attics and, in multi-dwelling houses, common areas (OECD definition).

[8] Deep renovation: a renovation that results in an annual primary energy use below 80kWh/m²/year (possible variation according to climatic zones) for the following uses: heating, cooling, domestic hot water, ventilation and in-built lighting (annex 3 and 5 of EPBD recast proposal).

[9] i.e. cities, towns and suburbs as defined by EUROSTAT.

Floor area

Definition: Useful floor space[10] of dwellings permanently occupied, divided by the population
Unit: m^2/pers.
Calculation: [Stock of dwellings permanently occupied] * [Average area of dwellings] / [population]
Alternative calculation*:** *(when the data of the stock of permanently occupied dwellings is not available):** [Average area of dwellings] / [Average household size]

Historical data

The analysis of the current situation is given Figure 1. It shows a significant disparity from **20-30 m^2/pers. (RO, PL, BG) to 50-60 m^2/pers. (NO, DK, FI, NL, CY, MT)**. The lowest values usually revealing social issues (e.g. overcrowded dwellings[11]).

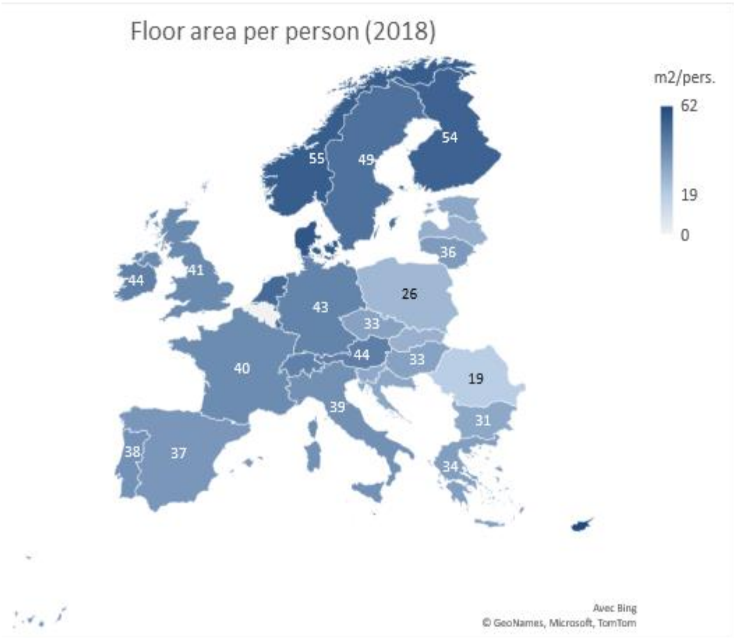

Figure 1: Floor area per person (m^2/pers.) in 2018 (Source: ODYSSEE).
The CLEVER partner and the CACTUS project gives a value of 46 m2/pers. for Germany

The evolution of this indicator over the past years also varies a lot among European countries (Figure 2 and Figure 3). Indeed, over the period 2011-2015, an increase of 0.6-0.8 m^2/pers./yr occurred in some of the countries with the lowest floor area per person (RO, LV, LT, CZ) whereas it decreased or increased moderately (< 0.2m2/pers./yr) in countries such as DK, NO, SE, PT, IT, DE.

[10] Useful floor space: the floor space of dwellings measured inside the outer walls, excluding cellars, non-habitable attics and, in multi-dwelling houses, common areas; (OECD definition)

[11] Source: EUROSTAT

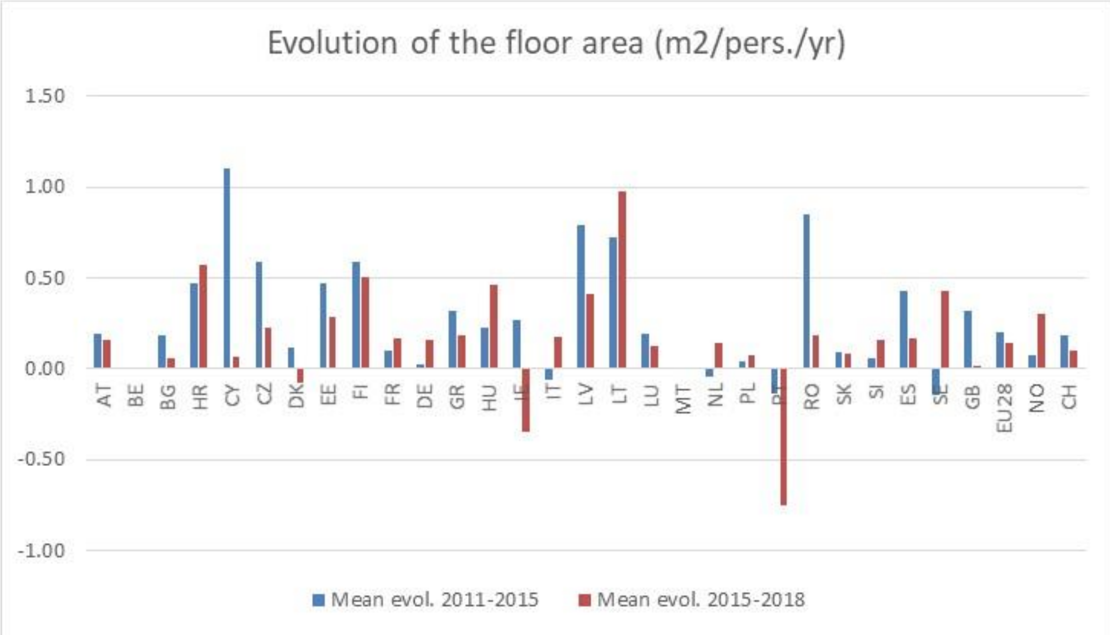

Figure 2: Mean evolution (m^2/pers./yr) of the floor area per person over 2011-2015 and 2015-2018 (Source: ODYSSEE)

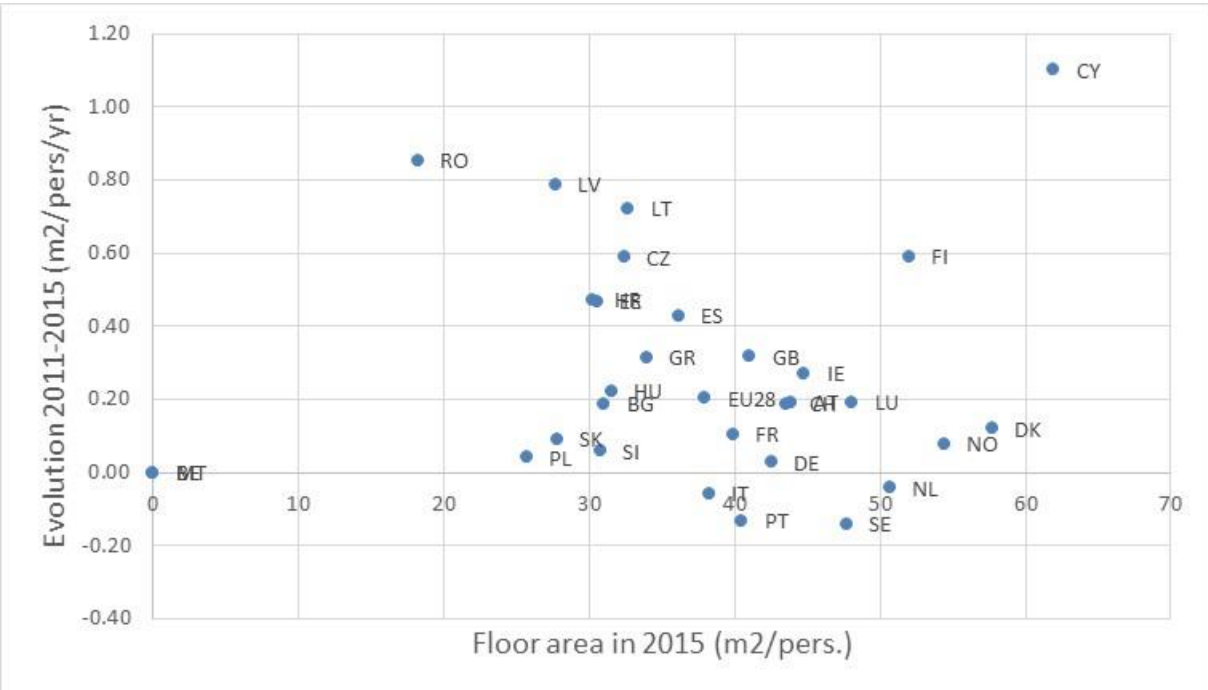

Figure 3: Relationship of the mean evolution (m^2/pers./yr) over the period 2011-2015 to the floor area in 2015 (Source: ODYSSEE)

Main factors considered when defining the level of ambition

The average area per person depends mainly on two factors: the **average size of dwellings** and the **average number of persons per household**. These factors evolve following the distribution of the housing stock by area of dwellings and the distribution of households by number of persons.

In order to reduce the floor area per person while allowing an improvement in living conditions (in particular the reduction of the rate of over-occupied dwellings), it is necessary to improve the adequacy between the characteristics of the building stock and the needs of households (distribution of households by number of persons, minimum number of rooms and floor area, etc.).

The associated levers are mainly related to:

- **The rate of new construction** that can allow for a renewal of the stock and a better adequacy of the housing stock to the needs of households
- **The stabilisation or increase in the size of households**, particularly by promoting collective housing (see the policy part below).

<u>Main obstacles:</u>

- **The existing housing stock** is unsuited to the needs of households or with large surface areas per person.
- **There are strong trends of a reduction of the household's size and an increase in the size of dwellings**, which influence the possibilities of reaching ambitious values in the short term
- **There is an ageing population in many European countries.** There is therefore potentially an increasing proportion of the population living in under-occupied dwellings, as elder people often continue to live in the dwelling they occupied when they were raising children.
- **There are possible lifestyles changes, particularly related to climate and teleworking**, which might influence the time spent in the dwelling and therefore potentially the need for space

Finally, the **joint evolution of the population and the floor area per person can lead to challenging situations:**

- In the case of a significant raise of both parameters, the large number of new buildings to be constructed might raise important issues: sustainability (e.g. soil sealing, CO2-emissions, …), costs, feasibility, ...
- Conversely, an important decrease of both indicators might lead to a strong decrease of the total floor area of residential buildings. This case raises questions about the need for new housing and the future of unused buildings.

Prospective: values considered in a selection of scenarios

European scenarios

In the EUCALC pathways, the assumptions at the European level for 2050 are[12] :

- **55m2/pers.** for the less ambitious level (corresponding to the assumptions of the EU reference scenario (2016))
- **37m2/pers.** for the most ambitious level, which is based on Rao and Min (2018) for rural areas.

In the ECF/Climact NetZero by 2050 pathways[13], the minimum and maximum values for floor area are approximately the same as in the EUCALC pathways.

The Net Zero pathways provide an additional information: a range of ambition level of the Compound Annual Growth Rate (CAGR) for the floor area at the European level:

- Less ambitious level: "the evolution of the floor area observed on 2010-2015 **(+0.58%/yr)** is maintained from 2016 onwards"
- Most ambitious level: "the yearly evolution is decreased down to **0%/yr by 2026 and further reduced to -0.3%/yr by 2030"**

National scenarios

A comparison of the prospective value of the evolution floor area in different national scenarios is given in Table 1.

Country	Base year (2017)	Prospective (2050)	CAGR (2015-2050)
France (nW2022)	40.6	39.5	-0.08%
Germany (Green Supreme)	47	41.2	-0.38%
Lithuania	35	32	-0.26%
Hungary	37	35	-0.16%

Table 1 : Data from the CACTUS project which compares CACTUS modelling for Lithuania and Hungary with an analysis of the negaWatt and Green Supreme scenario for France and Germany[14].

The evolution of the floor area in these national scenarios is more ambitious than in the EUCALC and Net Zero pathways. The German Green Supreme scenario present a CAGR higher than the Net Zero most ambitious level.

The analysis of the scenarios above suggests that the most ambitious level at the European level of the EUCALC and NetZero pathways might be reinforced in CLEVER assumptions.

[12] Pathways data available on this link ; assumptions detailed Costa et al., 2020 p. 49

[13] ECF/Climact, 2018 ; Pathways data available on this link

[14] See the CACTUS project publications, negaWatt, 2022 and Umwelt Bundesamt, 2019

Most ambitious objectives

Rao and Min (2018 - p.13) realised a benchmark of minimum social requirements for floor area:

- "*In Korea, the minimum standard is 12 m2 for one person, and 8–10 m2 for each additional member*". This would lead to **13 to 16m2/pers.** for household sizes varying from 1.9 to 3.1 persons.
- "*China's average home size urban (rural) areas of* ***32 (37) m2 [per person]*** *offers another potential benchmark*" (2012 data for China).

In Millward-Hopkins et al., (2020), **15m2/person** is considered in the *Decent Living Energy* scenario assuming 4 persons/household and 10 m2 of living space/capita plus 20 m2 of communal space/house. In the *Higher Demand* variant, the value for floor area is set at **27m2/pers.**

Proposition of a harmonised corridor

The value proposed in the Millward-Hopkins (2020) scenario of a floor area between 15 to 20 m^2 (considering the diversity of household size) could be considered as a theoretical social lower bound for the corridor in a sufficiency approach. Indeed, this scenario ensures that this value could allow to leave a decent life.

However, given the current values observed in Europe and the trend of other scenarios, **a target for the lower bound between 32 and 37m2/person is proposed.** This target is considered more realistic and consistent with:

- The decent living standard defined by Rao and Min (2018) in urban and rural area for China.
- The observed level in European countries such as France where the value of 40m2/pers allows a sufficient standard of living even if there is still a significant over-occupation rate (slightly below 10%).
- The estimations of other European level scenario considering 37m2/pers. in 2050 as the most ambitious target in the EUCALC and NetZero pathways.

This overestimation of the lower bound compared to Milward-Hopkins (2020) allows also for a certain flexibility in order to guarantee a decent standard of living for all, in particular to take into account some inequalities in the standard of living in the population that might persist.

Many parameters (speed of renewal of the building stock, reduction in the size of households, decrease in the population, etc.) reduce the possibilities to rapidly reduce the floor area per person. **An average decrease of 0.4%/year (CAGR) between 2015 and 2050 already seems very ambitious.**

To be consistent with the objectives for 2050 are therefore differentiated according to the historical level (2015 or 2020):

- **Countries above 40m2/pers. in 2015:**
  - Maximum value: **2015 figure** (reflecting a stabilisation)
  - Minimum value: **a decrease of 0.4%/year** (CAGR), between 2015 and 2050
- **Countries below 40m2/pers. in 2015:**
  - Maximum value: **40m2/pers.**
  - Minimum value: **32m2/pers.**

The achievement of these objectives can be detailed through the evolution of the two parameters below:

- **Stabilising or even decreasing the average size of dwellings**, for instance thanks to better match between the needs of households and the surface of new dwellings - which cumulatively represent by 2050 10-15% of the total stock in most of partners' scenarios (30% for DE).

- **Slowing down the trend of household size reduction (or even increasing the household size)**, to keep it at least above 2.1 pers./household (if it is not already lower in 2015). This can be achieved for example by promoting collective housing (see the policies proposed in the next paragraph).

Current vision of CLEVER's national partners

Following the definition of this corridor, the national partners reviewed their trajectory to reach it while taking into account their national characteristics. These first trajectory are given in Figure 4.

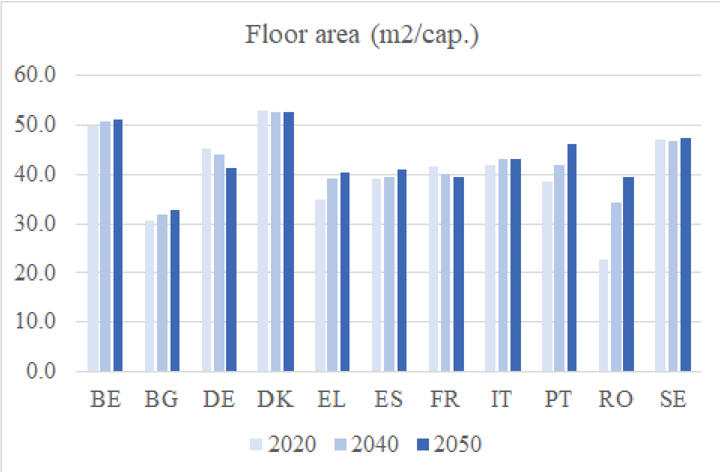

Figure 4: Floor area per person observed in 2015 and current values of a selection of national partners for 2050

Analysis of the assumptions:

- For countries (EL, RO) with low values for floor area in 2015 (<40m2/pers.) a raise of the floor area per person could be observed, leading to values between 32 and 45m2/pers.
- For countries with high values in 2015 a stabilisation (FR, CH, BE, DK, SE) or a slight increase (IT) could be observed.

The scale of the increase in countries like Greece (EL), Romania (RO), Portugal (PT) or Italy (IT) can be partially explained by the expected decrease of household size. The planned evolution for this indicator is given in Figure 5.

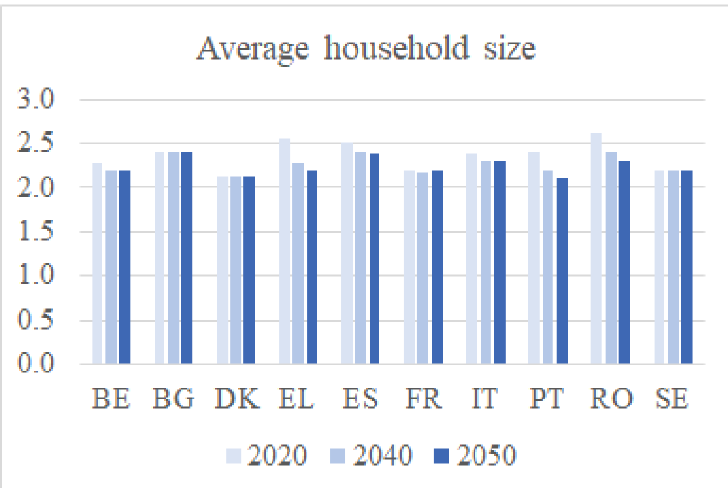

Figure 5: Average household size (pers./dwelling) in 2020, 2040 and 2050 (national partners' values).

First proposals for policy measures to support ambitious objectives

Key measures

Objective: Optimise individual floor space

- **Control the increase of floor area** (targeting over-crowded dwellings) in countries with a value below 40 m2/pers. (Romania, Slovakia, Latvia, Poland).
- Stabilise at the minimum and aim for a decrease of this space in countries above 40m²/pers., to the benefit of collective and shared living spaces development with less loneliness for elders or students.

EU level: **Increase the EU leadership of limiting land take (soil sealing)**. The EU Commission has set a target of no net land take by 2050 in its Roadmap to a Resource Efficient Europe[15]. However, its legislative role is limited to a regular sharing of guidelines on soil sealing (previous one in 2012[16] and next announced in 2024).

The EU Commission should recover the ambition of the aborted Soil Directive proposal in 2006 that intended to define soil sealing and enjoin member states to take measures to limit it[17].

National level: **Set ambitious targets for land take reduction** in every country above the corridors. These targets are already implemented in many country (zero-net land take in France by 2050, land take below 20 ha/day by 2030 in Germany…)[18]. They could be derived with measures to reduce individual floor area per capita at the local level[19]. For instance, land take reduction target led municipalities in Germany to prioritise multifamily buildings over single-family homes.

National/local level: Create **local and national housing agencies** dedicated to support collective living. Its extended roles could range from:

- *financial support:* help to get financial incentives for the less floor area intensive practices[20].
- *advice and assistance:* in moving and encouraging the swapping of older households with younger families or intergenerational cohabitation.
- *inform on the social benefit of collective living options*: co-living and co-working buildings combat loneliness while offering dedicated space for privacy and without reducing the comfort level.

Best-case example in Germany – local agencies:

The culture of cooperative dwellings in Germany[21] leads the municipalities to create local agencies to help people access these dwellings through different forms. They give preferential land release to building communities, organise information sessions, or commissioning an architect or project manager. The city state of Hamburg stands as a key example of institutional support for these type

[15] European Commission, 2011

[16] European Commission, 2012

[17] See the 2006 Soil Directive Proposal article 2 and 5.,

[18] Science for Environment Policy, 2016 ; Links for the targets for France and Germany.

[19] Targets should be set for local governments, not for individual persons.

[20] See policy proposal below.

[21] Holzl and Bernet, 2019 : there is today, 2.2 million cooperative dwellings in Germany.

of dwelling through a dedicated 'Agentur für Baugemeinschaften' plan (Agency for building communities). These local agencies could be used as a model to define housing agencies dedicated to support collective housing.

The 2000 watts target in Zurich – platform of dwellings exchanges:

The 2000 Watts target, set by the municipality of Zurich in 2008, led to a political reflexion on reducing the floor area[22]. Zurich implemented a platform for dwellings' exchange to adjust their size to the one of the households. The municipality is also exploring how teleworking and part-time jobs could contribute to reducing the floor area per capita in office buildings.

Intergenerational cohabitation network in France:

The French housing network Cohabilis has accompanied 30,000 people in their intergenerational housing experience. In the two formulas proposed, one of them offers free housing to the young person in exchange of low participation to charges and time presence with the senior. The other formula does not require any time presence with the senior but the payment of modest financial compensation well below average rental market prices.

National/local level: **Provide financial incentives for sufficiency practices** reducing floor area for both tenants and owners. There is a wide range of incentives, such as ESG-based Build-to-Rent Mortgages and tax exemptions for the development of multi-family housing for owner and tax incentives for moving into smaller locations or for non-touristy subletting for tenants[23].

Cross-parameter measures

EU Level: **Ensure through the EPBD, that all building emission are monitored.** This will both allow to optimise the energy consumption of every new construction and give a metric to monitor renovation.

The new EPBD proposal from December 2021 took a step in this way by complementing the energy performance indicator (kWh/m²) with a new operational emissions indicator. Indeed, the energy performance indicator isn't enough because it does not limit the energy consumption, nor emissions, of the built environment[24].

Going further, **both operational and embodied** emissions should be taken into account, as suggested in the ITRE Commission rapporteur on EPBD recast draft report[25].

This new emission indicator should be used to put limits **on operating and embodied carbon emissions into the net zero emission buildings (NZEB**) standards[26]. This should also include obligatory reporting on carbon emissions for new buildings.

It should finally be used to put a cap on lifecycle emissions for the overall dwelling in complement of the energy performance indicator.

[22] City of Zurich, 2011

[23] See a detail of these measures in this EEB study.

[24] Y. Saheb 2021

[25] Draft report, amendment 61

[26] NZEB goals for all EU members are governed by the EPBD. They currently binds EU members to ensure that all newly constructed building are nearly zero energy since 2018 (EU Commission).

Other measures

Local level: Establish an average floor area per person target through municipalities plans (non-legally binding)[27]. This target would be applicable to all cities so as not to disadvantage one city over another. It does not specify any reduction at first stage, the first objective is rather to halt further growth. Municipalities will be able to stay within the target providing financial incentives programs (fundings can use revenues from property taxes or energy taxes) to avoid shortages, excessive rents and make the cap acceptable. The cap should be set as a strategic but non-binding policy.

A softer complementary measure would include **bonus-malus systems for developers** depending on average housing units surface area in the project.

US example of binding regulation on maximum floor area ratios[28]:

Los Angeles, Austin, Ashland and Palo Alto in the US introduced new regulations in their municipal codes to fight against the rise of "McMansions" - large individual residencies in suburban neighbourhoods - using updated **maximum floor area ratios** (FAR, the ratio of a building's total floor area to the size of the piece of land upon which it is built) standards[29].

[27] Thomas et al. (2018) proposes to create this average floor area per person for German municipalities plans. A softer measure could be a bonus-malus system for developers on the average surface area of the housing units in the project

[28] The ratio of a building's total floor area to the size of the piece of land upon which it is built standards

[29] Los Angeles, CA, Municipal Code § 12.08 (C) (5) (2017). The impact of these measures could not be found.

Renovation

Renovation pace definition

Definition: Share of the floor area (of all permanently occupied dwellings) that has been deeply renovated since 2015. Deep renovation is defined[30] as a renovation that results in an annual primary energy use below 80kWh/m²/year[31] for the following uses: heating, cooling, domestic hot water, ventilation and in-built lighting[32].
Unit: %

Historical data

As shown in

Figure 6, in almost every country in Europe, the majority of the residential buildings were built before 1990 (i.e. before any EU building regulation)[33].

Except for a few countries (IE, LU, CY), the distribution of the building stock by period of construction is relatively similar:

- 45% to 75% were built before 1980
- **60% to 90% were built before 1990**
- 75% to 95% were built before 2000

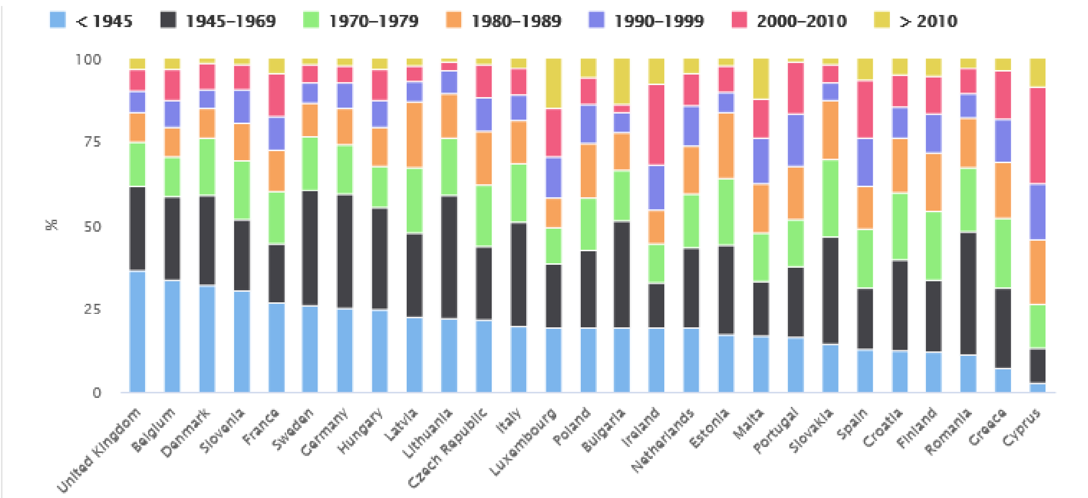

Figure 6: Breakdown of residential buildings by construction year in 2014 (Source: EU Comm building factsheet)

In addition, a BPIE analysis of available Energy Performance Certificate (EPC)[34] (Figure 7) shows that in all countries analysed (except for NL and IE):

[30] The given definition could be discussed, alternative definition could be found in Renovate Europe, 2021 and BPIE, 2021 (pp. 22 and 26)

[31] Could be adapted depending on climatic zone as defined in Annex III of the EPBD recast

[32] As defined in 2.a) - Annex V of the EPBD recast proposal

[33] EU Commission building factsheet

[34] BPIE, 2017

- More than 60% of the buildings are classified with label D or worse
- More than 80% are classified with label C or worse

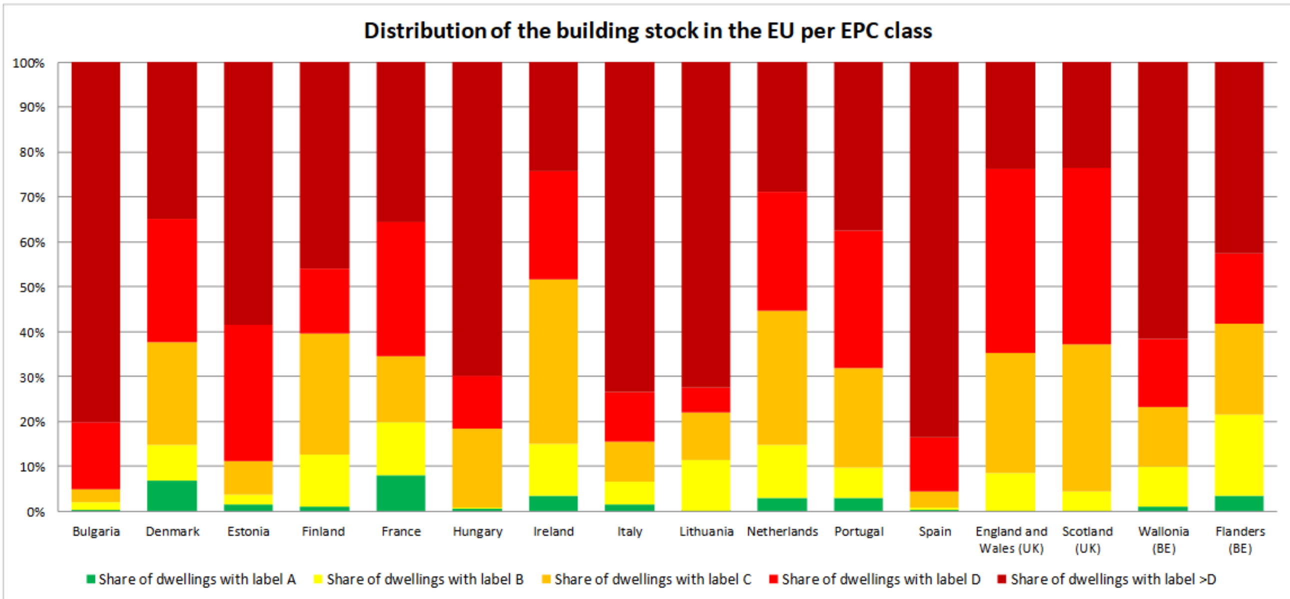

Figure 7: Distribution of the building stock per EPC class (Source: BPIE, 2017)

These figures show that, at least 65% of the residential buildings - and at least 80% in many important countries like UK, FR, IT, DE) - should be renovated or replaced.

However, the current annual deep renovation rate in EU is about 0.2% (and no country above 0.3%)[35].

Prospective: values considered in a selection of scenarios

European scenarios

In the EUCALC pathways[36] :

- Less ambitious level: *"The annual renovation rate is **1.0%.** 80% of the renovations are shallow (-30% energy demand), 15% are medium (-40%) and 5% are deep (-60%). 80% of new constructions have the lowest level of efficiency, 15% are medium efficient and 5% highly efficient. The demolition rate is 0.1%/annum"*
- Most ambitious level: *"The annual renovation rate is **3.0%.** 0% of the renovations are shallow (-30% energy demand), 30% are medium (-40%) and 70% are deep (-60%). 0% of new constructions have the lowest level of efficiency, 30% are medium efficient and 70% highly efficient. The demolition rate is 1.0%/annum."*

In the ECF/Climact Net Zero 2050 pathways[37] :

- Less ambitious level ("Technology scenario"):
  - Renovation rate: **1%/year**

[35] European Commission, 2019, p.17
[36] Pathways data available on this link
[37] ECF/Climact, 2018 ; Pathways data available on this link

  - Renovation depth: 20% energy savings
  - Demolition rate: 0.1%/year
- Intermediate ambition level ("Shared Effort" scenario):
  - Renovation rate: **3.4%/year by 2030**
  - Renovation depth: 75% energy savings
  - Demolition rate: 0.22%/year
- Most ambitious level ("Demand-focus" scenario):
  - Renovation rate: **4%/year by 2030**
  - Renovation depth: 90% energy savings
  - Demolition rate: 0.25%/year

In the European Commission scenarios 1.5TECH and 1.5LIFE[38], we find following assumptions:

- Annual renovation rate: **1.6 to 1.8%** (including deep and moderate renovations)
- Renovation depth: at least **62% energy savings.**
- About **40kWh/m2** of useful energy consumption for space heating (average for all residential buildings in the EU including new buildings and the one not renovated)
- New buildings ("to be nearly-zero in terms of energy consumption as of 2021"): 23% of the stock of residential dwellings in 2050 which means **0.75%** of annual demolition rate

Finally, in its Renovation Wave strategy (2020), the European Commission objective is to "**at least double the annual energy renovation rate of residential and non-residential buildings by 2030** and to foster deep energy renovations". Currently, "The weighted annual energy renovation rate is low at some 1%"[39].

Proposition of a harmonised corridor

The discussions within the CLEVER network has revealed a consensus on the relevance of a 2% renovation rate, as it would allow a sustainability of jobs given that regular refurbishments (not only thermal) are required every 50 years.

On the other hand, a renovation rate of at least 3%[40] would be required to renovate by 2050 all buildings built before energy performance standards have existed.

Proposal of corridors:

- **2% to 3%** of deep renovation annual rate reached **by 2030** and kept constant on the period 2030-2050
- **25 to 60 kWh/m2** for heating needs of renovated dwellings
- A maximum of 1%/year of new buildings

The cumulation of new buildings' construction and renovation must lead to **renovate or replace at least all buildings built before 1990.**

Current vision of CLEVER's national partners

As shown in Figure 8, all partners assumed that **at least 60%** of the building stock will be deeply renovated by 2050.

[38] EU Commission, 2018 pp.101-102

[39] EU Commission, 2020, pp. 2-3

[40] EU Commission, 2018 p. 90

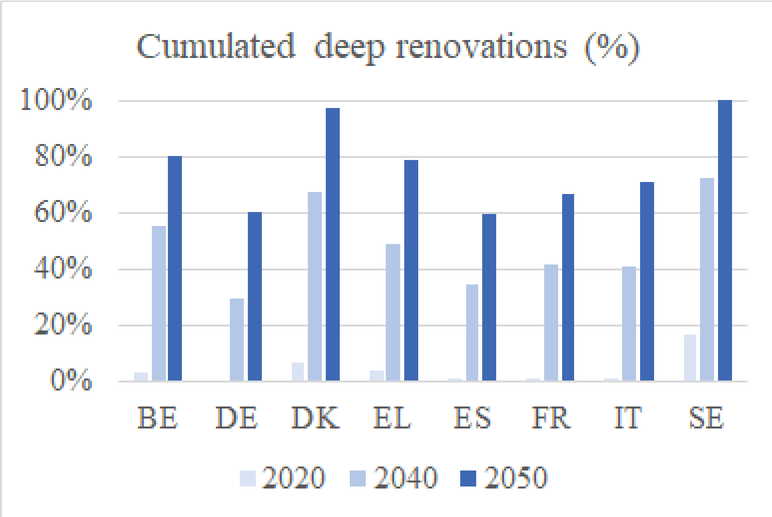

Figure 8: Proposed cumulated renovation pace over 2020-2050 by a selection of national partners

The heating needs (i.e. useful energy for space heating) assumption by the partners of renovated dwellings are variable, mainly due to the different climatic conditions (Figure 9):

- FR/BE/SE/IT/DE: 40-45 kWh/m2
- CH/EL: progressively reach 25 kWh/m2
- DK: 60 kWh/m2

These values are well below the target values following the climatic zones defined in the EPBD recast[41].

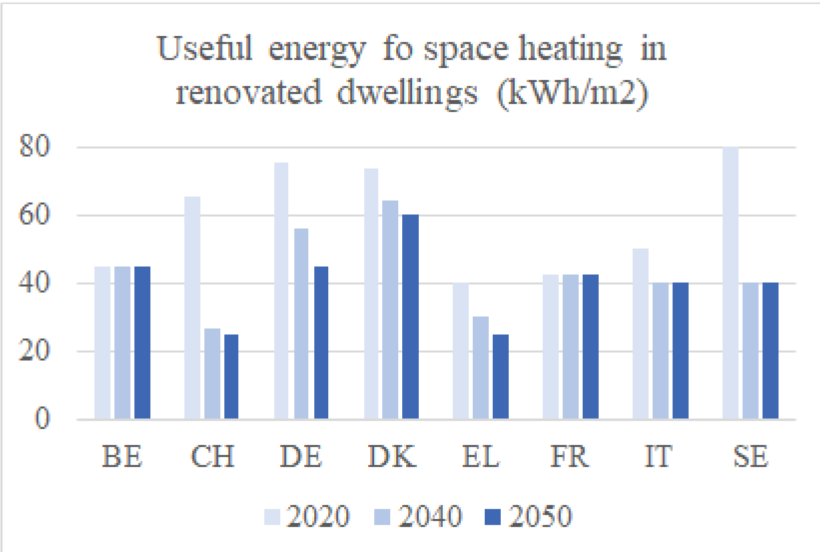

Figure 9: Useful energy consumption for space heating of renovated dwellings planed by a selection of partners over 2020-2050

Finally, the share of new buildings in the stock varied between 0.2%/year (e.g. PT) and 1%/year (FR) in 2015.

In 2050, 15% (DK, FR) to 30% (DE) of the buildings are assumed to have been constructed over the period 2015-2050.

[41] Annex III of the EPBD recast

First proposals of policy measures to support ambitious objectives

Buildings account for approximately 40% of energy consumption in the EU and 36% of greenhouse gas emissions[42]. Buildings are the single largest energy consumer in Europe; therefore, a massive deep renovation plan is urgent and necessary to decrease energy needs of existing buildings. In 2021, a BPIE report[43] concluded that decarbonisation in new buildings was happening too slowly and inconsistently compared to the ambitious climate goals.

This deep renovation plan requires a clear framing and targets with a deep renovation standard/obligation, strong implementation measures and important financial support. It will allow green and local jobs creation, and healthier, affordable, less energy-demanding homes in every part of Europe. Finally, it will make it possible to eradicate energy poverty.

Objective of the measures: Engage at EU level in a deep renovation paradigm

Urgently increase the pace of deep renovation plans based on 3 pillars:

- *Framing*: setting ambitious standards to guide the roll-out of deep renovations.
- *Implementing*: facilitating the renovation work through professional training and standardisation of requirements.
- *Financing*: making renovation financing as easy as possible through incentives for households and banks.

Framing

EU level: **Clearly define deep renovation** by setting a definition of deep renovation for all member states. It will address the current heterogenous European context. This definition should set two requirements:

- a *primary energy use below 80kWh/m²/year* after the renovation works, varying according to the climatic zone[44], for the following uses: heating, cooling, domestic hot water, ventilation and in-built lighting[45]. This requirement is well defined in the EPBD recast proposal from the EU Commission.
- GHG emissions below *20kg CO2eq/m2/year GHG emission* for the latter uses, also varying according to the climatic zone. This requirement isn't defined in the EPBD recast proposal. This definition should be based on **a measurement of both operational and embodied emissions of buildings** through an emission performance indicator going beyond the current energy performance indicator[46].

EU level: Set clear deep renovation EU targets to reach to a massive upscaling of deep renovation. Massively increase the pace of renovation and the level of ambition: favour deep renovation over incomplete or step-by-step renovation[47]. **Aim for 2% to 3% of deep renovation annual rate reached by 2030** and kept constant on the period 2030-2050. To reach 100% of deep renovation for the EU building stock in 2050, we should aim for 3.3%/year, but a balance between realism and ambition needs to be stroked. Implement intermediary targets on least energy-efficient

[42] EC Europa, 2019

[43] BPIE (Buildings Performance Institute Europe), 2021

[44] Aligned with the levels proposed by the EU Commission in Annex III of EPBD recast proposal

[45] As defined in 2.a) - Annex V of the EPBD recast proposal

[46] ITRE rapporteur's draft report on EPBD recast proposal, amendment 61

[47] It has been demonstrated (see ADEME,2020) that energy performance gains cannot be achieved without carrying out all of the renovation work steps (insulation of the walls, the low floors and the roof, replacement of the external joineries, ventilation and production of heating/sanitary hot water, as well as the interfaces, ensuring airtightness and continuity of insulation and the interactions between these items). Carrying out all the insulation work without ventilation, for example, will lead to a very low consumption housing, but with a bad quality of indoor air to the detriment of the health of the occupants.

buildings to be deeply renovated first: renovate to C level by 2030[48] and reach a fleet average on B level until 2040.

EU level: Introduce a "deep renovation standard" (and obligation) in the **EU regulatory framework** (EPBD) which would fully guide policymaking, planning and investment decisions; placing deep renovation as the default option in all policy making. This standard should set long term objectives[49] and minimum energy performance norms for all buildings (ex: a ban on the rental of low-energy performance dwellings). Harmonise energy performance diagnoses (EPD) based on two indicators: energy consumption and GHG emissions, the worse performing indicator sets the energy building class.

National level: Implement and monitor deep and complete renovation in one single step, or at least three minimum renovation steps, and avoid technical and financial deadlocks. The 6 renovation objectives should in priority be performed in one single round of renovation work ("complete renovation"): insulation of the walls, the low floors and the roof, replacement of the external joineries, ventilation and production of heating/sanitary hot water, as well as the interfaces, ensuring airtightness and continuity of insulation and the interactions between these items[40].

National level: Reduce allowed energy demand in new buildings to be at least in line with current EC recommendations. Update requirements once the EPBD establishes new, EU-wide definitions. Make it a requirement that **RES cover 100% of energy demand in new buildings[50]**.

Complementary measures

EU level: Complementary measures for the revision of the EPBD include: the introduction of requirements to shift towards positive energy buildings; and the implementation of measures for utilisation of low-carbon materials in the building.

Implementing

EU level: **Deep renovation should be made a priority** and should be applied to all aspects of policy making from designing building standards to elaborating planning strategies, running subsidy scheme, setting up advisory services, providing training to construction professionals and more[51].

To simplify renovation work and to reduce the cost, **develop the use of pre-calculated technical solutions** allowing craftsmen to know exactly the characteristics of thermal resistances, the levels of air tightness, the types of ventilation, etc.

In addition, **require member States to report on how their Long-Term Renovation Strategies (LTRS) policies are aligned with the deep renovation EU standard** (mentioned above) and 2050 EU Renovation Wave Target.

Also provide **support to member states to develop professional training**: implement a deep renovation label for businesses, including training on the technical, organisational and commercial issues of deep renovation (coordination of profession's interests, airtightness, cost optimisation etc.). Simplify access to these trainings for all by better coverage of training costs, systematic and efficient reimbursement relative to business total benefit for time spent in training and simplification of application files[52].

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[48] This target represent the goal for the EPBD rapporteur to be validated in Parliament.

[49] BPIE (Buildings Performance Institute Europe), 2021

[50] BPIE (Buildings Performance Institute Europe), 2021

[51] BPIE (Buildings Performance Institute Europe), 2021

[52] French negaWatt scenario 2022, part 3 page 13

National level: Use mandatory indicators of numerical energy performance (kWh/m2/year) and share or renewable energy in energy demand (expressed as a percentage)[53].

Finally, implement *ex ante* and *ex post* **indicators to evaluate energy saving results** in national policies, housing quality improvements and structuration of the renovation sector (number of craftsmen group).

Financing

EU level: Allow banks to systemically use Green Targeted Long-Term Refinancing Operations (TLTROs) to finance deep renovation schemes[54]. Through its TLTROs, the EU Central Bank (ECB) currently lends money to banks at a -1% interest rate for projects complying with the EU's Green Taxonomy. This effectively means banks are getting paid to borrow from the ECB and will therefore drive demand for loans towards banks. The ECB should develop, in parallel, facilities to evaluate and verify Green Taxonomy-compliance as documented by banks.

National level: **Create simplified zero-interest loans** which will cover all the cost of the deep renovation works. Households will be able to adjust their reimbursement period and the amount of subsidies received depending on their revenues. For collective housings, create a "renovation work fund" to protect buyers from necessary and inevitable works in the long-term[55].

European examples

There is a broad diversity of country situations of building stock. The solutions specific to each country are not necessarily directly transposable to another. Below are given four examples of good and bad practices to trigger a fast renovation wave in European countries:

Germany and national subsidies:

The energy renovation of buildings in Germany is **heavily subsidised**. Households, companies and municipalities benefit from several subsidy mechanisms to encourage them to renovate their buildings: soft loans, direct grants, tax credits. The public investment bank KfW (Kreditanstalt für Wiederaufbau) plays a key role in this financial support. However, this financial support is not conditioned to worse class energy houses and not specially targeted to poorest households.

Denmark:

Denmark has set **ambitious renovation targets** in various sectors of the building stock, in particular social housing (B label on average by 2020) and large commercial buildings (C label on average by 2023). However, the pace of deep renovations was too slow to enable high enough energy gains to reach these targets. Another target to reach a reduction of energy consumption of existing building stock by 50% is still possible if current policy measures are strengthened.

Sweden:

There are many lessons to be taken from the Swedish model which couples energy efficiency efforts (building insulation) with a policy of supply decarbonization. It used classical instruments to foster deep renovations such as **economic incentives, carbon taxes, tax credits and information tools**. However, the impact of taxation, is still insufficient to initiate deep renovations which also require specific regulatory and budgetary tools to achieve BBC level for the entire building stock.

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[53] French negaWatt scenario 2022, part 3 page 12

[54] Positive Money, 2021

[55] French negaWatt scenario 2022, part 3 page 13

UK:

The observed blockages in the implementation of regulations for the renovation of low-energy buildings offers lessons for the implementation of obligations such as the one set by the UK government. It is essential to provide local authorities with financial and human resources to identify dwellings in advance and to ensure that owners and tenants are aware of the obligation. The UK example also shows the difficulties of reducing energy insecurity with an approach that combines obligations to suppliers and obligations to renovate when financing is too low. It also raises issues of just transition for homeowners: additional mechanisms and funding are needed to support renovations, such as those in place in Scotland and Wales.

Domestic hot water

Definition: <u>final</u> energy consumption per person for hot water per year.
Unit: kWh/pers.

Two factors impact the final energy consumption for domestic hot water:

- the **hot water needs per person**, whether defined in terms of useful energy consumption (in kWh/pers.) or in terms of volume of hot water used (L/pers.).
- the **efficiency of the water heating** (expressed as a % of the energy transmitted to the water).

Ideally, the CLEVER corridor for this indicator should be divided into these two indicators in order to differentiate sufficiency and efficiency assumptions.

Historical data

There is a lack of historical data on useful energy consumption and on the volume of hot water used. But the final energy consumption enables first analysis (Figure 10 and Figure 11).

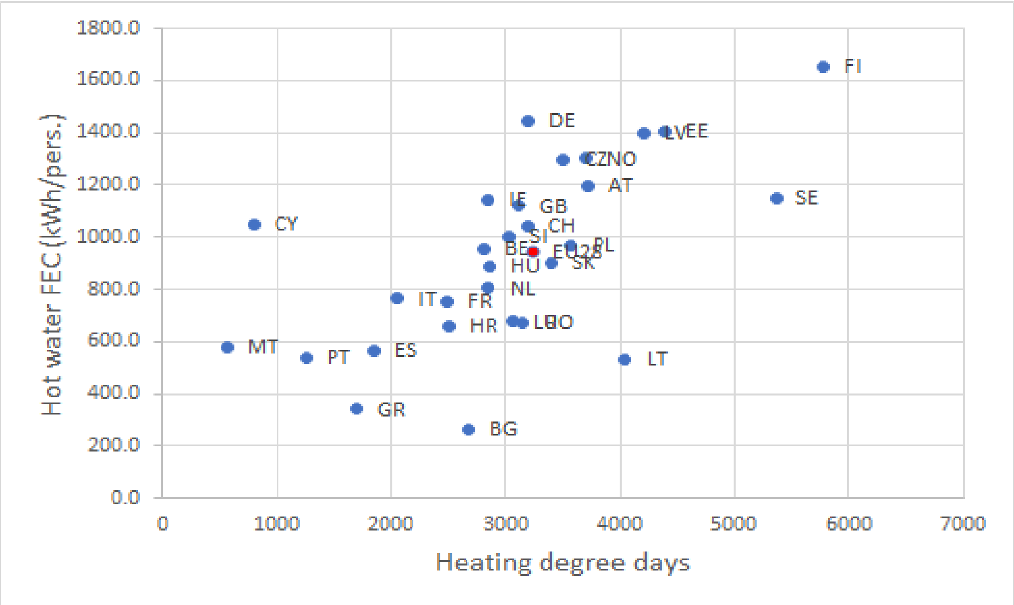

Figure 10: Relationship of heating degree days to FEC (kWh/pers.) for hot water in 2018 (Source: ODYSSEE)

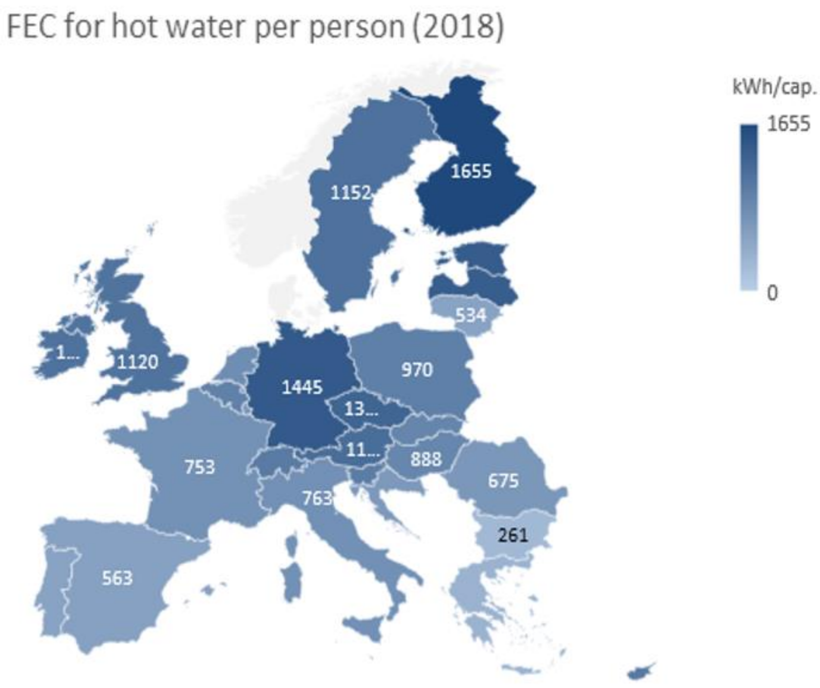

Figure 11: FEC (kWh/pers.) for hot water in 2018 (source: ODYSSEE)

These figures show important differences in energy consumption for hot water within Europe, **from 600kWh/pers. in Spain to 1400kWh/pers. in Germany or Estonia.**

This could be caused to **data inconsistencies** (e.g. ODYSSEE data for BG/EL seems very low). For instance, the estimation for Greece is almost twice lower than the estimation of the CLEVER partner (NOA estimation: 668 kWh/pers.).

The **differences in climate conditions** could partially explain this huge variability in hot water final energy consumption (Figure 10). Indeed, it could influence the volume of water used, the target temperature and the starting temperature (i.e. close to the outdoor temperature)

Differences between countries on the **efficiencies of the heating systems** could also explain this disparity.

Prospective: values considered in a selection of scenarios

The hot water needs and the efficiency of water heating in negaWatt (2017) and Millward-Hopkins (2020) are detailed in Table 2.

In Milward-Hopkins et al. (2020), the authors assume the following needs[56] :

- A domestic hot water needs of **20L/pers./day** (15L for showering and 5L for sanitation). In a variant called "High demand scenario" they consider **40L/pers./day**.

[56] The methodology is detailed in the supplementary information of the article pp.7-8

- An energy needs per litre of 96 to 220kJ/L, or **27-62Wh/L** (incl. losses for an efficiency of 95%) for a target temperature of 50°C. These differences reflect extreme climate like Burkina Faso and Canada.

In the negaWatt scenario for France, 294 to 376 kWh/pers. are considered[57], reflecting a need for domestic hot water between **18 and 23L/pers./day** (the differences depend on the type of housing: individual or collective).

Scenario	Variant	L/cap./day	Energy required (Wh/L)	Useful Energy (kWh/cap.)
Milward-Hopkins et al (2020)	Low demand / Burkina Faso	20	27.8	203
Milward-Hopkins et al (2020)	Low demand / Canada	20	61.1	446
Milward-Hopkins et al (2020)	High demand / Canada	40	61.1	892
nW 2017	Collective housing	18	44.7	294
nW 2017	Individual housing	23	44.8	376

Table 2: Comparison of assumptions (hot water volume and energy per volume) and results (useful energy) between several scenarios and a proposal of assumptions for the EU scenario.

Proposition of a harmonised corridor

Target value

According to previous analyses, a reasonable corridor including sufficiency could be **265-510kWh/pers. of useful energy** for hot water. It was calculated using the formula below used in Milward-Hopkins et al (2020)[58]:

"Energy use = $C_p V \rho (T_{out} - T_{in}) / Eff$,

where V is the volume of water and ρ the density (0.997 kg/L), C_p is the specific heat capacity of water (4,184 J/kg.K) and Eff is the heat transfer efficiency of the boiler."

and the assumptions below for the CLEVER scenario:

- V: **18-25 L/pers./day**
- A water **output temperature** (T_{out}) of **50°C**
- A water input temperature (T_{in}) between 2°C and 15°C, leading to 40-56 Wh/L.

These figures needed to be adapted when hot water use due to tourism couldn't be differentiated and classified in the tertiary sector. Then an additional consumption for hot water was considered, based on the total nights spent in the country by foreign tourists and assuming tourists will consume the same amount of water as locals. For example, in Greece, 120 million nights[59] were spent in the country by foreign tourists in 2019. Given that the population is about 10.8 million (spending 365 nights a year in Greece), then, it would imply an additional 3% hot water need.

Trajectory

As little historical data is available for the useful energy consumption, it is not possible to directly build a trajectory and a corridor for both hot waters needs and the efficiency of water heating systems.

[57] negaWatt, 2017 bottom of p.19

[58] The methodology is detailed in the supplementary information of the article p.8

[59] Source: EUROSTAT

A first possibility to have a trajectory with each parameter detailed (hot water needs and efficiency) was considered as illustrated in the example Table 3. The useful energy in 2015 or 2020 could be calculated thanks to FEC and efficiency. A linear trajectory for useful energy could then be computed for 2020-2040 along with a definition of X% (e.g. 80%) of efficiency improvements are reached by 20XX (e.g. 2035). Hence, in the example Table 3, the parameters in orange are input values.

kWh/pers.	2015-2020	2035	2050
Efficiency	60%	84%	90%
Useful energy	720	525	330
FEC	1200	625	367

Table 3: Example of strategy for a given country starting with an FEC of 1200 kWh/pers and an average efficiency of 60% to compute historical data to be able to directly define a trajectory to reach the useful energy for hot water corridor.

To set corridor directly link to historical data, the CLEVER network has decided however to build a **linear trajectory (2020-2040) only for the final energy consumption for hot water** based on assumptions on the target for efficiency and the target for hot water needs in useful energy (267-510kWh/pers.).

Global efficiency will depend on the carriers' shares and was approximated by a weighted average of each carriers' efficiency among the share of each carrier in the building stock. A 100% efficiency was considered for solar thermal and thermodynamic (heat pumps) heaters. According to the efficiencies in 2050 in Table 4 and given the current share of carriers for hot water proposed by partners in 2050 (very little biomass and almost no coal or oil), **the efficiency in 2050 will be between 75% and 100%, and for most cases around 90%.**

	Share of the building stock	Efficiency
Coal	0%	66%
Biomass	5%	66%
Oil	0%	70%
Gas	14%	76%
Electric	14%	75%
Heat networks	5%	81%
Thermodynamic	61%	100%
Solar thermal	2%	100%

Table 4 : Hot water systems' efficiencies for France in 2050 leading to 90% of global efficiency (weighted average; negaWatt, 2022). For other countries, global efficiency varies between 83% and 90% depending on the carriers'share

The addition of the two targets: efficiency between 75% and 100% and useful energy consumption between 267 and 510 kWh/pers. Defines a final energy consumption corridor **between 270 and 680 kWh/pers.**

The target is assumed to be **reached by 2040** as several partners indicated that objectives for FEC for hot water could be reached much quicker than for space heating. This would require a complete renewal of water heaters in less than 20 years (which means at least a **4% renewal rate**) and a significant change in hot water consumption.

Current vision of CLEVER's national partners

The current partners' trajectories FEC for hot water FEC in 2040 and 2050 are given in Figure 12. The 2040 values are within the corridor (except for DE). These final values for every country are **between 300 and 700 kWh/pers.** A majority of partners value are between 350 and 550 kWh/pers.

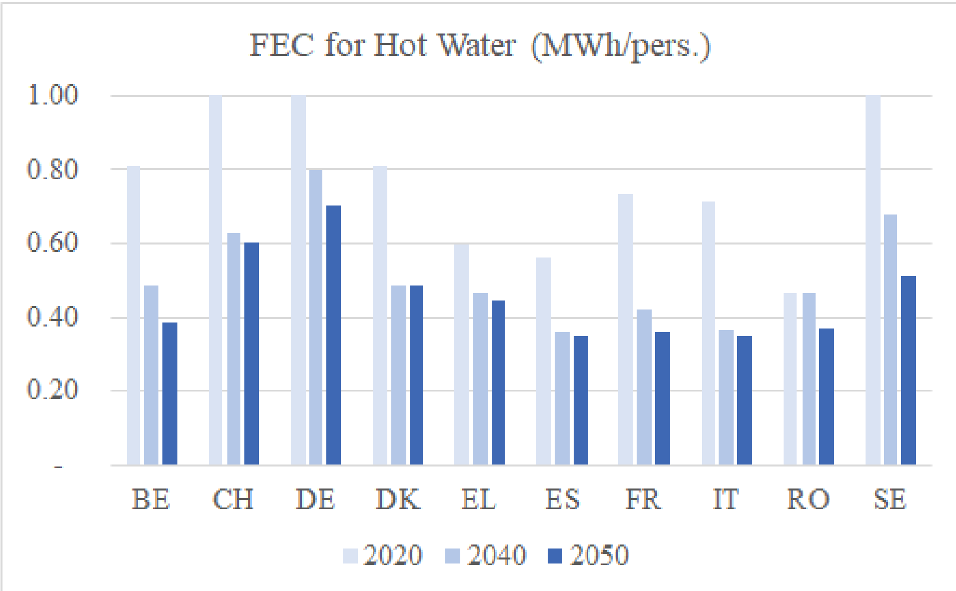

Figure 12: FEC for hot water (MWh/pers.) in 2015 and current values of a selection of national partners for 2040 and 2050

First proposals of policy measures to support ambitious objectives

Objective: Decrease domestic hot water (DHW) consumption and generalise most efficient water heating systems.

Decrease DHW consumption through awareness raising, systematic monitoring, appropriate technologies and financial incentives. Aim at a phase out of oil and coal systems in all buildings as soon as possible.

EU level: **Ban the sale of new fossil fuel heating systems** by 2025 in the new Energy Performance Building Directive (EPBD) [60]. In December 2021, the revised version of the EPBD only prevents Member states from subsidising fossil fuel heating systems in 2027. Set a target that **no more oil and coal water heating systems are in operation in existing buildings in 2040[61]**.

Accompany the replacement wave through the use of EU recovery and structural funds (Green Climate fund and revenues from the ETS taxes) and national funding's. Provide gradual grants to Member States depending on the share of fossil fuel heating systems (higher grant for most dependent countries on fossil fuels). Grant higher financial support for the installation of most efficient heating systems such as thermodynamic water heaters.

These measures must be taken in parallel with measures on space heating systems (see the next policy part).

EU level: Plan to **set a EU ecodesign regulation (implementing measure) on taps and shower heads** and prioritise catching up with the measure on labelling of taps and shower heads stalled since years. National regulations in order to reduce water flow on taps and shower heads are already in place in Switzerland, Portugal, Sweden. Mandatory labels on water use for taps, showerheads. etc., is estimated to save 20% within 10 years from the legislation enters into force[62]. As a complement, the implementation of an EU Energy label on these products should be finalised.

National level: Develop national programs subsidising the installation of very efficient water heaters to all types of households in new and in existing buildings. Accompany households and provide them with advices from energy experts during the renewal.

French example "My Renovation Grant" subsidising the installation of most efficient water heating systems:

For the installation of new water heater installations, the grant of Ma Prime Rénov – "My Renovation Grant" - program can range from 1,200 euros for thermodynamic water heater, 4000 euros for solar water heater and up to 10,000 euros for geothermal or solar heat pump installation.

[60] ECOS,2020

[61] The EPBD ITRE rapporteur's draft proposal goes even beyond (amendment 19, p.20) with a ban of the sale as soon as the EPBD is transposed and a fossil fuel phase out by 2035 at the latest.

[62] EU Joint Research Center, 2014

National level: Inform consumers on most impactful habits to save hot water: showers instead of baths, reducing shower length and reduce number of showers per week[63], installing more sufficient showerheads and taps (equipped with calibrated and self-regulating flow limiters), setting the hot water temperature at a reasonable level (50-55°C), insulating hot water pipes. Set a **maximum recommendation/objective on hot water (50°C) consumption at 18-25L/person/day.**

National to local level: Set regulations and advises to optimise the use of hot water:

- Spread advises to place the storage and domestic hot water production tanks at the level of single user points (e.g. washbasins, bidets, showers). This eliminates all distribution losses, which are the main source of energy consumption in the DHW (domestic hot water) system [64].
- Provide incentives to insulate the water tanks and the entire DHW distribution with appropriate jackets[65].

Local level: Improve consumption monitoring through systematising **progressive water pricing.** Progressive pricing means that water price rates per unit of volume increase, as the volume used increases [66]. It is an instrument to manage water demand and help reduce excessive water consumption through an economic dis-incentive. Thus, the largest consumers of water pay higher rates for the volume of water consumed beyond a certain threshold.

Good case example:

Many European cities are implementing **progressive water pricing** (Barcelona, Bruxelles…)[67].

[63] Many Europeans shower or bath every day, while it is not considered necessary or even healthy by dermatologists (Shmerling, 2021). Avoiding one or two showers per week could probably save about 10% to 20% on total energy use (Toulouse et Attali, 2018 – p.24)

[64] Andreau et al., 2022 report for a French research agency (ADEME).

[65] Andreau et al., 2022 report for a French research agency (ADEME).

[66] UN CTCN

[67] Wikiwater

Efficiency of residential space heating systems

Definition: Average efficiency of heating systems in the building stock. Efficiency is defined as heat delivered in the dwelling divided by the final energy consumption (i.e. energy supplied to the heating system based on lower heating value for fuels). *Then it defines the efficiency of the whole system, including losses from generating, storing, distribution, and transfer of heating energy (and regulation of the system).*
Unit: expressed in % of FEC delivered as heat in the dwelling

Historical data

We did not find relevant data of the current efficiency of domestic heating systems by country.

Prospective: values considered in a selection of scenarios

European scenarios

The majority of the scenarios reviewed do not precise heating systems efficiency as it seems to be included in energy savings from renovation.

An analysis[68] on technologies pathways was undertaken in 2018 to support the assumptions for the PRIMES modelling for the European Commission (Table 5). It includes data for residential heating systems, but the definition of the indicators (lower heating value or gross heating value; efficiency of the generation or of the whole system, …) has not been retrieved.

[68] European Commission, 2018, p.39

	Current	2030			Ultimate		
		From		To	From		To
Technology	%						
Cooking							
Cooker, oven and hobs (electric)	0.79	0.80	0.82	0.87	0.80	0.87	0.93
Cooker, oven and hobs (gas)	0.42	0.42	0.44	0.45	0.43	0.46	0.47
Space Heating							
Boilers Gas	0.79	0.81	0.85	0.87	0.81	0.89	0.94
Boilers condensing Gas	0.87	0.89	0.93	0.96	0.90	0.98	1.03
Boilers Oil	0.77	0.79	0.83	0.85	0.79	0.87	0.94
Boilers condensing Oil	0.85	0.87	0.92	0.94	0.88	0.97	1.02
Wood stoves or Boiler pellets	0.72	0.74	0.77	0.79	0.74	0.79	0.81
Heat Pump Air							
in South Countries	2.65	2.86	3.29	3.58	2.88	4.19	4.90
in Middle South countries	2.38	2.56	2.95	3.21	2.58	3.75	4.39
in Middle North countries	2.17	2.33	2.69	2.93	2.35	3.42	4.00
in North countries	1.98	2.13	2.45	2.67	2.14	3.12	3.65
Heat Pump Water	3.30	3.55	4.10	4.52	3.58	4.98	5.73
Heat Pump Ground	3.60	3.88	4.47	4.93	3.90	5.43	5.94
Heat Pump Gas	1.30	1.40	1.61	1.78	1.41	1.96	2.14
Electric Resistance (e.g. convectors)	0.99	0.99	1.00	1.00	0.99	1.00	1.00
Gas individual (autonomous heater)	0.82	0.87	0.91	0.93	0.88	0.95	1.03
Solar Thermal	0.58	0.59	0.61	0.62	0.60	0.63	0.65

Table 5: Efficiency assumptions for PRIMES modelling for the EU Commisison (Source : European Commission, 2018)

Proposition of a harmonised corridor

The trajectory proposed is defined based on the definition of a target value for 2050 at the latest and considering a linear trajectory reflecting a constant renewal rate between 2020 and 2050.

Initial values (2015 and 2020)

As no reliable data by country has been found, a corridor has been defined based on the data provided by the partners. This approach has limits as the situation can strongly vary in each country, depending for example on the distribution of the systems by age.

Target value

For the efficiency in 2050, the values of the negaWatt scenario have been mainly used as it is the most complete values encompassing the data of efficiency for the whole system[69] .

Target year

The year in which the target might be reached depends on the renewal rate of systems. As the average lifetime is about 25 years. And for mature technologies (i.e. fuels and biomass), no major changes of the efficiency of new systems are expected after 2030. **Then, high efficiency systems are supposed to equip all buildings by 2045-2050.** Of course, this would depend on how quickly incentives are set up to favour highly efficient systems (see the policy part below).

[69] The efficiency of the whole system should include the losses of generation, distribution, emission and regulation

Two particular cases must be considered:

- Technologies not yet widespread (e.g. heat pumps): the average efficiency of the stock might quickly reach the efficiency of new systems as most systems will be installed in the coming years. But on the other hand, the efficiency of new systems is expected to improve (see Table 5). Then, the trajectory considered is the same as other systems.
- Technologies which will be replaced: boilers using fossil fuels - coal and oil (and gas in some scenarios) - will be replaced by decarbonised technologies. For these technologies, no new systems will be installed and the efficiency will remain the same as in 2020.

The target efficiency corridor for each carrier is given in Table 6.

	Value 2015-2020		**Target value**	**Target year**
	Partners	**Proposed***	**-**	
Solid Biomass	15-70%	40-60%	70-75%	2050
Gas	66-90%	70%	75-80%	2050
Electric	88-98%	94%	94%	2050
Heating networks	68-90%	70%	75-80%	2050
Heat pumps**	2.4 - 4	2.6	3.5-4.5	2050

Table 6: Chosen corridor for the efficiency of residential space heating of different key carriers
*If no data encountered at national level ; **Supposed with a high proportion of ground heat pumps

First proposals of policy measures to support ambitious objectives

The policies impacting residential space heating are merged into the policy section of the share of carriers in residential space heating part below. Indeed, “Efficiency” and “Share of carriers” indicators are directly linked as their evolution depends on the replacement rate of heating systems.

Share of carriers in residential space heating

Definition: Final consumption for space heating of the carrier divided by total FEC for space heating, including ambient heat (e.g. heat pumps) and solar thermal.
Unit: Expressed in % of FEC delivered by the given carrier.

Historical data

The energy mix for space heating in the residential sector is very different among countries (Figure 13). It raises different issues for the decarbonisation of this sector:

- Some countries strongly rely on oil and coal:
  - More than **30%** from oil: BE, EL, ES, IE, LU
  - More than **40%** from coal in Poland
- Gas represents a significant share in many countries:
  - 15 countries with 20% of gas, or more
  - 6 countries with 50% of gas, or more (HU, IT, LU, NL, SK, UK)
- 15 countries use a share of solid biomass between 25% and 65%
- Some countries (EE, DK, SE, LT…) have a district heating well developed (up to 40-50% in DK/SE)
- Energy from heat pumps (e.g. ambient heat). It becomes significant in some countries (PT, NO, FI…).

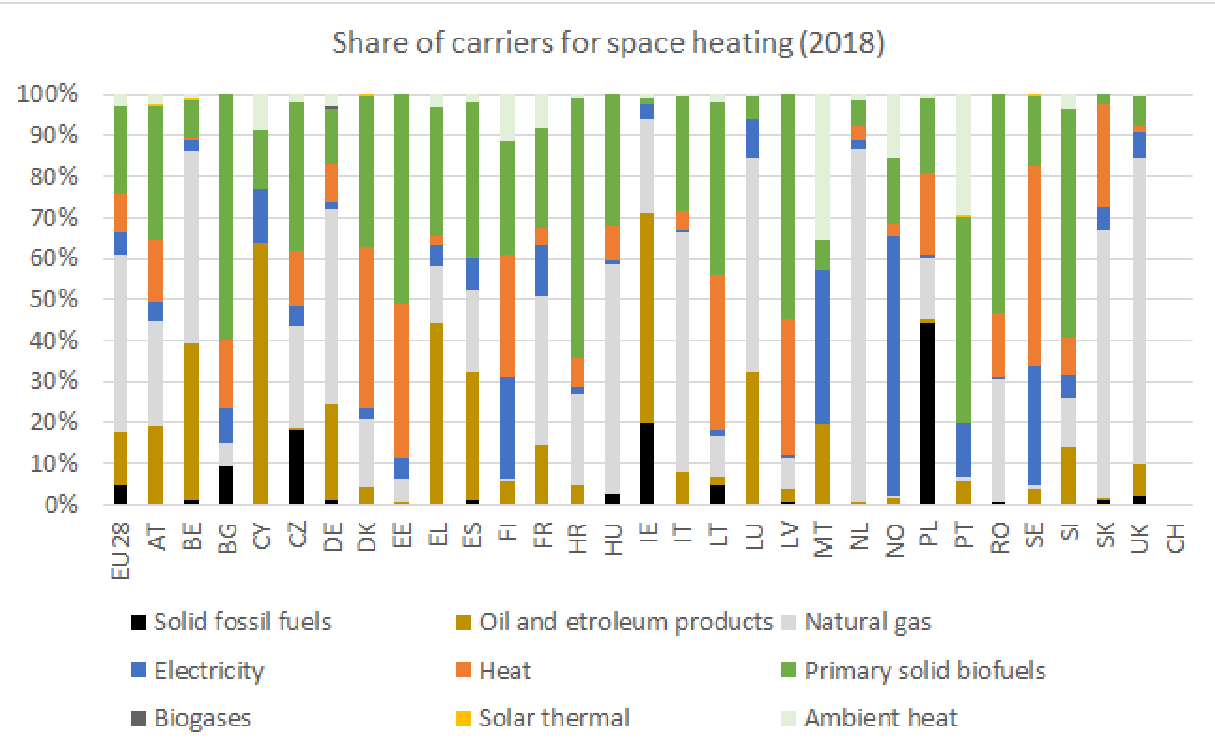

Figure 13: Share of carriers in FEC for space heating in 2018 (Source: EUROSTAT).

Issues at stake

For each carrier, the shares in 2050 (and the reach of an intermediate target like an early phase-out of coal and oil) will depend on the renewal rates for domestic heating systems and the priorities (e.g. coal or gas or inefficient systems). Considering a lifetime of equipment of 25 years, the renewal rate would be 4%. Then, all systems could be replaced before 2050 if **corresponding incentives are set up before 2025**.

Coal and oil must be phased out as soon as possible given there are no existing alternatives to decarbonate these carriers. Bioliquid fuels can be produced and could replace oil, but the sustainable potentials are very low and they will be prioritised in the most difficult sectors to decarbonise.

The shares of solid biomass and gas must be limited because the associated systems are not the most efficient ones and the renewable potentials are limited (especially in countries with high population density like DK, DE, BE, NL) and might be prioritised for the sectors harder to be decarbonised (e.g. industry and transports).

On the other hand:

- Gas (from methanisation or methanation) and biomass are considered as zero emissions energy sources;
- They can be better suited for some types of dwellings;
- As stock energies, they limit the fluctuations of electricity demand ;
- For countries with very high shares of fossil fuels (oil, coal and gas) in 2015, a complete renewal of systems might be very challenging.

District heating networks have many benefits, in particular to facilitate a quick integration of more renewable energy in heat. They are also the only way to deliver some types of renewable energy sources for space heating (e.g. deep geothermal energy, solar thermal, …). However, the profitability of such infrastructure mainly depends on the density of consumption, like city centres. Their profitability should be further studied considering the generalisation of deep renovations (which reduce the density of consumption).

Heat pumps (HP) have many benefits: high performance, especially for heat pumps with ground exchangers, no direct pressure on the bioenergy resources. There are however limitations on a large spread of HPs:

- Its integration in urban areas might be complex: the outdoor space is not always available to integrate it, there is noise in the case of air source HP, important need for indoor space (and therefore limited possibilities) in the case of a ground exchanger, ...
- A high share of HP might impact the variability of electricity demand and then the supply-demand balance and the needs for electric/thermal storage means
- There is a COP degradation in case of low temperatures, in particular for air source HP, which reinforce the variability of electricity demand

Solar thermal: not detailed here as it is not a solution privileged in a large proportion by any partner for space heating.

Proposition of a harmonised corridor

A harmonised corridor has been set for each carrier:

Oil and coal: complete phase out

- At the latest in 2050
- Earlier where possible, considering the 2020 share and a 4% renewal rate effective by 2025. (For example, for Belgium, this would lead to a complete phase out by 2035)

District heating:

- Lowest share: share in 2019
- Highest share: share of the population not living in rural areas[70] *(which strongly varies across countries: from 50-60% in LT, LV, PL, RO to 80-90% in NL, DE, UK and over 99% in Malta, in 2018). This is a theoretical maximum as some dwellings in cities might not be adapted.* But in some specific cases, district heating can also be suited in rural areas.

Solid biomass*

- Lowest share: 0%
- Highest share: current share. This would reveal a significant raise in the number of dwellings equipped with biomass given that an important raise in efficiency is expected

A share close to the one in 2015 seems reasonable, except in countries with low potentials in comparison to the population density.

Gas*:

- Highest share: 15% according to the first partners' ambitions

**Regardless of the level initially determined, a further analysis is being carried out to check that the total consumption (over all sectors including biomass/gas supply for district heating) does not exceed national sustainable renewable energy potentials, and that the gas use is coherent with European ambitions and the current context*

Heat pumps: Most of the remaining share (i.e. once the shares of DH, solid biomass and gas have been determined). However, this share should be limited to 80-90% of the total FEC for space heating to reflect the inadequacy of HP in some contexts (see "Issues at stake"). The variability of the limit is set to take into account the differences between southern and northern countries, especially for the relevancy of air source HP (overall efficiency and issues for very low temperatures) depending on the climate conditions.

Electric heating: should remain marginal (below 5%) because of the low efficiency in comparison to heat pumps, although it can be better suited for very performant buildings.

Solar thermal: not detailed here as it is not a solution privileged in a large proportion by most partners for space heating).

[70] Source : EUROSTAT

Current vision of CLEVER's national partners

There is a disparity for the level of use of the carriers in residential space heating among the partners' ambitions for 2050 which reflect the wide variety of national contexts (Figure 14):

- *Heat networks* (labelled as "Heat") share varies from 1% in EL to 70% in DK.
- *Biomass* is up to 20% to 40% in FR/IT/BG and below 10% for other countries
- *Gas* still remain in the trajectories in EL/FR/IT (up to 12%).
- *Heat Pumps* use (incl. ambient heat, e.g. carriers "Elec" and "Ambient") represent a FEC between 50 to 70% of the total FEC for space heating for most country. Portugal is specific in that regard with a share of heat pumps on 90% in 2050.

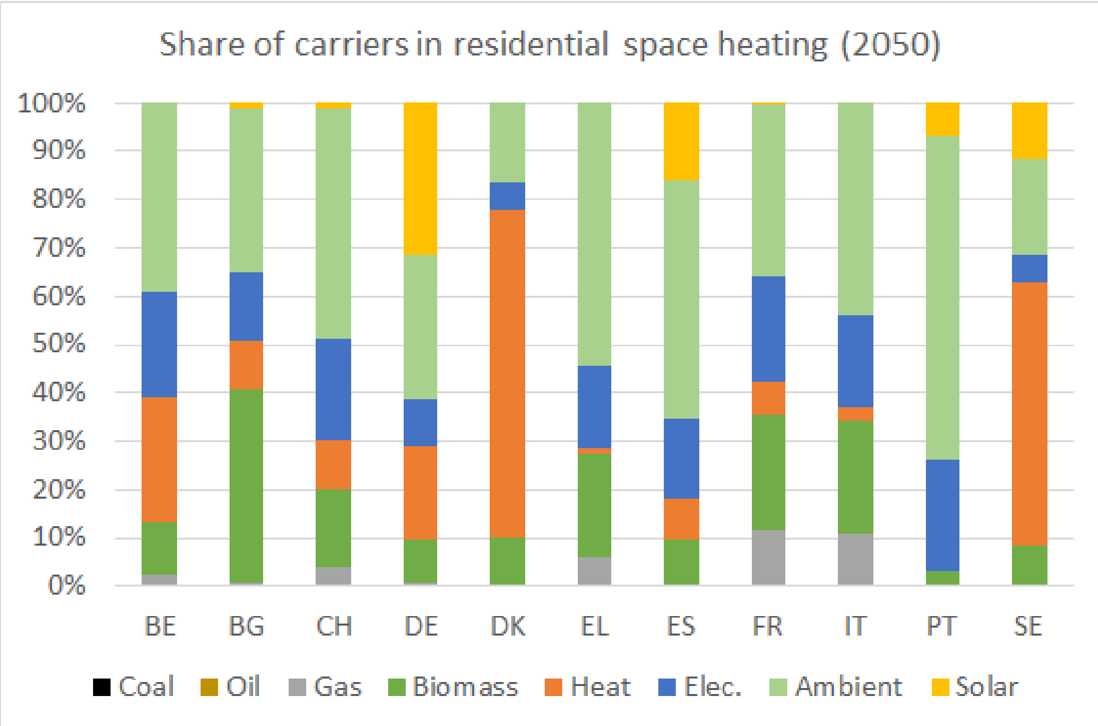

Figure 14: Share of carriers in FEC for space heating in 2050 (current values from a selection national partners)

The partners are however ready to strongly adapt these trajectories, notably in order to increase the electrification thanks to heat pumps.

First proposals of policy measures to support ambitious objectives

Objective: Reduce heat demand and trigger a massive replacement of existing boilers with more efficient and renewable energy-powered devices.

Decrease heat demand through deep renovation and improved consumer used. Aim at a phase out of oil and coal boiler in all buildings as soon as possible.

Key measures

EU Level: Reduce heat demand through thermal improvement: deep renovation (see renovation policies) and construction of buildings benefitting from sufficient solar gains.

EU level: Ban the sale of new fossil fuel boilers by 2025 in the new Energy Performance Building Directive (EPBD)[71]. Set a target to ensure that **no more oil and coal water heating systems are in operation in existing buildings in 2040**[72].

Secure the replacement wave through new EU Ecodesign regulations: remove G-class by 2023 and F-class by 2025. Strengthen Energy labels: rescaling to A-G classes rather than keeping A+ to A+++.

Accompany the replacement wave through the use of EU recovery and structural funds (Green Climate fund and revenues from the ETS taxes) and national funding's. Provide gradual grants to Member States depending on the share of fossil fuel heating systems (higher grant for most dependent countries on fossil fuels). Grant higher financial support for the installation of most efficient heating systems such as: efficient heat pumps, condensing boilers consuming an increasing share of renewable gas[73].

Support the EU industry to carry out the replacement wave. For example, there is a real need to support the development of a European industrial offer for **efficient heat pumps**[74].

National level: Reduce heat demand through thermal improvement of buildings (deep renovation, see renovation policies) and more conscious consumer use of space heating: with a target to obtain a limit of space heating to 19°C. This limit should be reached through maximum requirements at 19°C in public buildings and awareness raising campaigns for consumers.

Good case example in Germany on maximum temperature:

The German State as set for the 2022 winter regulations in public building to be heated to 19°C while hallways and corridors won't be heated[75].

National level: End the installation of coal and oil-based systems and inefficient systems in new constructions and deep renovation works. Allow only the installation of most efficient water heating systems. Develop national programs subsidising the installation of very efficient boiler in all

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[71] ECOS, 2020

[72] The EPBD ITRE rapporteur's draft proposal goes even beyond (amendment 19, p.20) with a ban of the sale as soon as the EPBD is transposed and a fossil fuel phase out by 2035 at the latest.

[73] French 2022 negaWatt scenario: part 4, p.23

[74] Euractiv, 2022

[75] Euractiv, 2022

types of households in new and in existing buildings. Accompany households and provide them with advices from energy experts during the renewal.

Austria progressively banning fossil fuel heaters in all buildings in 2035

The Austrian Federal Government planned to **prioritise the phase-out of fossil-fuel heating systems**, with:

- a first ban in 2021 on the installation of oil heaters in new buildings.
- a ban on the installation of gas heaters in new buildings in 2025 (in the Austrian NECP).
- a final ban on both oil and gas-fired heating systems in all buildings starting in 2035 with "a target of 2040 for phasing out liquid fossil fuel energy sources for heating purposes".
- a further aim is to replace liquid fossil fuel-powered boilers which are over 25 years old with renewable energy sources or district heating as from 2025.

As part of the renovation initiative in 2019, the Federal Government introduced a **funding priority** to phase out fossil-fuel powered heating systems in residential housing ('Oil Phase-Out Premium'). In 2019, 62.7 million euro was made available for the 'Oil Phase-Out Premium', including the renovation check and thermal renovation measures in buildings used for commercial purposes.

France bans oil and coal boilers in new homes in 2022:

Oil and coal boilers will be forbidden in new homes thanks to the environmental regulation (RE2020). Two situations are distinguished: collective housing and single-family homes with different timings and thresholds[76]. In case of replacement of oil or coal boiler, households will have to opt for another type of installation that is more efficient and more environmentally friendly[77]. **Households will be accompanied** in installing new efficient heating systems (sometimes more expensive) through **increased renovation grants** especially for the most modest (MaPrimeRénov' grant). The budget allocated to this grant will be increased by two billion euros over 2021 and 2022.There are already other grants available to help people replace their old heating system with a more efficient one at a lower cost.

Other measures

<u>EU to local level:</u> Use educational campaign and tools to accompany habits changes (lowering heating temperature, heating only inhabited rooms, installation of smart thermostats)[78]. Public communication material can be focused on promoting sufficiency-based behaviours.

Good Practice: eco guides by national energy agencies:

ADEME, the French environment and energy management agency, regularly publishes eco-guides for consumers on various topics. For instance, the guide "Better use and cheaper use of heating at home" provides advice to optimise heating systems and water heaters[79].

<u>National level:</u> Encourage people to move away from fossil fuel by setting energy building certificate for both energy consumption and GHG emissions.

[76]- For single-family homes, where non-fossil fuel solutions are common and perfectly mastered (notably for heat pump or biomass heating), the threshold will be set at 4 kgCO2/m2/year from the entry into force of the RE2020 and will de facto exclude systems using only gas (measured during performance audits).

- For collective housing, the transition will occur between 2022 and 2025. The threshold will initially be set at 14 kgCO2/year/m², still leaving the possibility of installing gas heating if the dwellings are very energy efficient. Then, from 2025, the threshold will be reduced to 6.5 kgCO2/m2 /year

[77] L'énergie tout compris, 2021

[78] Toulouse et Attali, 2018

[79] ADEME, 2019

Good practice in France:

This measure is applied in France. Thus, a home with a space heating system with high GHG emission will have a lower score in their energy building certificate, which encourages to move away from fossil fuels.

National to local level: Develop district heating networks locally with highly insulated networks[80] and with caution. District renovation and district heating should be designed in a coherent way in order to minimize the energy bill of final consumers and reduce their GHG emissions. Indeed, if the tariff scheme of district heating is based on the number of sold kWh and on subscribed thermal power, the lower energy demand of renovated housings could jeopardize the profitability of district heating. A perfect maintenance of district heating is also key to avoid any energy distribution losses. New district heating networks for new or renovated districts must also have highly insulated networks and use distribution temperatures not exceeding 40 or 50°C in order to reduce their line losses. **If these losses are greater than the energy consumption distributed (in low-energy buildings) with "conventional" networks, district heating will not be efficient, nor economically viable** (high construction cost)[81].

Provide direct, indirect financial support (investment subsidies and long-term debit funding) and relevant tax incentives (environmental taxes, reduced VAT) to allow their development, provided that their losses are much lower than the energy sold. Focus on local policies and coherence with urban planning: integrated long-term approach for urban planning, development of compact and mixed-use districts.

District heating increase the share of local and renewable energies in the network, easily allows the substitution of energies upstream and can facilitate the integration of intermittent renewable energies in the electricity mix. These systems should be developed taking into account the specificity of each area

Sweden, good practice example on district heating and improved air quality:

Municipalities in Sweden fuel their cities from renewable energy sources by relying on district heating. **85%** of all multi-dwelling Swedish houses and all public buildings are connected to district heating[82]. Today all towns in Sweden have district heating networks, which have enabled the Swedish heating sector to become **almost completely fossil free.** They use mainly biofuels like wood and peat, but also burn household waste (which must be reduced through a move towards circular economy). The main reason to invest in district heating in Sweden was to **create a healthy environment in Sweden's cities**. Sweden has the lowest average CO_2 intensity of residential heating of the EU-27, at 29 gCO_2/kWh due to a high concentration of biomass, nuclear and renewables in their heating sector[83].

[80] European Commission (2016)

[81] Sarma et al., 2019

[82] Bertelsen and Vad Mathiesen (2020). By relying on district heating combined with heat and power production, municipalities in Sweden power their cities from renewable energy sources.

[83] Climate exchange, 2021

Specific electricity

Definition: Final energy consumption per person for specific electricity
Unit: kWh/pers.

Specific electricity usually includes almost all end uses apart from space heating, space cooling, water heating and large cooking appliances. This means that specific electricity covers 2 categories of energy services defined in the EUROSTAT classification[84]:

- **Lighting and appliances**: "*This category include the use of electricity for lighting and any other electrical appliances in a dwelling not considered within other end uses"*
- **Other end-uses***: "*This category covers any other energy consumption in households such as use of energy for the outdoor and any other activities not included into five major energy end-uses mentioned above (e.g. lawn mowers, swimming pool heating, outdoor heaters, outdoor barbeques, saunas, etc.)."*

**As we can see in the historical data below, the FEC associated with "other end-uses" represents less than 10% of specific electricity (except for AT, CZ, FI, SE). And data from EUROSTAT also indicates that electricity is the major carrier for "other end-uses" (100% for SE, AT, IT, IE, NO and 80% for CZ), except in Finland where half of the FEC for "other end-uses" is covered by solid biomass.*

Historical data

Except in SE/FI/NO, in 2018, the FEC for specific electricity ranges from **570 to 1300 kWh/pers.** among European countries (or between 1380 and 3150 kWh/dwelling).

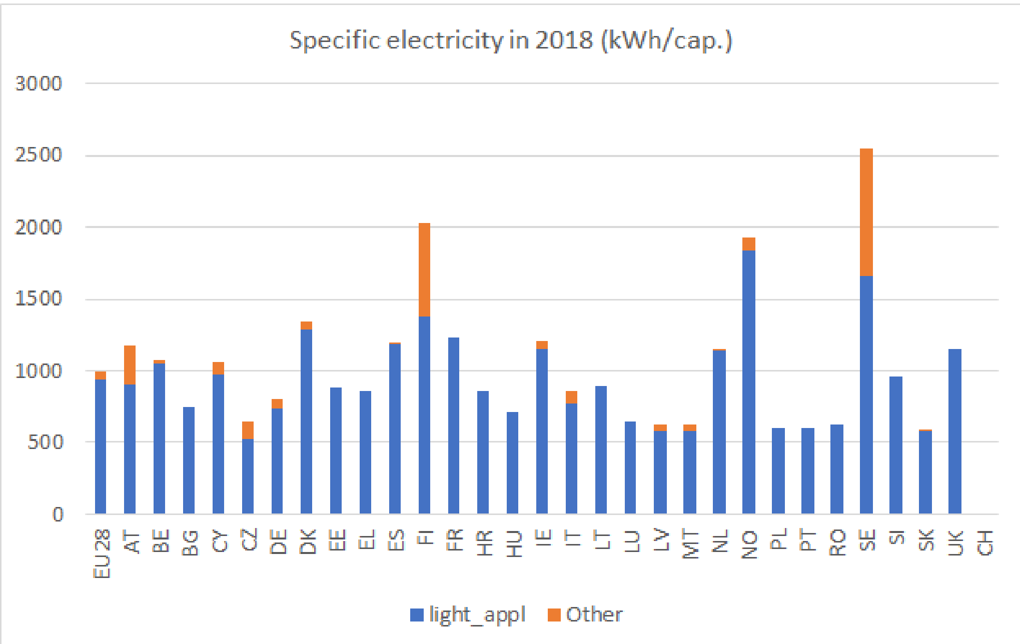

Figure 15: FEC per person for specific electricity in 2018 distinguished between "Lighting and appliances" and "Other end-uses" (Source: EUROSTAT)

[84] Definitions of end-uses in households in EUROSTAT, 2013 pp.37-38

Disaggregation of the indicator

For prospective matters it is required to further detail the end-uses included in this category. Here below a proposal based on the 2017 négaWatt scenario for France[85] :

- **"Lighting"**
- **"Building management": circulator pumps, ventilation and common areas of buildings[86]**
- **"Appliances":**
    - **"Washing"** including FEC associated with washing machines, dryers and dishwashers.
    - **"Refrigeration"**: refrigerators and freezers
    - **"Small appliances": vacuum cleaners, irons, small kitchen appliances...**
- **Electronics:**
        - **"Recreational electronics"**: screens, computers, music, internet & TV boxes, gaming consoles
        - Standby of devices if not included in other sections
- **Other devices** (e.g. aquarium, garage doors, DIY tools, etc) and potential reserve for future products

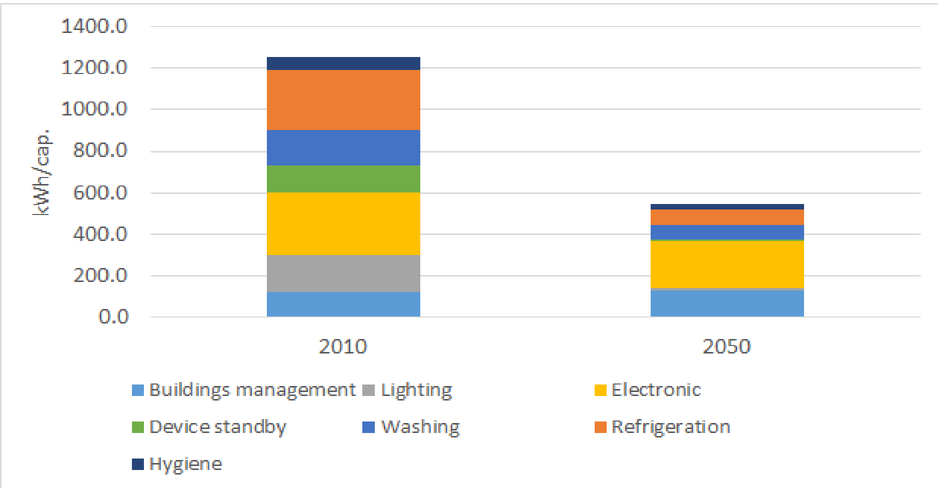

Figure 16: Evolution between 2010 and 2050 of the FEC for each category of specific electricity in negaWatt (2017)

For each device of each category the energy consumption can be estimated by multiplying:

- **the rate of equipment ownership** (sufficiency lever)
- **the frequency / duration of use** (sufficiency lever and impact of optimisation technologies such as sensors, AI…)
- **the average energy performance of the equipment** depending on the technologies (efficiency lever), the size/capacity (sufficiency lever), and the settings/programme selection (sufficiency lever)

[85] negaWatt, 2017

[86] Energy use related to common areas of buildings is sometimes accounted in the Tertiary sector

Prospective: values considered in a selection of scenarios

Four sets of scenarios were analysed in Table 7:

- The negaWatt scenario for France (2017)
- Millward-Hopkins et al. (2020) with 2 variants:
  - The default one referred as "DLE (default)" in Table 7 below.
  - A variant assuming higher level of demand referred as "DLE (high demand)" in Table 7 below.
- Brischke et al. (2015 – pp.8-9) including estimated potentials which "should be understood as maximum theoretical potentials assuming, that all of the main electrical applications must remain available".
- The EU PRIMES reference scenario from 2016 (EUREF16)[87].
- The ECF/Climact Net Zero 2050 "Shared effort" pathway[88].

kWh/cap.	négaWatt 2017	DLE (default)	DLE (High demand)	Brischke et al.	EUREF16	ECF "Shared effort"
TOTAL	**546**	**132**	**175**	**152**	**1273**	**426**
Buildings management	**129**	-	-	-	-	-
Lighting	**17**	**25**	**50**	**14**	**112**	**76**
Appliances & Electronics	**273**	**107**	**125**	**114**	**1161**	**350**
Washing	*69*	*53*	*71*	*28*	-	-
Refrigeration	*76*	*30.6*	*30.6*	*24.0*	-	-
Electronics	*93*	*23*	*23*	*63*	-	-
Device standby	*11*	-	-	-	-	-
Hygiene	*24*	-	-	-	-	-
Others	**127**	-	-	**24**	-	-

Table 7: FEC for specific electricity (kWh/pers.) for a selection of scenario. The values presented are for 2050 except for Millward-Hopkins et al., 2020 (DLE) and Brischke et al., 2015 which has no target year defined.

The 2022 update of the negaWatt scenario for France for specific electricity in 2050 is more ambitious than negaWatt 2017 values:

- Building management: 119 kWh/pers.
- Lighting: 14kWh/pers.
- Appliances & main electronics: 302 kWh/pers.
  - Large appliances (TV, refrigerator, freezer, washing machine, dishwasher, dryer): 213 kWh/pers.
  - Small appliances (other: PC, video, vacuum cleaner...): 89 kWh/pers.
- Small kitchen devices: 45 kWh/ pers.
- Others: 114 kWh/ pers.

[87] Pathway's data available on this link

[88] ECF/Climact, 2018 ; Pathway's data available on this link ; details on assumptions available on this link

Proposition of a harmonised corridor

Given the prospective values, the following corridor could be used when we disaggregate the indicator:

- **200-350 kWh/pers. for appliances & electronics** (the DLE estimation on electronics only detail the following needs: one phone per person and one computer per household)
- **10-30 kWh/pers. for lighting**
- **100-130 kWh/pers. for building management** (the négaWatt scenario being the only one detailing this end-use)
- **100-175 kWh/pers. for other existing uses**

A "reserve" for yet non-existing uses and future devices could also be added. In the latest negaWatt scenario, it amounts to 67 kWh/pers. in 2050.

According to this disaggregation, a target of **400-700 kWh/pers. in 2050** seems reasonable. No national specificities have been found which could justify a differentiation of this target among countries except for SE/NO/FI where, according to historical data, there appear to be particular more energy consuming end-uses.

A linear trajectory has been considered to reach the values of this corridor.

Current vision of CLEVER's national partners

Most partners are currently within the specific electricity corridor in 2050 with consumption values between **500 and 700kWh/pers.**

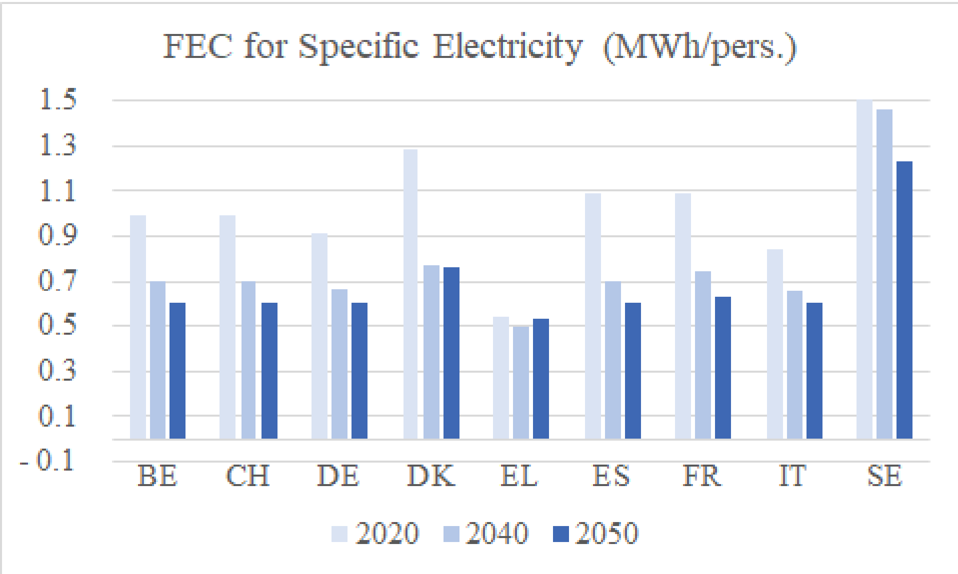

Figure 17: FEC for specific electricity (MWh/pers.) in 2015 and current value in 2040 and 2050 for a selection of partners.

First proposals of policy measures to support ambitious objectives

Despite solid efficiency progress of products in the EU and existing policies (ESPR/Ecodesign for Sustainable Products Regulation), energy consumption from products in the domestic and tertiary sectors has at best stabilised, but not taken a strong downward trend. The reasons usually mentioned are the proliferation of products and gadgets, the inflation in sizes and functionalities, longer usage hours, and constantly new areas of application. Energy sufficiency is therefore an option which must be considered through enhanced regulation[89].

Key measures:

Objective: Integrate a sufficiency culture in the use of specific electricity.

- Include sufficiency in the labelling strategy.
- Optimise life duration of appliances.
- Reach consumers to help them to modify their uses.

EU level: **Define a labelling strategy including sufficiency**. Indeed, the EU Commission Ecodesign and Energy Labelling Working Plan focuses on energy efficiency[90]. The EU Ecodesign and Energy Labelling directives should **include a mandatory label** on electronic products and appliances integrating: **CO2 and life-cycle footprints through all the value chain**, criteria for repairability, recyclability, share of recycled material and durability of the product. This label would be visible as a letter from A to E on the good, and detailed information will be made available through a unified digital product passport in line with transparency principles of algorithms[91].

Regarding **energy consumption labels,** the situations in which an efficient energy rated product can consume more than a smaller product in a lower energy class[92].

Both energy and life-cycle label could be used to ensure that products that are harming the environment (too high GHG foot print or energy consumption) are removed from the market[93].

EU level: Prohibit planned obsolescence[94] and extend life duration of appliances. A global framework for reparability could be developed under the umbrella of a "right to repair"[95]. Concretely in this framework it should be compulsory for manufacturers to offers spare parts for reparation for at least 5 years[96]. In addition, a labelling telling the reparability and recyclability of the products should be put in place. A move in this direction has already been made by the EU Commission in its revision of the consumer's right[97]. Following that way, the legal guaranty period should be extended.

EU level: Integrate a sufficiency narrative in the **EU Ecodesign** policies. For instance, theses directives could have references to dimensional usage and collaborative aspects of the products (e.g.,

[89] Toulouse and Attali, 2018

[90] EU Commission, 2022

[91] See the ECOS coalition recommendations (March, 2022) on this effective disclosure and communication.

[92] Toulouse et al., 2015 - this can be done by adjusting the steepness and levels of the labelling formulas so that there is less risks of overlaps.

[93] See the ECOS review of the Ecodesign Directive and negaWatt 2022 scenario policies p.17

[94] France for instance prohibits planned obsolescence by law since 2015 (Article L 441-2 of the Consumer Code).

[95] Request from the European Parliament

[96] It is in particular Friends of Earth position to reduce overproduction.

[97] Right to access to reparability and updates information EU Commission proposal, 30/03/2022

thresholds on size of washing machine, requirement for businesses to install a "home mode" ecological setting that should be the default set up choice, etc.)[98].

Another sufficiency lever is to ban adds promoting high energy consuming goods[99].

National and local levels: Increase consumer education to optimise product usage[100]. Encourage users to use their equipment for a longer period, to optimise usage of appliances (full load washing machines, switching off lights), share products and reduce product ownership: especially for products such as irons, vacuum cleaners, washing machines and dryers in collective housings and condominiums. This sharing of product is complementary with an increase of cohabitation and multi-family building as promoted to reach the consumption corridor defined for the floor area.

Other measures

EU level: A more prominent visualisation of sufficiency. Increase easy access to information for consumers on most efficient products through consumer guides and initiatives such as Topten ACT[101] which identifies the top energy-efficient products in 16 European countries and makes the information available on national tailored websites.

National level: Additional **national schemes to support the purchase of the most efficient appliances** through financial subsidies, white certificates, green public procurement, etc.

[98] Toulouse et al., 2015

[99] Proposal that could be found in the Belgium National Energy Climate Plan (NECP), p.129

[100] Toulouse and Attali, 2018

[101] Topten ACT is a project financed by the EU Horizon 2020 project. It identifies the top energy-efficient products in 16 European countries, and makes this information available to consumers and large buyers on tailored national websites. The most energy efficient models in different product categories (such as household appliances, lighting, office equipment, consumer electronics, cars) are presented with comprehensive product information based on official labels and standardized declarations.

Other policy proposals in the residential sector

Progressive energy tariffs

EU to national level: An interesting solution to create a culture of sufficiency in the use of energy in buildings is to set **progressive tariffs on energy**. It means to increase prices per unit of energy consumed as this consumption increases. It is generally defined per bracket of energy consumption per year[102]. This solution could be applicated to every energy carrier (electricity, gas, heat in district heating). It could influence the achievement of many corridors in this note as it will represent an incentive for renovation, for low demand in hot water and space heating and sufficiency in the use of specific electricity.

Good case practice: electricity progressive tariff in Malta:

Since 2014, Malta is using progressive tariff for electricity[103]. It is used as part of the Maltese National Energy and Climate Plan[104].

Air conditioning (AC)

Room AC is a growing source of energy consumption in the residential sector[105]. The renovation imperative presented previously could reduce its needs. However, there is an important **sufficiency lever** to be used to limit the needs for room AC. The different sufficiency measures could lead to using less energy intensive solutions (comfort fans, efficient solar protections); promoting passive cooling during the conception of buildings; reduce size of installations and recommend moderate indoor temperatures.

Good-practice in Swiss Geneva Canton[106]:

An energy law specifies that tertiary (not residential) air-conditioning installations for comfort are only possible if:

- The need for it has been duly demonstrated,
- A part of the heat generated by the equipment is reused,
- And the cooling water in the system is reused.

The law also stipulates that alternative to air-conditioning, such as solar protections, passive cooling, geo-cooling, etc. should be prioritised.

Example in several countries of minimum cooling temperature:

In Japan, the government has decided to save energy in summer through the 'Cool Biz' campaign (2005), and then 'Super Cool Biz' campaign (after the Fukushima disaster). The prescribed indoor temperature in administration buildings has been raised to **28°C in summer**, and a liberal summer

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[102] See for instance the brackets of energy consumption set by Malta since 2014 for electricity consumption.

[103] REWS, 2014

[104] Malta, 2018 – p.82

[105] "Room AC are steadily increasing (by 6%/year). An 80% further growth is expected by 2030. Central air-cooling systems have been multiplied by 5 in the last 25 years (Toulouse and Attali 2018).

[106] Toulouse and Attali 2018 – p.46

dress code introduced and encouraged. According to official evaluations, the Cool Biz campaign has saved 2.2 million tons of carbon emissions in 2012 and has become inspirational worldwide[107].

Since the start of the 2022 energy crisis in Europe, many countries discussed on setting minimum cooling temperature in public places (27°C in Spain or Italy[108]).

[107] Toulouse and Attali 2018

[108] Buisness Insider, 2022 and Reuters, 2022

References

Data and modelling

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