Schneider Electric™
Sustainability Research Institute

Towards Net-Zero Buildings
A quantitative study

July 2022

Life Is On | Schneider Electric

Introducing the Schneider Electric™ Sustainability Research Institute

Gwenaelle Avice-Huet (left)
Chief Strategy and Sustainability Officer,
Schneider Electric

Vincent Petit (right)
SVP Climate and Energy Transition Research,
head of the Sustainability Research Institute,
Schneider Electric

Progress on energy and sustainability is at an all-time high. How will that momentum fare in a new decade – and under radical new circumstances?

It is our responsibility, as a large organization, to make a positive impact by reducing our energy consumption and CO_2 emissions, and contributing to societal progress, while being profitable.

At Schneider Electric we have set ambitious targets with our 2021–2025 Schneider Sustainability Impact (SSI), in line with the United Nations Sustainable Development Goals; our technologies reconcile growth, access to energy for all, and a carbon-free future for our planet. Our climate commitments aim to minimize carbon emissions for both our customers and our own company. For Schneider, this means the neutrality of our business ecosystem by 2025, net-zero carbon from our operations by 2030, and net-zero carbon of our end-to-end supply chain by 2050.

With pioneering technology and end-to-end solutions for sustainability, we've been building momentum.

The Schneider Electric™ Sustainability Research Institute examines the issues at hand and considers how the business community, as well as societies and government, can and should act. We seek to make sense of current trends and what must happen to maintain momentum, and preview the changes that we believe are yet to come.

In this study, we propose a new and innovative approach to the decarbonization of the building sector. Taking stock of the potential of modern technologies now available, we find that their combination offers two-thirds (or above) carbon abatement opportunity by 2030 while generating massive savings on annual energy spend for building dwellers (up to 70%), a positive equation which is, we argue, the only practical route to a rapid and successful decarbonization of the building sector. New constructions and service building retrofits are prime targets for rapid development while residential retrofits will require more policy focus and business innovation (notably for low-income households).

To achieve the sustainability goals set out by hundreds of global organizations, bold steps are required to reduce emissions and operate more sustainably.

Join us in this series where we explore compelling predictions and conclusions in the areas of energy management, digital innovation, climate action, goalsetting and confidence, and fresh financing mechanisms.

It is time to embrace sustainability as a business imperative, and to capture the momentum now, for the future.

Gwenaelle Avice-Huet
Chief Strategy and Sustainability Officer, Schneider Electric

Vincent Petit
SVP Climate and Energy Transition Research, head of the Sustainability Research Institute, Schneider Electric

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Executive summary

Buildings represent globally around 30% of total CO_2 emissions today (excluding embodied emissions). 60% of those emissions stem from residential buildings, the rest from service buildings. Buildings are a very fragmented sector, and all attempts to modernize it have often been prey to skepticism. Yet, the entire building stock must reach net-zero by 2050 for the world to be on a path consistent with a global warming trajectory compatible with the 2015 Paris Agreement.

Solutions are well known and technologies are ready, they involve energy efficiency measures and the deployment of decarbonized heating technologies (notably electric). More modern solutions have also recently emerged, among which are active energy efficiency (enabled by digital controls), smart electric heat pumps, and onsite solar (and storage). Many of these solutions have been studied already. While there is a relative consensus globally on what needs to be done, the general line of thought is that it will come at an extra cost for dwellers, which represents a significant political burden. Hence the slow pace at which this massive transformation materializes.

One of the reasons for this conclusion is that these solutions have often be studied in isolation. The reality, however, is that benefits are magnified when they are bundled together:

- Heat electrification becomes more economically compelling when relying on zero-marginal cost electricity from distributed photovoltaic installations, while enabling a greater use of those.
- Active energy efficiency brings about a more efficient use of heating and helps optimize (and maximize) the use of onsite solar.
- At the same time, active energy efficiency, and digital controls, enable more flexible load management, optimizing the economic equation while providing flexibility support to the infrastructure, another key burden of this massive transition.

This is what we refer to in this paper as **Buildings of the Future**. This report studies the interlinkages between these solutions and evaluates the potential of carbon abatement of Buildings of the Future, the impact on energy spend for consumers, and their economic rationale (e.g. return on investment). We investigate six building types in 19 regions and countries, for both retrofit and new construction use cases, and evaluate the situation today, as well as its projected evolution to 2030. Overall, through this analysis we cover around two-thirds of the existing emissions, and more over time as we also account for new constructions.

Figure 1 summarizes the key findings of this report(1). Overall, we find:

- An obvious rationale in service buildings today (for both retrofit and new constructions, 40% of global building emissions). By 2030, we estimate that 60-70% of carbon emissions could be abated in the segment, generating savings around 15-50% on annual energy spend, with paybacks below 10 years (for retrofits) and an additional cost for new constructions below 4%.
- A growingly compelling rationale in new constructions (both service and residential segments), with an additional cost of building acquisition which should fall below 4-6% by 2030 for all building types.
- A more complex picture on residential retrofits, which, despite significant carbon abatement (60-90%) and a halving of annual energy spend, comes at paybacks that are not low enough to generate massive adoption, particularly for lower-income communities. This is the main area of focus for policies and business innovation in the coming years. At the same time, when retrofit is realized at transfer of ownership (sale transaction), the impact on the cost of acquisition remains around or below 6% by 2030.

The building sector is in a decarbonization deadlock and change remains too slow. Yet, the solutions exist to break this deadlock and rapidly accelerate the decarbonization of the stock, at a pace and at a scale which are probably overlooked. For that to happen, however, will require the embracing of modern solutions and innovative approaches. Today's problems will not be solved with yesterday's solutions.

Figure 1 – Making sense of it all

	Building of the Future Potential		
	CO_2 emissions	**Energy spend**	**Return on investment**
	Service buildings (excluding retail)		
Retrofit	Typical CO_2 savings around **-20-30%** today Emissions divided by 2-3 (**-60%**) by 2030	Energy spend typically drops by around **-20-30%**	Paybacks at or below **10** years At ownership transfer, inpact on cost of acquisition (TCO) below **4%**
New build	Typical CO_2 savings around **-20-50%** today Emissions divided by 3 (**-60-70%**) by 2030	Energy spend savings typically ranging between **-15-50%**	Impact on cost of acquisition (TCO) below **4%** today, falling at around **2-3%** by 2030
	Residential buildings (single family households)		
Retrofit	Emissions divided by 2-3 (**-60%**) today and by 5 (**-80%**) by 2030	Energy spend divided by 2 in average (around **-50%** savings)	Paybacks above **20** years today, cruising toward **20** years or less by 2030 At ownership transfer, impact on total cost of acquisition (TCO) below **10%** today, falling at around **6%** by 2030
New build	Emissions divided by 5 (**-80%**) today, and by 10 (**-90%**) by 2030	Energy spend divided by 3 in average (around **-70%** savings)	Impact on cost of acquisition (TCO) at or below **8%**, falling below **5-6%** by 2030

(1) The figures provided on this page are global averages over the 19 regions studied in this report. Details per region are reviewed further down and available in Annex.

Breaking the decarbonization deadlock

We are in a deadlock

The COP26 was held in November 2021 in Glasgow. Government commitments (Nationally Determined Contributions – NDCs) were updated and new commitments (not necessarily integrated yet in NDCs) were also made, prompting the International Energy Agency[2] to comment that, while insufficient, these commitments would (provided they be kept) put the world on a path toward a global warming of 1.8˚C by the end of the century. 2022 has also been the year of the 6th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2022). While the results of the first working group were published in August 2021, the second and third working groups completed the report in the first quarter of 2022. This is a major resource for the world's better understanding of the scientific evidence on climate change and the pathways available to humanity to avoid a climate catastrophe.

2022 was thus supposed to be a year of clear acceleration. Yet, the IPCC report hardly made the news. More importantly, the pace at which the transition is engaged is dramatically slower than what most scenarios project is needed. In fact, at the current pace of change, it is likely that the entire 1.5˚C carbon budget will be consumed by as early as 2030, or even before (IPCC, 2022).

Why such lack of momentum?

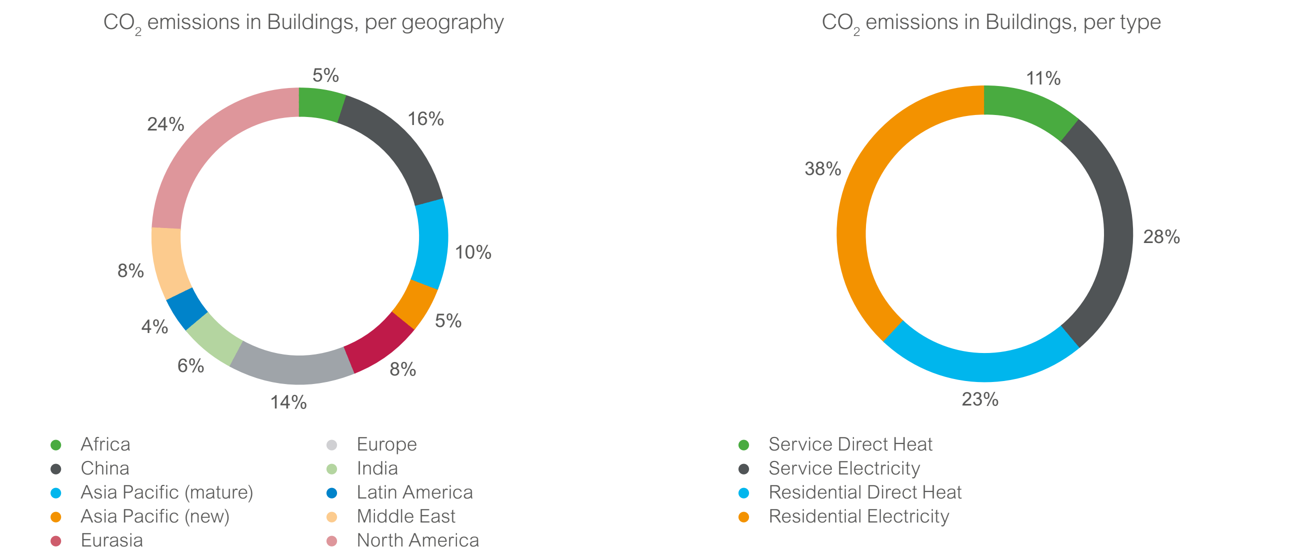
A general (yet not consensual) assessment of the transition is that it will come at a cost to society. This is often referred to as "green premiums[3]", or the cost it would take to operate an economy with decarbonized energy resources. This is maybe why, at a high level, conversations have fallen short, not to say they stumbled in some form of deadlock. It is almost an impossible political task to adopt measures that impose an actual burden on societies, particularly for those who struggle to make ends meet. This resistance to change was largely exemplified by the Yellow Vest's protests in France in 2018, opposing the implementation of another tax on fossil fuels, to support decarbonization of the mobility sector.

This deadlock is also particularly apparent in the buildings sector, responsible for around 30% of global carbon dioxide emissions (excluding embodied emissions from construction, Figure 2).

- The rate of deep retrofits in buildings (with massive energy efficiency measures) is an order of magnitude below what it should be in practice. Many approaches have been tried in the past, but they all failed to sustain over a long period of time, and they often proved to perform below expectations[4] (rebound effects).
- While electrification is widely regarded as a key solution to remove fossil fuels from buildings, electric heating solutions represent only 5% of global heating demand, and while several policy evolutions have begun to shift the tide, notably in favor of heat pumps, many countries continue to rely on antiquated pricing systems which turn electrification into a non-competitive option, hence a difficult political bargain[5].
- It is widely acknowledged that onsite solar represents a key solution to accelerating the penetration of renewable energies into the power mix, but mismatch in incentives and unclear benefits often continue to hamper its development[6].

All being considered, the grand plans around a 30-year energy transition thus face numerous challenges that are likely to make it more hectic than often imagined. Some form of a deadlock.

Figure 2 – Building CO_2 emissions[7]



(2) Birol F. (2021), COP26 climate pledges could help limit global warming to 1.8°C, but implementing them will be the key.
(3) Gates B. (2021), How to avoid a climate disaster: the solutions we have and the breakthroughs we need.
(4) Schneider Electric (2021), Cracking the Energy Efficiency case in buildings.
(5) Schneider Electric (b) (2021), Building heat decarbonization.
(6) BloombergNEF (2021), Realizing the potential of customer-sited solar. Schneider Electric (2022), The unexpected disruption: distributed generation.
(7) Schneider Electric research, based on data from ©OECD/IEA, WEO (2021), Shell (2018).

But there is an answer to the deadlock

What if the glass ceiling of an expensive decarbonization could be broken?

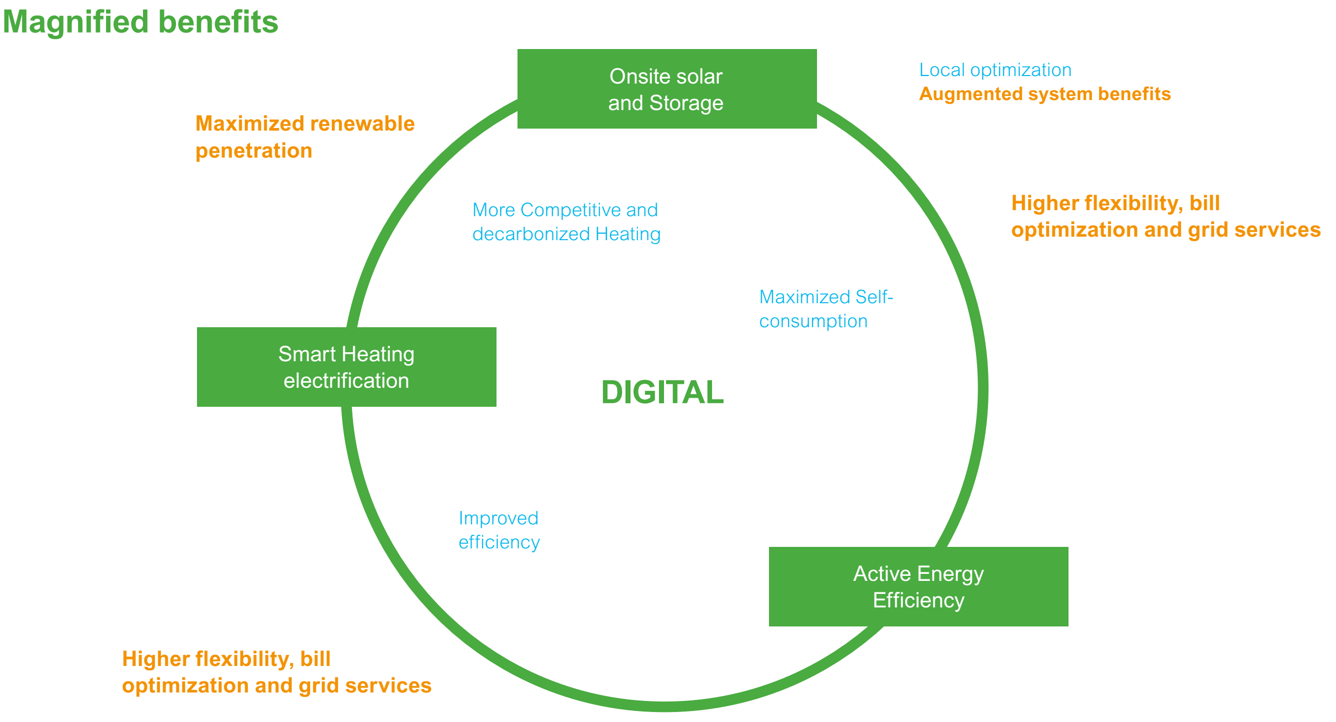
In other words, what if a different pathway could be crafted, one that not only contributes to decarbonization but also yields positive outcomes for the consumer, thereby prompting more rapid (and smooth) adoption?

This is what this research sets out to explore. In the literature, the decarbonization-cost conundrum has already been reviewed by many researchers and institutions. In general, these studies focus on one element of the transition (e.g. energy efficiency, electrification, onsite solar, etc.) without focusing on others[8].

Where this analysis departs from others is that for the first time, we combine the performance of various decarbonization options together, looking for the intrinsic benefits associated to their combination. We focus on the implementation of active energy efficiency (enabled by digital controls), the smart electrification of heating, and the implementation of onsite solar[9] (and storage). Indeed, while heating electrification may, under certain circumstances[10], come at a higher cost for the user, the access to near-zero marginal-cost electricity from onsite solar completely changes the paradigm, while offering to onsite solar the opportunity to maximize self-consumption. Similarly, active energy efficiency and digital controls are critical to optimize the use of onsite solar and improve the efficiency in heating use (smarter controls), but they also perform better thanks to more flexible electric resources (Figure 3).

Overall, the combination of different solutions together, what we call Buildings of the Future, offers magnified benefits that help chart a clearer and more practical route toward rapid (and cost effective) decarbonization of the building stock.

Figure 3 – Magnified benefits from technology integration



(8) See for instance, Schneider Electric (2021), Cracking the Energy Efficiency case in buildings. Schneider Electric (b) (2021), Building heat decarbonization BloombergNEF (2021), Realizing the potential of customer-sited solar.
(9) This research builds on a series of detailed analyses on key aspects of the energy transition paradigm in buildings, published in 2021 by the Schneider Electric™ Sustainability Research Institute. Schneider Electric (2021), Cracking the Energy Efficiency case in buildings Schneider Electric (b) (2021), Building heat decarbonization BloombergNEF (2021), Realizing the potential of customer-sited solar Schneider Electric (2022), The unexpected disruption: distributed generation.
(10) See notably Schneider Electric (b) (2021), Building heat decarbonization, to understand better how actual price positions and notably how current tax schemes effectively impact the competitiveness of different options.

2 Methodology

Buildings of the Future

To assess the benefits of combining these solutions together, we compare current buildings to buildings that integrate all of these solutions, i.e. what we refer to as Buildings of the Future (Figure 4). Benefits can be measured in carbon dioxide emissions and in energy demand and utility costs. Their economic performance (e.g. their payback) is also measured to provide a better understanding on how economic their implementation may be.

Figure 4 – Toward Net Zero with Buildings of the Future

From Buildings of Today to Buildings of the Future

Fossil fueled
Grid-tied + fossil fuel-based gen sets for backup power

Low electrification
Furnaces and boilers for heating.
Gas-powered water heaters, ovens and burners

Manual control
Manual controls, gas meters, inefficient lighting, shutters, heating systems and air conditioners

Clean electricity
Self-generation with rooftop solar panels and energy storage

Electrification at end use
Heat electrification for spaces and water heating

Digital efficiency
Active energy efficiency with IoT zone control combined with Energy Monitoring Systems

The “Buildings of the Future” model

To run this research, we have used a simple “Buildings of the Future” model[11] developed at Schneider Electric. The model evaluates:

- The impact on energy demand and energy mix of:
  - A switch to heat pumps.
  - The deployment of active energy efficiency[12].
- Taking into account the maximum potential of onsite solar deployable on that building.
- Taking into account local energy costs (per type of energy) and grid carbon intensities. Associated impacts on energy costs and overall carbon footprint (operational emissions only) are then computed[13].
- The model also retrieves capex levels[14] (between current settings and Buildings of the Future) to evaluate the economic performance of the implementation:
  - Capex for heating systems (electrified vs natural gas), active energy efficiency, onsite solar, and storage[15] are retrieved.
  - The additional capex is used to compute the project’s economic performance, either in terms of years of payback (retrofits) or as a percentage of total cost of acquisition (for new constructions or retrofits at transfer of ownership)[16].

(11) See Annex for more details on the “Buildings of the Future” model.
(12) We have considered advanced controls (category A as per EU.bac standard), see Annex for more details.
(13) Savings on energy spend are evaluated on current tariffs on energy, prior to any carbon price or other incentive.
(14) Prior to any incentive.
(15) In this study, we consider an approach where PV generation is maximized, and essentially self-consumed. This is not necessarily representative of current market reality, but provides an indication of the maximum decarbonization potential of the building stock, as well as the maximum annual savings on energy bills. This, however, requires careful dimensioning of the energy storage system and has a material impact on paybacks. Further elaborations will be realized in subsequent studies to explore more complex balances of PV and storage. See Annex for more details.
(16) For new constructions, total cost of acquisition varies significantly as it depends on the location (and the land acquisition cost). We have used different baselines. See Annex for more details.

Modelling benefits

This approach is then applied to a variety of different use cases, to check for differences and enable comparisons (Figure 5). We have modelled:

- Six building archetypes representative of office buildings, hospitals, hotels, retail centers, education buildings, and individual residential households[17]. Each building archetype has different energy demand profiles, and thus shows different potential.
- For each archetype, we model an existing building (consistent with 1980 construction standards) and a new building (consistent with 2018 construction standards). The existing buildings offer us a view on the potential in retrofits, while we assess separately the paradigm for new constructions. It is worth noting that energy intensity is generally higher in existing settings, the potential of onsite solar lower, and capex costs higher, as they include additional installation and overhead costs.
- Finally, we project these 12 building types in 19 regions, including North America, Asia, and Europe[18], to get a better understanding of local particularities. Weather conditions are different and the same buildings perform differently. Costs of various sources of energy, grid carbon intensities, and capex levels also vary across regions.

We performed the analysis over these 228 use cases, following two scenarios (i.e. 456 simulations in total):

- Current: a scenario which takes stock of the current costs of hardware and installation, as well as current grid carbon intensity.
- 2030: a scenario which evaluates how these performances vary over time, considering 2030 cost improvements and expected grid-retailed electricity decarbonization[19].

Figure 5 – Buildings of the Future model

Step 1 – 12 building configurations

6 building archetypes energy profiles
Residential individual – single family home (150m², 2 floors).

Office (45,000m², 10 floors).

Hospital (20,000m², 6 floors).

Hotel (4,000sqm, 4 floors).

Retail (2,000sqm, 1 floor).

Education (20,000sqm, 3 floors).

With 2 profiles
Variations in energy intensity with different construction dates.

1980 building (e.g. retrofit use cases).

2018 building (e.g. new construction use cases).

Step 2 – in 19 regions

In 19 regions, with different load profiles (weather patterns).

North America (5 regions).

Asia (7 regions).

Europe (7 regions).

6 * 2 * 19 = 228 use cases

Step 3 – 3 combined technology changes

For each use case, we compare a standard building performance with one integrating.

Heat electrification: Heat Pumps are considered and compared to their fossil counterpart.

Active energy efficiency: the integration of advanced digital solutions for energy efficiency.

Distributed generation (and storage): the maximized potential of distributed generation available in each use case is harvested.

For each use case, we measure CO_2 abatement and energy spend evolution.

Capex for each solution is also evaluated and the additional cost serves as a baseline for economic performance analysis.

For retrofits: performance is measured in **years of payback**.

For new acquisitions: extra investment is measured as a **percentage of total costs of acquisition** (different baselines are used).

Step 4 – 2 scenarios

For each use case, 2 scenarios are evaluated.

Current: CO_2, energy spend and capex are evaluated in the current situation.

2030: the evolution of the current performance is evaluated to 2030, projecting savings on hardware and installation costs, as well as grid electricity carbon intensity.

228 * 2 = 456 simulations

(17) Residential in the below report stands for a Single-Family Home.
(18) See Annex for all details on assumptions and data used.
(19) For 2030, we take specific assumptions regarding the evolution of grid electricity's carbon intensity, as well as hardware and installation costs for the solutions deployed, based on a number of existing forecasts. See Annex for more details.

3

Key finding #1: The decarbonization of buildings comes at a net saving for building dwellers

In this chapter, we look at the impact of deploying the Buildings of the Future approach in operational emissions and energy spend. In other words, what is the impact of these solutions on emissions reduction and costs of energy?

The potential for CO_2 abatement and energy savings is highest in the retail and residential segments

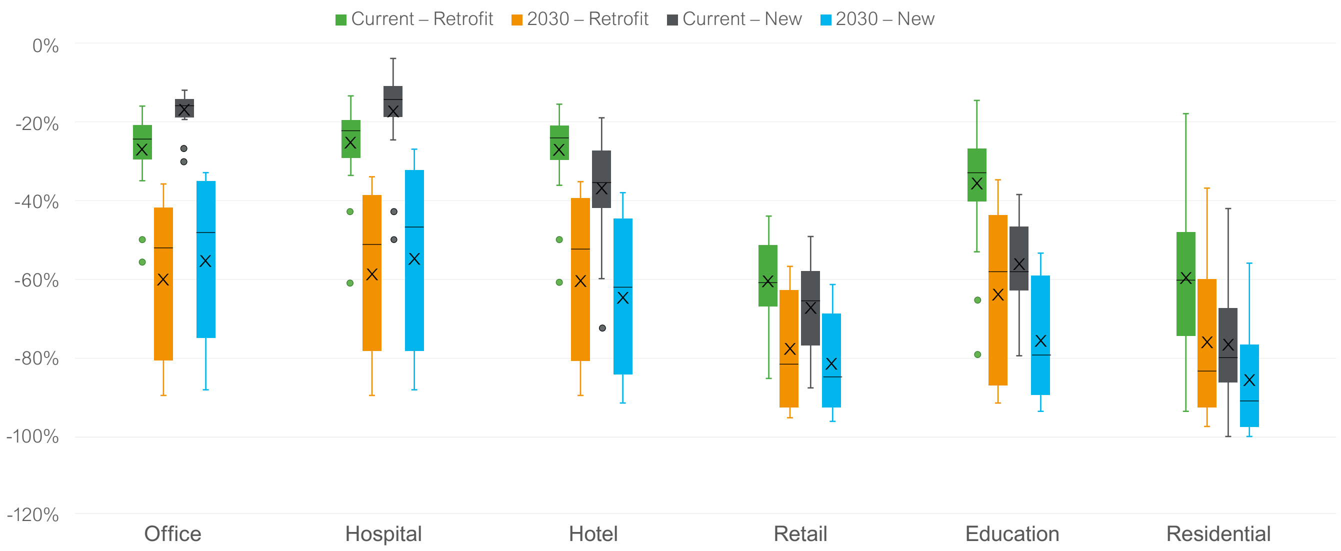
The 456 simulations are first consolidated by segments. Figures 6 and 7 provide a perspective of CO_2 abatement and energy spend savings by segment of activity[20]. For each, four data sets are plotted:

- Existing settings (e.g., retrofits) and new construction cases are both represented.
- Two scenarios are plotted for each: the current situation, and a projection to 2030 (lower grid carbon intensity).

In terms of CO_2 abatement potential:

- In the current situation for existing buildings, service buildings (outside of retail) show lower carbon abatement potential, at around 20-30% on average, compared to retail and residential at around 60%.
- The potential for abatement in new constructions (in current situation) is higher in most segments, except in office and hospital buildings. This is related to the differentiated contribution of various solutions to carbon abatement:
  - New constructions have more efficient envelopes, reducing the impact of active energy efficiency and electrification, compared to retrofits.
  - New constructions have, however, a greater penetration of onsite solar, increasing its impact significantly[21] (but not in highly vertical buildings, where the potential remains low compared to overall energy demand).
- By 2030, the performance increases strongly. This is essentially related to the lower carbon intensity of grid-retailed electricity, which improves the carbon abatement potential of heat electrification. The carbon abatement potential then ranges on average at around 60-90% across the entire stock.

Figure 6 – CO_2 abatement per segment



(20) These graphs are not a statistical representation of the results, but the plot of all simulations realized. Data points for specific regions are either lower or higher, as visible on the graph. See Annex for full details per region.
(21) New constructions also benefit from improvements in design, from competency development as well as a growing use of digital tools (e.g. BIM) across the lifecycle, which positively impact equipment and systems sizing.

In terms of energy spend:

- Similar patterns emerge as those of carbon abatement potential, with annual savings ranging around 15-50% (in current situation) for service buildings (outside retail), and a greater potential at around 50-70% for retail and residential.
- By 2030, there is no improvement as we do not model in our scenario any change in retail energy costs[22].

Figure 7 – Energy spend savings per segment

The regional outlook strongly differs depending on the grid carbon intensity

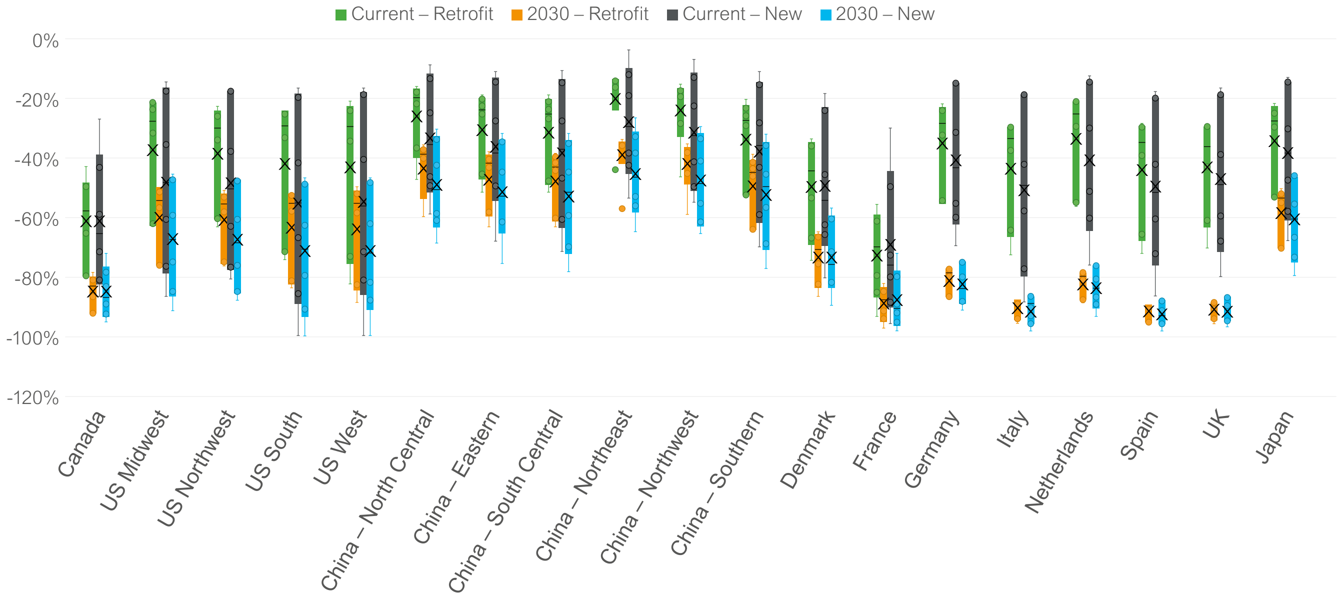
Figures 8 and 9 provide a perspective of CO_2 abatement and energy spend savings by region[23].

In terms of CO_2 abatement:

- In the current situation, the benefits strongly depend on the "starting point" in terms of grid-retailed electricity. The potential is higher in regions with already low grid-retailed carbon intensities (justifying the electrification of heating, blue and grey bars), for instance Canada and France (above 60%). China presents a lower potential, due to the high current carbon intensity of grid-electricity, in the range of 20-40%.
- By 2030, the decarbonization of the power system dramatically improves the potential. This applies to every region, and is particularly visible in some European countries with stringent 2030 targets (e.g. Germany, Italy, the Netherlands, the United Kingdom, etc.).

(22) See Annex for more details on the assumptions taken for each scenario.
(23) The figures below are simple plots of the 456 simulations realized. They thus represent a range of possible outcomes across different use cases, not a statistical average.

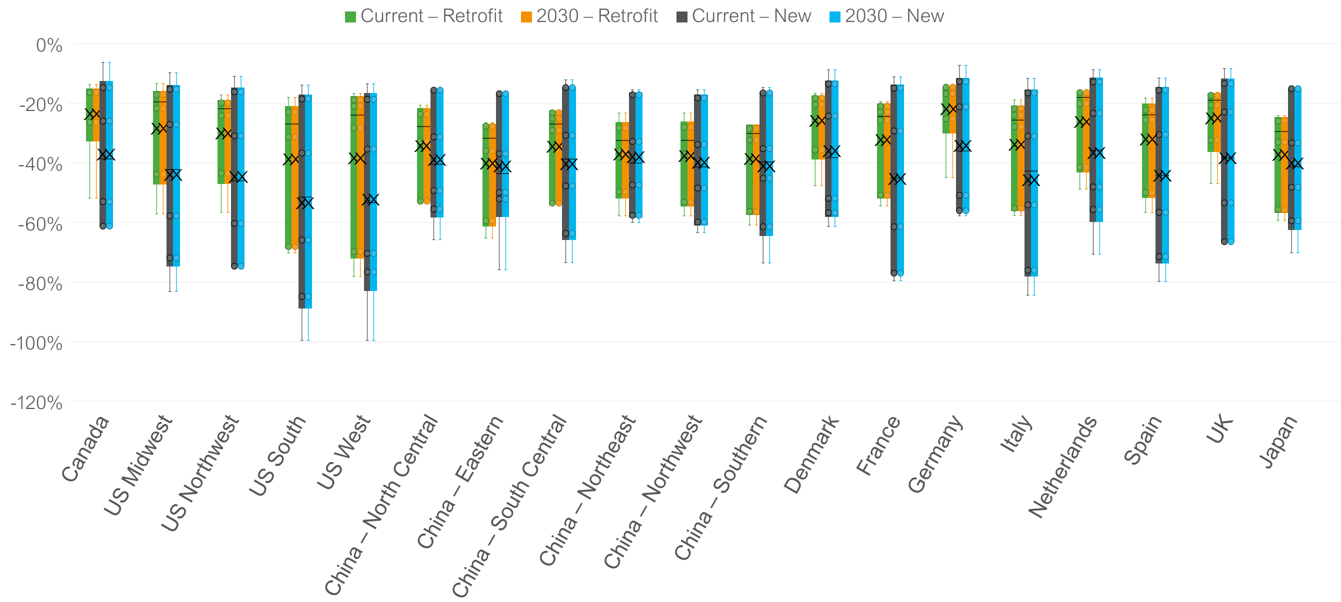
Figure 8 – CO_2 abatement per region



In terms of energy spend:

- Savings are representative of the segment gaps identified above, with a greater range for new constructions than for existing buildings (all building archetypes are plotted here, per region).
- Savings tend to be lower in regions with either a greater demand for heating or higher spread between natural gas and electricity prices, or both. The switch to more expensive electricity (relative to natural gas) for a large part of energy demand tends to lower the benefits. This is particularly relevant in Canada, Germany, and the United Kingdom.

Figure 9 – Energy spend savings per region

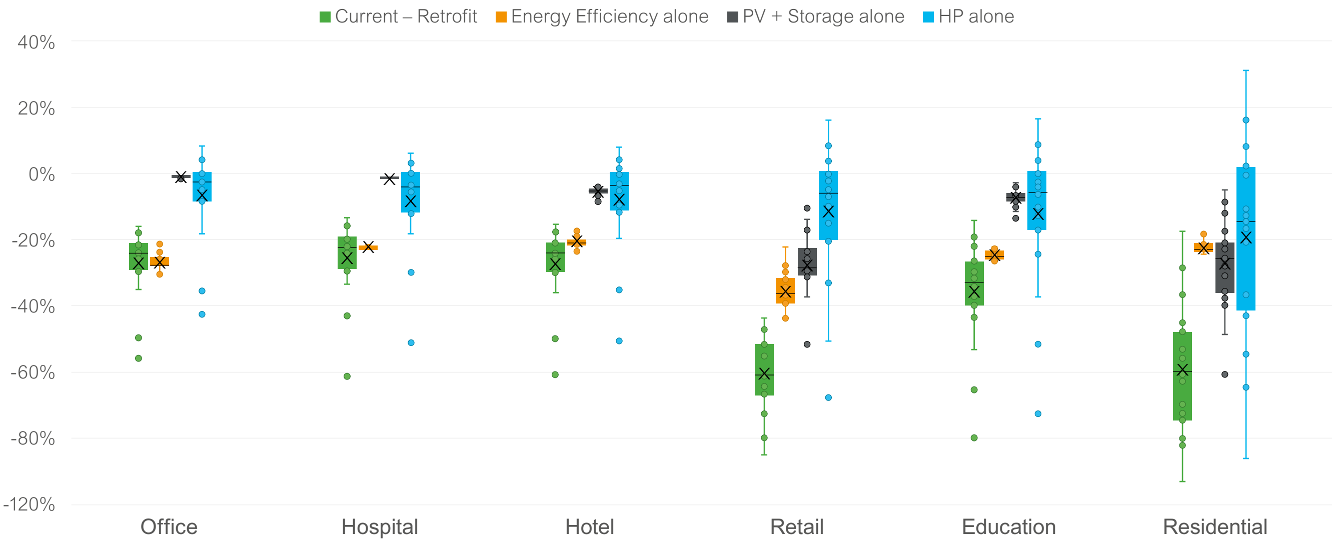


Different building archetypes show different opportunities for rapid decarbonization, at cost

The above analysis has focused on consolidated savings from the implementation of the complete set of solutions described (active energy efficiency, heat electrification, and onsite solar). Yet, each of them has a different contribution depending on the building archetype. We ran specific simulations accounting for the implementation of each one individually to assess their relative importance per building archetype. For the sake of simplicity, we only plot here results for existing buildings[24] (Figures 10 and 11).

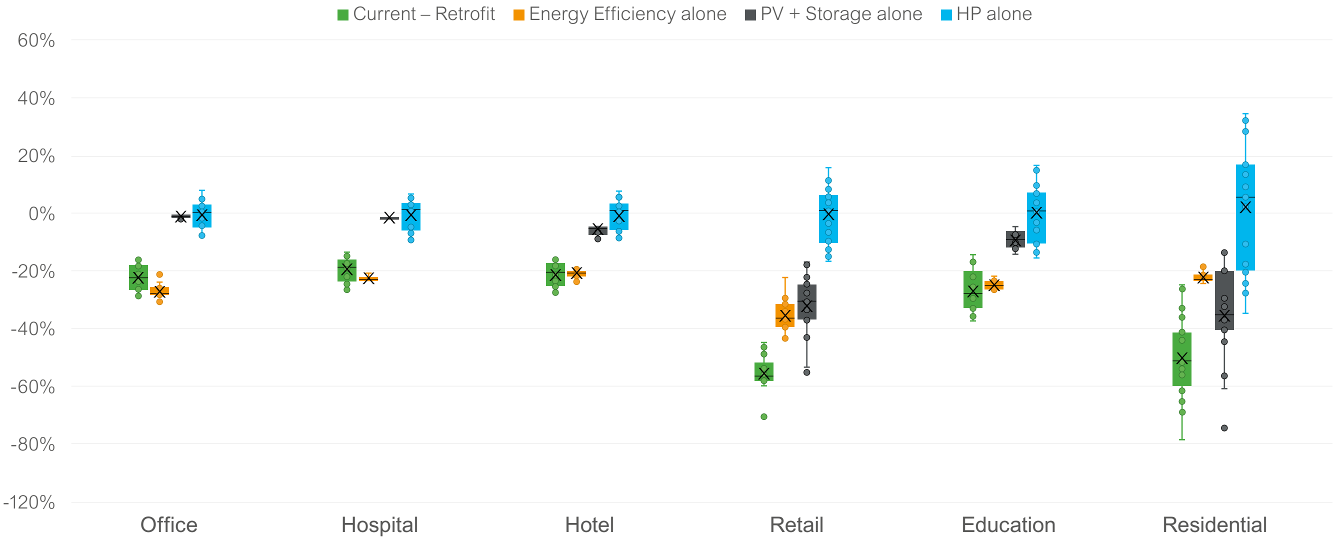
- For service buildings (outside of retail), the main contribution to CO_2 abatement and energy spend comes from the implementation of active energy efficiency.
- For retail and residential settings, onsite solar also plays a very significant role (given the overall generation potential in those buildings, i.e. larger suitable rooftop surface available, relative to total floor area).
- The electrification of heat has also a significant impact, but it depends on:
  - The carbon intensity of the grid (carbon abatement potential increases over time as the power system decarbonizes).
  - The actual cost of grid-retailed electricity (relative to natural gas). In certain use cases, the electrification of heat indeed comes at a net additional cost, clearly making the case for the combined adoption of active energy efficiency and onsite solar (with digital) to enable competitive decarbonization of heat in buildings[25].

Figure 10 – CO_2 abatement per segment, and per key contribution, retrofits



(24) Results for new constructions are available in the Annex. In general, the contribution from active energy efficiency is slightly lower in such buildings (due to more efficient envelopes) while that of onsite solar increases (more suitable roof surface available).
(25) It is important to note that:
For many regions, the electrification of heat comes in fact as a net saving, though not everywhere (notably in regions with distorted tax regimes).
Our estimation of costs of heating electrification do not include here fixed charges (which have a material impact on the natural gas route), hence our results are fairly conservative.
For more, see Schneider Electric (b) (2021), Building heat decarbonization.

Figure 11 – Energy spend savings per segment, and per key contribution, retrofits



Key takeaways

Looking across the full score of simulations realized, the six building archetypes modelled in 19 regions and for two use cases (existing buildings and new constructions), we conclude that **the potential for carbon abatement and energy spend optimization ranges around 20-80% today. By 2030, the carbon abatement potential will naturally further increase to around 60-90% across the entire stock**, from the natural decarbonization of the power system. Over time, the further decarbonization of the power system will ensure zero operational emissions.

4

Key finding #2: A strong economic case exists, notably in new acquisitions and service buildings

Buildings of the Future offer the opportunity to decarbonize the stock by around 20-80% today (and 60-90% by 2030) while providing energy spend savings of a similar magnitude, a major positive equation for building dwellers.

There is a way to break the decarbonization deadlock by leveraging modern (but existing) technologies. The key question that remains, however, is that of its economic performance, or in other words the upfront cost of implementing such solutions across the entire stock. Two cases here need to be reviewed separately:

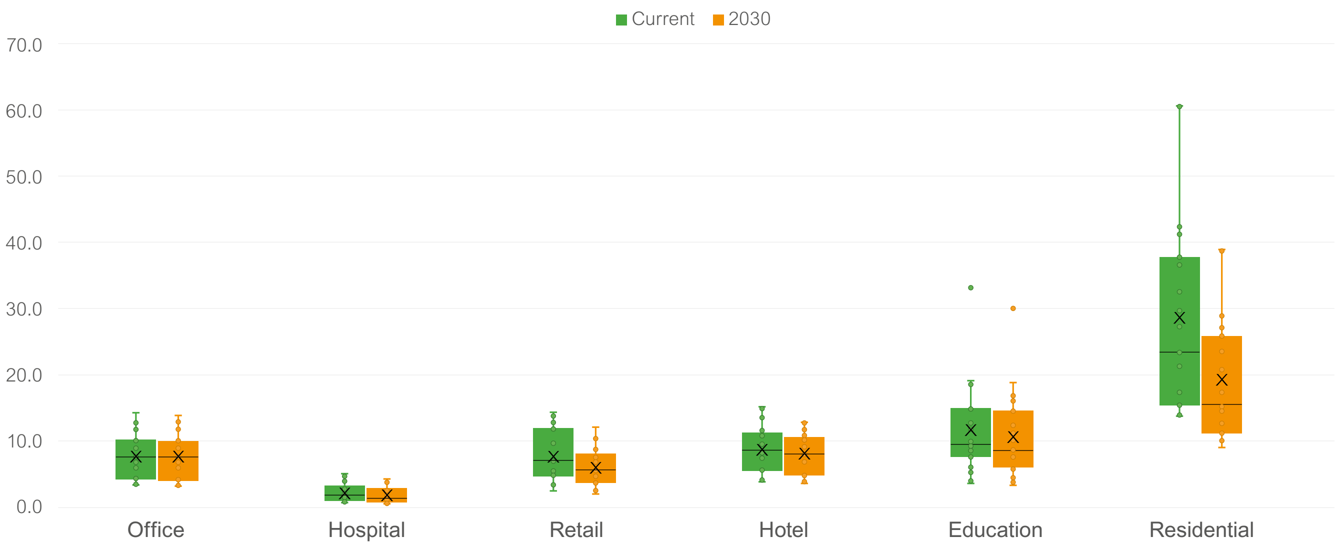
- Retrofitting the existing stock toward Buildings of the Future: the key parameter to review is the payback of deploying such solutions, measured in years of annual savings[26].
- Building *for* the future, right from the start: paybacks are of less interest here, and we measure instead the impact of the additional upfront capex on total costs of acquisition[27].

Retrofits: a strong payback equation in service buildings

Paybacks are defined by the actual upfront additional cost (from the deployment of active energy efficiency and digital controls, onsite solar and storage, and the differential cost of switching to a heat pump) divided by annual savings, and is expressed in years.

- Service buildings show paybacks typically at or below 10 years on average. In other words, there is already a very strong economic rationale to deploying such approach.
- Residential buildings (individual households, single family) show much higher paybacks. This is likely where the bulk of the support is required (outside of luxury segments which will likely rely on different drivers of adoption). The full implementation of the Buildings of the Future profile generates for a typical 150m^2 home around USD 1,000-2,500 of annual savings, but comes at an extra upfront investment of around USD 30-40k.
- By 2030, the reduction in capex improves the overall equation. This is particularly visible in the residential segment. This is, however, not enough (on average) to reach a self-sustaining equation (for the same home, the initial investment reduces to around USD 20-30k).

Figure 12 – Paybacks for retrofits, per segment

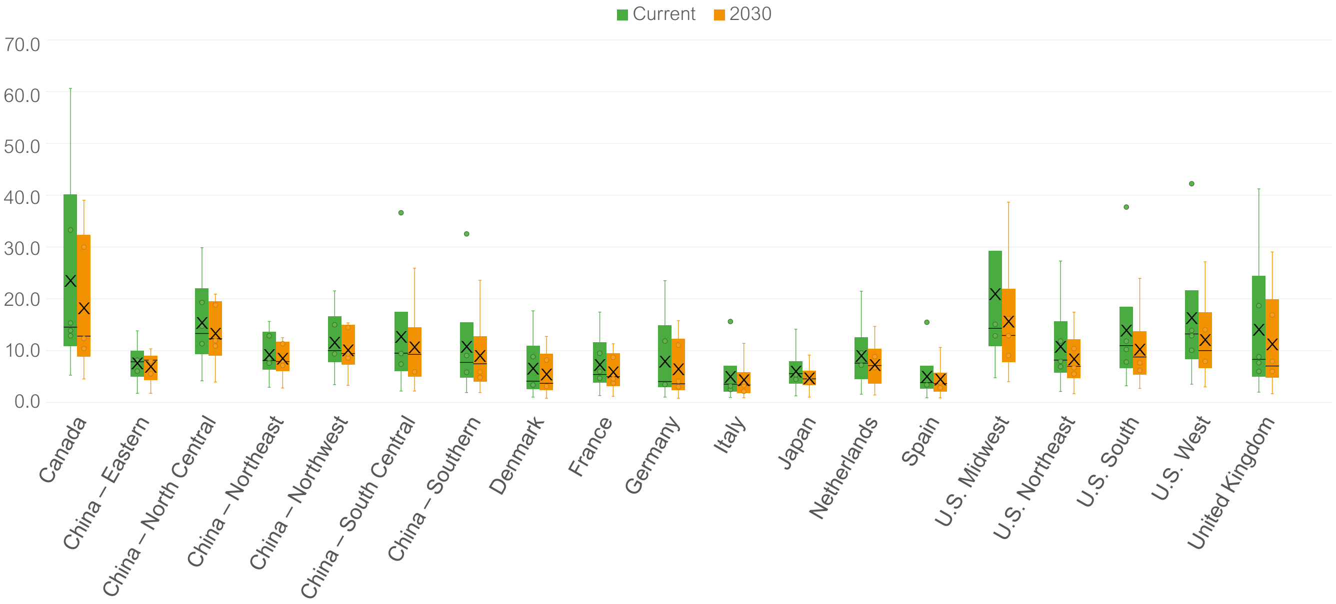


A view by region provides further interesting findings:

- Paybacks tend to be much lower in Europe in general. This is due to stronger annual savings overall, notably as costs of energy are typically much higher in this region of the world, compared to North America or China.

(26) See Annex for more details. It is important to note that in this study, there is no assumption of the possible implementation of carbon prices, which could further incentivize the decarbonization of buildings from an economic standpoint.
(27) We have used three scenarios for total costs of acquisition, at USD 2,000/m^2, USD 3,000/m^2, and USD 5,000/m^2. These costs integrate those of construction and those of land acquisition. We have evaluated that the former is fairly representative of small cities and rural areas, while the latter is more consistent with typical costs in metropolitan areas (likely even larger in city centers), notably for residential. The higher the cost of acquisition, the lower the impact of the implementation of Buildings of the Future. For the remainder of this chapter, we plot only data for our USD 3,000/m^2 use case, what we consider typical of the average stock. See annex for more details.

Figure 13 – Paybacks for retrofits, per region



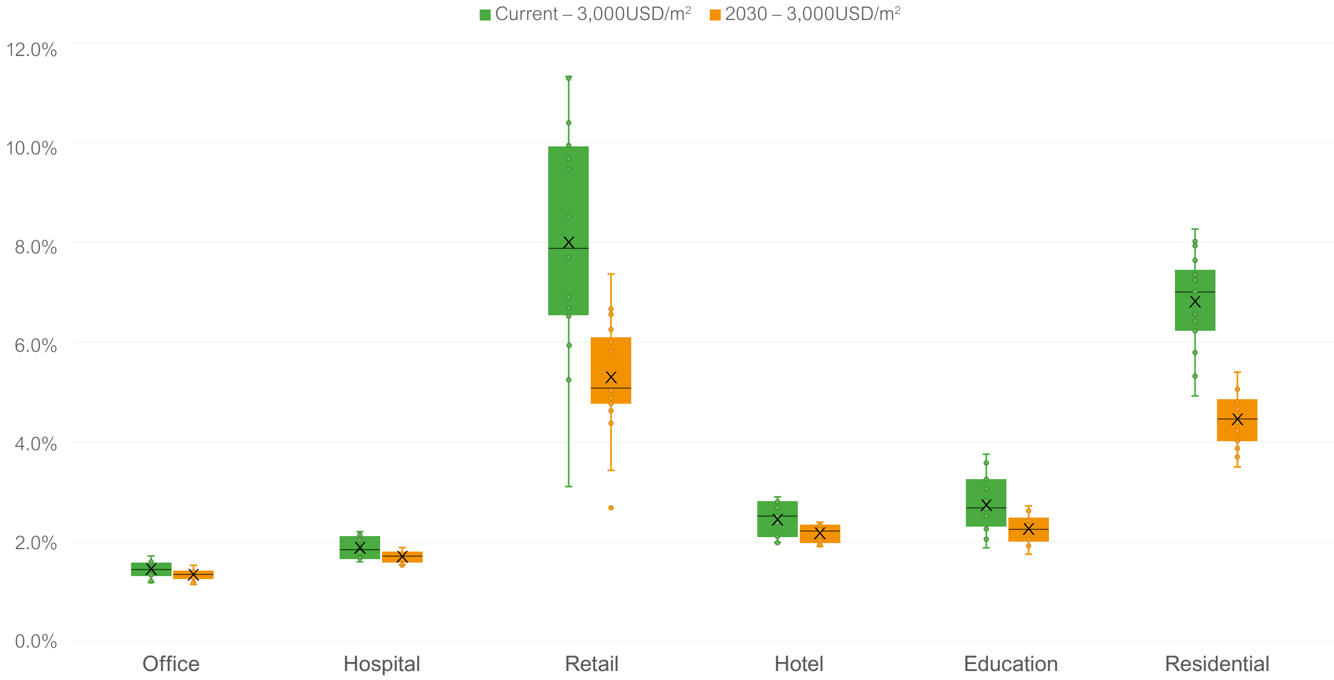
New acquisitions: low impact on total costs

For new constructions, we retrieve the total impact of additional upfront investment on the total cost of acquisition, and plot here only the data for the scenario with an average cost of acquisition of USD 3,000/m^2[(28)].

- For service buildings (outside retail), the additional upfront cost typically ranges well below 4%, a figure which falls toward 2-3% by 2030. The impact of building right from the start is thus minor.
- For retail and residential, the additional upfront cost is also very dependent on the costs of onsite solar and storage, and the impact is higher. It ranges below 10% today, but equally falls to 4-6% by 2030.

(28) See Annex for the detailed sensitivity analysis on the cost of acquisition.

Figure 14 – Impact on total cost of new acquisition, per segment

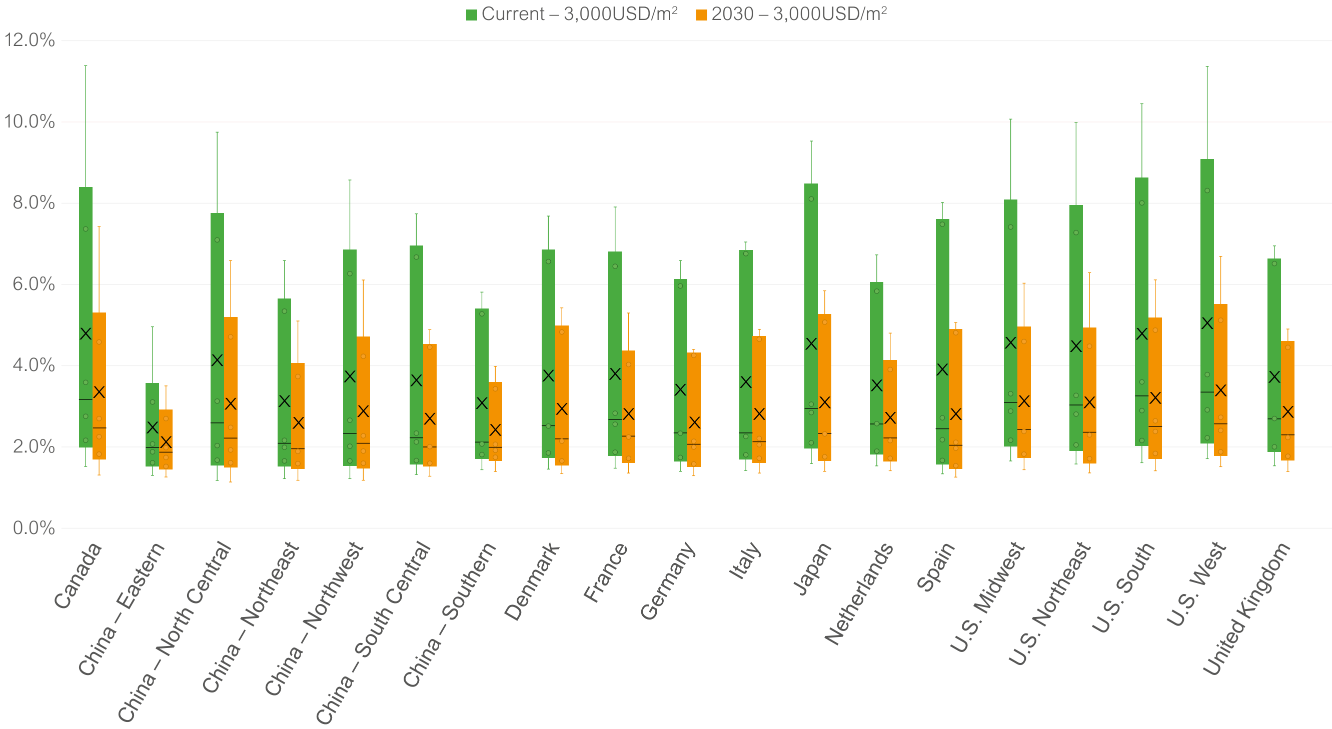


The regional outlook is relatively consistent across the board. This is essentially due to the assumptions taken[29]. This being said, the key conclusion is that the impact on new constructions falls at or below 4-6% across all regions and building archetypes by 2030, a very compelling economic case.

Finally, higher costs of acquisition (more expensive land, e.g. metropolitan areas) lead to lower levels, while lower costs of acquisition (e.g. rural areas) lead to higher impact. In our simulation, we get costs up to 10-15% for residential and retail in our worst-case scenario (more limited impact on service buildings), which fall below 10% by 2030. For our best-case scenario, incremental cost is below 6-7% today, and typically below 4% by 2030.

(29) The total cost of acquisition of a new building is indeed much higher than the actual extra upfront costs of building it right, which is reflected in the relatively low percentages estimated. As a consequence, differences across regions are less visible.

Figure 15 – Impact on total cost of new acquisition, per region



Measuring the impact on total costs of acquisitions does not apply to new constructions alone, however. When retrofits are realized at time of transfer of ownership (selling/buying a building or a home), the metric of interest is no more the payback, and the cost of acquisition becomes again relevant.

When computing the impact of a retrofit on an existing building in terms of impact on total cost of acquisition, we find that, in our central case:

- the impact on service buildings is similar to that of new constructions, falling toward 2-3% by 2030.
- the impact on residential buildings (retrofitted) ranges below 10% today, cruising toward 6% (or below) by 2030.

While retrofitting residential settings show long paybacks, a key conclusion is thus that when this retrofit is done at time of transfer of ownership, the financial feasibility is thus much greater[30].

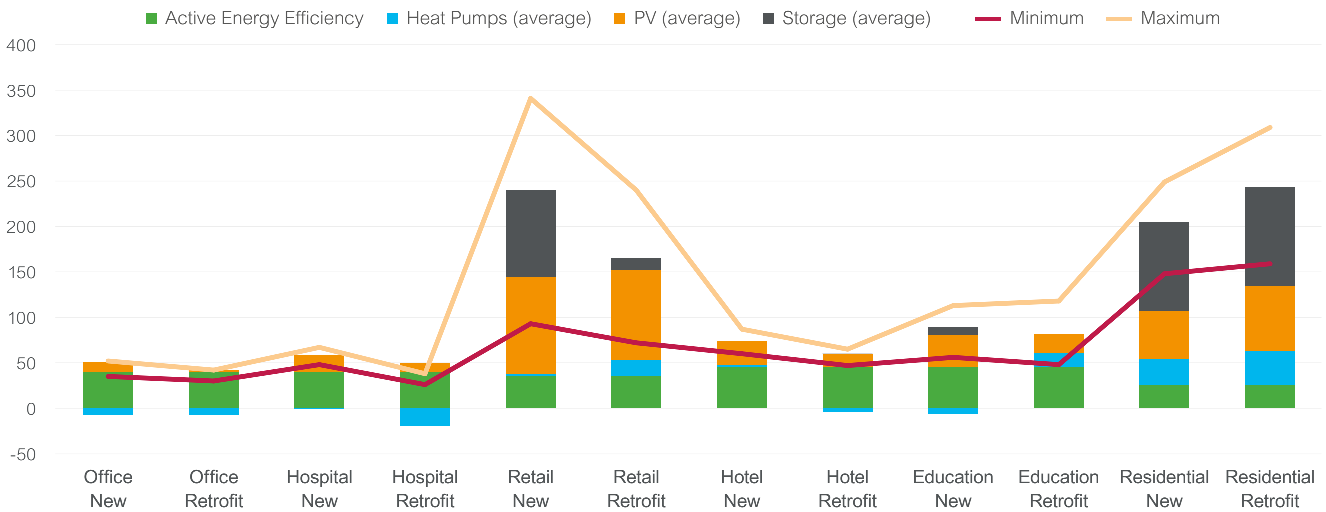
(30) See Annex for more details.

What drives costs?

The additional capex required to implement Buildings of the Future in both existing buildings and new constructions can further be broken down to illustrate key drivers of costs, and opportunities for further optimization. Figure 16 provides a perspective of these costs across regions[31].

- The additional cost of heating electrification is generally not material, offering interesting returns (although in some regions, the cost of heat electrification may be an issue, particularly in residential). The key driver of costs thus often comes from onsite solar and storage.
- In buildings with limited potential for onsite solar, the bulk of the increase in costs thus comes from active energy efficiency. In buildings with greater potential for onsite solar (relative to the floor surface area), the increase is mainly related to such provisions.
- The optimization of the capex equation (paybacks, share of total cost of acquisition) will thus come from optimization of the hardware and installation costs of onsite solar and storage.
- By 2030, most of these costs decline significantly (heat pumps, solar panels, storage systems)[32].

Figure 16 – Additional upfront costs of Buildings of the Future



Box 1 – The future of active energy efficiency with new digital technologies

The evaluation of upfront costs used in this report are based on existing benchmarks of current technologies already widely available. Yet, technology continues to improve, and this offers increased opportunities for more affordable solutions. Technology development spans across a multitude of categories:

- Digital design tools that enable automated and pre-standardized engineering for simpler applications.
- Radical reduction of the number of engineering hours for installation and startup, notably through the recourse to wireless sensors, as well as pre-configured systems.
- Overall optimization of the hardware installed through better integration of Internet of Things.

Recent developments suggest savings in upfront costs that could range between 70-90%, considerably improving the economics, while also simplifying deployment at scale[33].

(31) Full details per region are available in the Annex. For the sake of simplicity, we project here average costs (across 19 regions) for each component, as well as the minimum and maximum total costs of the solution (as they vary across regions).
(32) See Annex for more details.
(33) Schneider Electric research, based on existing field experiments.

Key takeaways

To conclude, **retrofitting existing** buildings to Buildings of the Future makes obvious economic sense in service buildings, with **paybacks at or below 10 years, but remains a key hurdle in residential,** which consequently requires specific incentives and further progress in delivery. The key issue there is the upfront cost of onsite solar and storage (see Box 2).

The situation is much **more promising in new constructions,** as the actual additional upfront cost translates overall into below **10% increase of the total cost of acquisition** (cruising well **around or below 4-6% by 2030)**. Even in areas where the cost of acquisition is lower, the impact on residential should remain well below 10% by 2030.

Finally, retrofits can also happen at time of ownership transfer. In such cases, a better indicator of return on investment is that of the impact of retrofit on total costs of acquisition. In such case, the impact remains below 10% today, cruising toward 6% by 2030, a similar paradigm as for new constructions, and an indication of workable business models for the renovation of the existing stock, notably in residential.

In addition, multiple reports and analyses have demonstrated that upgrading (or building anew) to greener standards generates significant benefits for asset owners: around 7-8% increases in asset value, with noticeable increases in rents, which significantly improve the investor's business case[34].

Box 2 – Retrofits in the residential market, a deeper look

The outcome of this analysis shows that retrofitting residential households, while providing significant annual savings in both carbon emissions and energy spend, comes at an upfront cost which may make the economic case unattractive in some instances.

This is in part related to our approach to modelling Buildings of the Future. In this study, we maximize the local PV generated (as a key enabler to accelerated decarbonization of the power system), and we model building archetypes which maximize self-consumption (in order to yield the greatest impact on annual energy bills optimization). This, however, comes at the expense of upfront costs as typically greater-than-needed storage systems need to be deployed. There are several alternatives that could be considered to make the case more compelling for household owners:

- **Deploy less onsite solar.** As the potential of onsite solar on residential rooftops far exceeds peak demand during daytime, an alternative could be to deploy less distribution generation (hence less storage) and improve the upfront cost accordingly. The drawback would obviously be greater reliance on grid-retailed electricity, hence a negative impact on CO_2 savings and energy spend. Our sensitivity analysis shows that benefits in terms of paybacks are not substantial across most regions, however, thereby discarding this option[35].
- **Use different forms of storage.** The analysis in this report is based on battery (e.g. Lithium-ion) stationary storage solutions. While cost savings to 2030 are substantial, this remains an expensive solution for energy storage, notably when considering that more than half of energy demand in a household comes from heating and cooling. Alternatives such as thermal storage, and potentially new storage technologies could significantly change the game[36].
- **Mutualize storage at district or grid level.** A key component of the upfront cost is energy storage. If no storage is distributed at household level, then the upfront cost is considerably lower. One option growingly considered could be the use of electric vehicles as a stationary storage solution, but drawbacks exist with regards to storage use profiles[37]. Storage could also be mutualized at either the district or grid level. In such case, excess generation would then be flowing to the grid, and would call for specific monetization schemes[38]. Assuming no costs for storage in the capex equation, our modelling suggests paybacks would then reach much lower levels, typically below 10 years in most regions of China and Europe today, and cruising toward 10 years by 2030 in most regions of North America.

(34) World Green Building Council (2016), About Green Building. Nossent P. (2019), *Un bâtiment durable certifié rapporte plus, à plus de monde et plus longtemps.*
(35) This conclusion could, however, be subject to debate in selected regions. See Annex for more details on the sensitivity analysis. See as well Keiner et al. (2019), Cost optimal self-consumption of PV prosumers with stationary batteries, heat pumps, thermal energy storage and electric vehicles across the world up to 2050.
(36) This will be the object of a following analysis in 2022.
(37) See notably Schneider Electric (c) (2021), Electric Vehicle Smart Charging in Buildings. Electric Vehicles can indeed serve as a backup storage system, but their availability depends on patterns of use. If the vehicle is not plugged at time of onsite solar generation (e.g. a typical weekday with the vehicle parked at the office), it cannot be used for charging (at the household's location).
(38) These already exist. See BloombergNEF (2021), Realizing the potential of customer-sited solar. The analysis of their impact on energy spend savings is outside of the scope of this study. What can be said, however, is that similar CO_2 savings could be realized (as zero-carbon electricity is produced anyhow), while energy spend savings would depend on the scheme in place. Would onsite solar generation be resold to the grid at the cost of grid-retailed electricity (net-metering), then the savings in energy spend would be similar to those presented in this report. As typically reselling schemes use lower price levels, savings would be lower, but again paybacks would be improved.

5 A practical pathway to net-zero buildings

Making sense of it all

Figure 1 reproduces key findings from this study[39]

- Building for the Future brings significant opportunity for decarbonization, notably in the residential sector today, although the potential also increases by 2030 for service buildings (as grid electricity gets further decarbonized). By 2030, emissions could be reduced by three to five on average across the stock effectively built and retrofitted.
- At the same time, this approach – and this is what makes it unique – offers savings on energy spend that range between 15-50% for service buildings and up to 70% (or more) for residential households.
- The additional investment in new acquisitions is not a critical roadblock and will continue to improve over time.
- While paybacks make it a no-brainer in service buildings, a key hurdle will remain the retrofit of existing residential settings, when not realized at time of transfer of ownership[40].

Figure 1 – Making sense of it all

	Building of the Future Potential		
	CO_2 emissions	Energy spend	Return on investment
	Service buildings (excluding retail)		
Retrofit	Typical CO_2 savings around **-20-30%** today Emissions divided by 2-3 (**-60%**) by 2030	Energy spend typically drops by around **-20-30%**	Paybacks at or below **10** years At ownership transfer, impact on cost of acquisition (TCO) below **4%**
New build	Typical CO_2 savings around **-20-50%** today Emissions divided by 3 (**-60-70%**) by 2030	Energy spend savings typically ranging between **-15-50%**	Impact on cost of acquisition (TCO) below **4%** today, falling at around **2-3%** by 2030
	Residential buildings (single family households)		
Retrofit	Emissions divided by 2-3 (**-60%**) today and by 5 (**-80%**) by 2030	Energy spend divided by 2 in average (around **-50%** savings)	Paybacks above **20** years today, cruising toward **20** years or less by 2030 At ownership transfer, impact on total cost of acquisition (TCO) below **10%** today, falling at around **6%** by 2030
New build	Emissions divided by 5 (**-80%**) today, and by 10 (**-90%**) by 2030	Energy spend divided by 3 in average (around **-70%** savings)	Impact on cost of acquisition (TCO) at or below **8%**, falling below **5-6%** by 2030

What should be prioritized

The combination of active energy efficiency, heating electrification, and onsite solar, enabled by digital controls, thus increases the potential of decarbonization of the building stock, while reducing energy spend from building dwellers.

- Heating electrification is more economically compelling (and less carbon intensive) when supplied with onsite solar, while it drives more demand for self-consumption of onsite solar, maximizing its potential.
- Active energy efficiency enables a more rationale and efficient use of heating while it provides the key resource to properly balance onsite solar and optimize its use.
- At the same time, the actual electrification of heating and increased provisions from onsite solar offer significant flexibility in load management at the building level, what improves the economic equation and offers additional flexibility support to the supply infrastructure.

We thus argue this positive and self-reinforcing combination provides a new avenue for a successful and rapid decarbonization of the building stock, effectively breaking the decarbonization deadlock. In other words, **the only way to effectively solve modern problems is to embrace modern solutions and modern approaches.**

(39) All detailed tables are available in the Annex. Figures effectively differ across regions and building archetypes. We provide here a consolidated and more readable overview from the most recurring levels observed across different use cases.
(40) All these results must be understood prior to any subsidy/incentive at capex stage, or any carbon price on energy tariffs.

However, to make this transition successful, barriers to adoption must be removed.

- We find that the economic equation is a **no-brainer across the service building stock** (outside retail), both for retrofits and new builds. Mandates to adoption appear here as an obvious route going forward.
- The economic equation is, however, more complex in residential.
  - The **impact on new constructions remains limited overall,** particularly on higher-class assets, and it is also expected to further improve by 2030. Supporting policies will play a role to facilitate the transition of lower-class assets until the economics of such solutions reach compelling levels with scale.
  - **Retrofitting the existing stock of residential households is, however, the key issue going forward.** While, again, it may prove less of an issue for higher-class assets (especially as such provisions will ultimately support asset prices on the mid-term), the key issue will remain that of lower-class assets, which will require specific support and incentives, as well as continuous innovation, notably around onsite solar and storage implementation. This is also a critical matter of energy justice, as benefits are not naturally evenly distributed, and as lower-income categories of the population are also the ones who suffer the most from high energy bills.
- Split incentives (e.g. building owner vs building dweller) are probably one of the largest barriers to adoption. Regulations and mandates can help alleviate some of these issues.
- The availability of competencies and of the right value chain will also play a fundamental role in bringing costs down to better levels and should therefore be a critical point of focus. In that regard, mandates on new constructions (standards) and targeted and phased retrofits[41] are key enablers to dramatically accelerate the ramp up of the value chain.
- Mandating renovations at time of transfer of ownership will also provide a route to efficiently foster the renovation of the stock, with an impact on total costs of acquisition which remains similar to those of new constructions.

To conclude, a key takeaway is that while there is a clear route toward successful and overall positive decarbonization of the building stock, this transition, likely growing naturally as the economics become more obvious, could also leave aside lower-income categories of the population, who ultimately suffer the most from high energy bills. 50-100 million people in Europe would face what the European Union calls energy poverty. In the United States, out of the 50 million low-income households, energy burden can be, in some cases, as high as 30% of global budget. Moreover, these categories of population are often renting their household (around 59% of low-income households in the United States), which constitutes a key barrier to adoption[42] (split incentives). While governments have a key role to play into fostering adoption across the building stock (which ultimately makes great economic sense for investors and dwellers alike), a targeted focus on low-income households will remain critical.

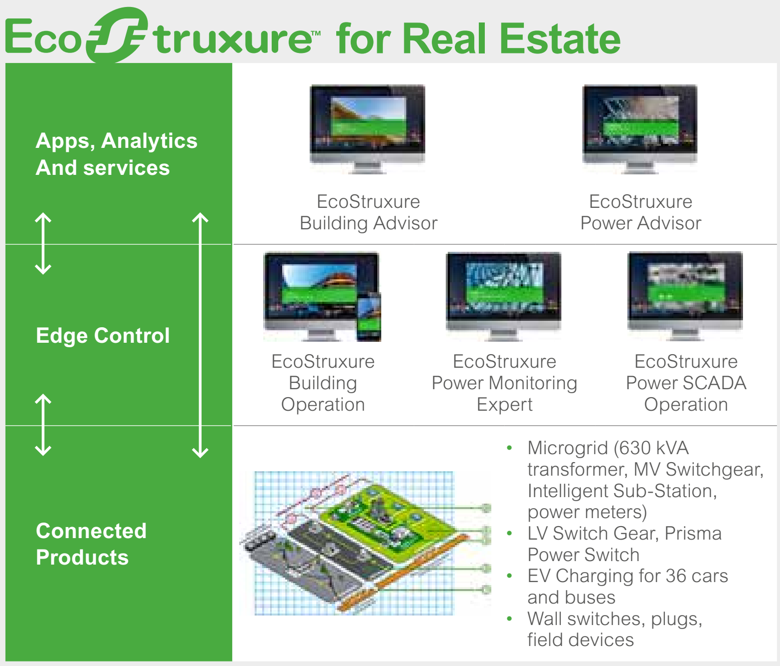
An example, EUREF-Campus, Berlin

5.5-hectare smart district development for companies working in the fields of energy, sustainability and mobility.

"On the EUREF-Campus, the Climate targets 2050 the Federal Government has already achieved – this would be without the intelligent solutions from Schneider Electric impossible! Wherever we Engineers and architects at the end are, Schneider Electric sets yet once and pressed the lemon so right out, thereby saving even more than

30% of energy."

Reinhard Müller,
CEO of EUREF AG



(41) See notably a best practice in the Netherlands: Energiesprong (2022). This Dutch construction innovation shows it's possible to quickly retrofit every building. The initiative targets to be "subsidy-free" by as early as 2025.
(42) European Commission (2022), Energy Poverty. US Department of Energy (2022), Low-income community energy solutions.

6

Annex

Buildings of the Future model

The Buildings of the Future model developed by Schneider Electric is built on two independent modules:

- The Operational module, which evaluates the carbon abatement and energy spend performance of upgraded buildings.
- The Capex module, which evaluates the difference in upfront investments (Capex).

Operational module

The Buildings of the Future Operational module works as depicted in Figure 17. We use this model for six different building archetypes, with two different years of construction (1980 and 2018), in 19 regions of the world. Moreover, we test the sensitivity of our results by running two scenarios: one in current context, and one assuming 2030 values, leading to a total of 456 simulations in this report.

Figure 17 – Operational module

Data	Today	Future	DELTA	
Average Energy Intensity – before Digital Efficiency	201.6	148.7		Initial data retrieved from databases, varies across building archetypes, date of construction (performance of the envelope) and region (weather conditions). Electrification through heat pumps provides savings: the Coefficient of Performance varies across regions (weather conditions).
– Heating (space + water)	91	38		
– Cooling	12	12		
– Lighting, ventilation, water, appliances (cooking…)	99	99		
Average energy intensity with Digital Efficiency	201.6	127.5		Active energy efficiency (advanced controls, category A as per EU.bac) provide savings over energy demand.
Total energy demand (kWh/Y)	806,209	509,840		
– Total gas demand (kWh/Y)	362,166	0		
– Total electricity demand (kWh/Y)	444,044	509,840		
Distributed generation	0	137,900		PV production (in kWh/m^2/y) varies across regions (irradiation levels). The surface of solar panels is dependent on the roof size (floor-to-roof ratio) and the share of roof, suitable for PV (no equipment, no shaded area). The latter varies across building archetypes and designs (we assume new constructions accommodate more space for PV).
– Solar panels surface (m^2)	0	700		
– PV production (kWh/m^2/y)	0	197		
Carbon intensities				
– Natural gas kgCO_2/kWh	0.2	0.2		Carbon intensities of electricity vary across regions. We assume carbon intensity of PV at zero, and those of natural gas equivalent across regions.
– Grid electricity gCO_2/kWh	0.134	0.134		
– Distributed generation gCO_2/kWh	0	0		
Cost of natural gas USD/kWh	0.03	0.03		Cost of energy varies across regions.
Cost of grid electricity USD/kWh	0.11	0.11		
Mobility use case				
CALCULATION				
Hotel – 4,000m^2, 4 storeys				
– Total energy demand (kWh/m^2/y)	202	127	-37%	Total energy demand, utility costs and carbon emissions are retrieved across both cases, yielding levels of operational savings.
– Fossil spend (USD/m^2/y)	3	0	-31%	
– Electricity spend (USD/m^2/y)	12	10		
– Carbon emissions (kgCO_2/m^2/y)	33	12	-62%	

Energy demand profiles

Key data on energy profiles are input in the model, for a given archetype, in a given region. This data is retrieved from the US department of energy databases[43].

- Six building archetypes have been retrieved:
  - Residential individual household (150m^2, 2 storeys).
  - Office building (45,000m^2, 10 storeys).
  - Hospital (20,000m^2, 6 storeys).
  - Hotel (4,000m^2, 4 storeys).
  - Retail center (2,000m^2, 1 floor).
  - Education building (20,000m^2, 3 storeys).
- Two years of construction have been retrieved as well: 1980 (depicting an existing building) and 2018[44] (depicting the most modern forms of buildings, and which we use for modelling new constructions).
- These 12 building types have been projected in 19 regions with different weather conditions, leveraging the same databases.

Figure 18 – Regional coverage

Region covered in this research	Regional code (ASHRAE)	Source used in the database
Canada	7	International Falls
China – Eastern	4A	New York
China – North Central	6B	Great Falls
China – Northeast	7	International Falls
China – Northwest	7	International Falls
China – South Central	3A	Atlanta
China – Southern	2A	Tampa
Denmark	5A	Buffalo
France	4A	New York
Germany	5A	Buffalo
Italy	3A	Atlanta
Japan	4A	New York
Netherlands	4C	Seattle
Spain	4A	New York
U.S. Midwest	4B	Albuquerque
U.S. Northeast	5A	Buffalo
U.S. South	3B	El Paso
U.S. West	3C	San Diego
United Kingdom	4A	New York

The energy demand profiles used as an input to the model and retrieved from these databases are detailed in Figure 19 below. We have assumed these profiles do not change in our 2030 forecast.

- This is not debatable for the existing buildings use cases (as most buildings erected in 1980 will still be standing).
- This is more debatable for new constructions, as performance requirements will continue to evolve in the coming decade.

Figure 19 – Building energy profiles

		1980	2018	1980	2018	1980	2018	1980	2018	1980	2018	1980	2018	1980	2018
Segment	Country	Heat	Heat	Cooling	Cooling	Lighting	Lighting	Water	Water	Ventilation	Ventilation	Appliances	Appliances	TOTAL	TOTAL
Residential	Canada	319	133	5	5	15	5	31	29	7	7	33	46	**410**	**225**
Residential	China – North Central	233	88	6	6	15	5	29	26	7	7	33	46	**321**	**178**
Residential	China – Eastern	174	63	11	9	15	5	25	23	5	5	33	46	**262**	**152**
Residential	China – South Central	96	33	17	12	15	5	22	21	6	5	33	46	**188**	**123**
Residential	China – Northeast	319	133	5	5	15	5	31	29	7	7	33	46	**410**	**225**
Residential	China – Northwest	319	133	5	5	15	5	31	29	7	7	33	46	**410**	**225**
Residential	China – Southern	28	14	28	22	15	5	19	17	6	7	33	46	**128**	**112**
Residential	Denmark	222	90	0	0	15	5	27	25	6	7	33	46	**303**	**173**
Residential	France	174	63	0	0	15	5	25	23	5	5	33	46	**252**	**143**
Residential	Germany	222	90	0	0	15	5	27	25	6	7	33	46	**303**	**173**

(43) US Department of Energy (2021), Commercial Reference Buildings. US Department of Energy (b) (2021), Prototype Building Models NREL (2011), U.S. Department of Energy Commercial Reference Building Models of the National Building Stock.
(44) The building profiles used here for 1980 and 2018 configurations come from different databases from the US Department of Energy, and we have noted slight discrepancies, notably on the demand for appliances. After careful review, however, we consider the impact on overall results to be minimal.

		1980	2018	1980	2018	1980	2018	1980	2018	1980	2018	1980	2018	1980	2018
Segment	Country	Heat	Heat	Cooling	Cooling	Lighting	Lighting	Water	Water	Ventilation	Ventilation	Appliances	Appliances	TOTAL	TOTAL
Residential	Italy	96	33	17	12	15	5	22	21	6	5	33	46	**188**	**123**
Residential	Japan	174	63	11	9	15	5	25	23	5	5	33	46	**262**	**152**
Residential	Netherlands	118	46	4	0	15	5	26	24	5	6	33	46	**201**	**127**
Residential	Spain	174	63	11	9	15	5	25	23	5	5	33	46	**262**	**152**
Residential	U.S. Midwest	98	34	13	12	15	5	24	22	6	6	33	46	**189**	**126**
Residential	U.S. Northeast	222	90	6	6	15	5	27	25	6	7	33	46	**309**	**179**
Residential	U.S. South	63	20	20	14	15	5	21	20	7	6	33	46	**158**	**112**
Residential	U.S. West	42	10	10	7	15	5	23	21	4	4	33	46	**125**	**93**
Residential	United Kingdom	174	63	0	0	15	5	25	23	5	5	33	46	**252**	**143**
Hospital	Canada	188	116	160	16	104	41	11	18	60	42	98	120	**620**	**352**
Hospital	China – North Central	143	90	153	14	104	41	10	17	59	43	98	120	**567**	**324**
Hospital	China – Eastern	154	36	252	31	104	41	9	15	63	39	98	120	**680**	**283**
Hospital	China – South Central	144	23	264	39	104	41	8	14	66	41	98	120	**683**	**278**
Hospital	China – Northeast	188	116	160	16	104	41	11	18	60	42	98	120	**620**	**352**
Hospital	China – Northwest	188	116	160	16	104	41	11	18	60	42	98	120	**620**	**352**
Hospital	China – Southern	133	14	282	58	104	41	7	13	68	41	98	120	**691**	**286**
Hospital	Denmark	166	48	212	24	104	41	10	16	63	40	98	120	**652**	**288**
Hospital	France	154	36	252	31	104	41	9	15	63	39	98	120	**680**	**283**
Hospital	Germany	166	48	212	24	104	41	10	16	63	40	98	120	**652**	**288**
Hospital	Italy	144	23	264	39	104	41	8	14	66	41	98	120	**683**	**278**
Hospital	Japan	154	36	252	31	104	41	9	15	63	39	98	120	**680**	**283**
Hospital	Netherlands	159	32	206	19	104	41	9	16	58	39	98	120	**635**	**267**
Hospital	Spain	154	36	252	31	104	41	9	15	63	39	98	120	**680**	**283**
Hospital	U.S. Midwest	114	22	177	25	104	41	9	15	63	43	98	120	**564**	**265**
Hospital	U.S. Northeast	166	48	212	24	104	41	10	16	63	40	98	120	**652**	**288**
Hospital	U.S. South	143	16	238	32	104	41	8	14	63	42	98	120	**653**	**265**
Hospital	U.S. West	155	18	210	29	104	41	9	15	58	39	98	120	**632**	**261**
Hospital	United Kingdom	154	36	252	31	104	41	9	15	63	39	98	120	**680**	**283**
Hotel	Canada	77	36	17	12	73	14	38	54	16	13	75	73	**295**	**202**
Hotel	China – North Central	48	19	17	12	73	14	34	50	17	13	75	73	**265**	**181**
Hotel	China – Eastern	31	12	33	18	73	14	29	45	17	12	75	73	**258**	**173**
Hotel	China – South Central	18	5	41	24	73	14	26	41	18	12	75	73	**252**	**169**
Hotel	China – Northeast	77	36	17	12	73	14	38	54	16	13	75	73	**295**	**202**
Hotel	China – Northwest	77	36	17	12	73	14	38	54	16	13	75	73	**295**	**202**
Hotel	China – Southern	10	1	60	36	73	14	23	36	19	12	75	73	**259**	**172**
Hotel	Denmark	46	20	27	14	73	14	32	48	17	11	75	73	**269**	**180**
Hotel	France	31	12	33	18	73	14	29	45	17	12	75	73	**258**	**173**
Hotel	Germany	46	20	27	14	73	14	32	48	17	11	75	73	**269**	**180**
Hotel	Italy	18	5	41	24	73	14	26	41	18	12	75	73	**252**	**169**
Hotel	Japan	31	12	33	18	73	14	29	45	17	12	75	73	**258**	**173**
Hotel	Netherlands	26	6	17	13	73	14	31	46	16	14	75	73	**237**	**166**
Hotel	Spain	31	12	33	18	73	14	29	45	17	12	75	73	**258**	**173**
Hotel	U.S. Midwest	20	4	30	19	73	14	29	44	19	14	75	73	**245**	**167**
Hotel	U.S. Northeast	46	20	27	14	73	14	32	48	17	11	75	73	**269**	**180**
Hotel	U.S. South	6	2	32	24	73	14	26	39	18	12	75	73	**229**	**165**
Hotel	U.S. West	15	0	20	20	73	14	29	41	16	14	75	73	**227**	**162**
Hotel	United Kingdom	31	12	33	18	73	14	29	45	17	12	75	73	**258**	**173**
Office	Canada	77	14	12	10	51	16	2	4	7	14	50	88	**198**	**146**
Office	China – North Central	45	19	12	10	51	16	2	4	6	16	50	88	**165**	**152**
Office	China – Eastern	31	4	38	14	51	15	1	3	10	14	50	88	**181**	**139**
Office	China – South Central	22	2	44	19	51	15	1	3	10	15	50	88	**178**	**142**
Office	China – Northeast	77	14	12	10	51	16	2	4	7	14	50	88	**198**	**146**

Segment	Country	1980 Heat	2018 Heat	1980 Cooling	2018 Cooling	1980 Lighting	2018 Lighting	1980 Water	2018 Water	1980 Ventilation	2018 Ventilation	1980 Appliances	2018 Appliances	1980 TOTAL	2018 TOTAL
Office	China – Northwest	77	14	12	10	51	16	2	4	7	14	50	88	**198**	**146**
Office	China – Southern	13	0	56	28	51	15	1	3	10	16	50	88	**182**	**150**
Office	Denmark	47	7	23	13	51	15	2	4	7	14	50	88	**180**	**141**
Office	France	31	4	38	14	51	15	1	3	10	14	50	88	**181**	**139**
Office	Germany	47	7	23	13	51	15	2	4	7	14	50	88	**180**	**141**
Office	Italy	22	2	44	19	51	15	1	3	10	15	50	88	**178**	**142**
Office	Japan	31	4	38	14	51	15	1	3	10	14	50	88	**181**	**139**
Office	Netherlands	32	7	14	8	51	16	1	4	6	13	50	88	**155**	**134**
Office	Spain	31	4	38	14	51	15	1	3	10	14	50	88	**181**	**139**
Office	U.S. Midwest	21	5	20	15	51	15	1	3	8	17	50	88	**151**	**144**
Office	U.S. Northeast	47	7	23	13	51	15	2	4	7	14	50	88	**180**	**141**
Office	U.S. South	9	2	38	21	51	15	1	3	9	17	50	88	**157**	**147**
Office	U.S. West	16	0	18	13	51	15	1	3	6	14	50	88	**142**	**134**
Office	United Kingdom	31	4	38	14	51	15	1	3	10	14	50	88	**181**	**139**
Retail	Canada	336	154	4	15	140	91	10	10	47	33	20	17	**557**	**319**
Retail	China – North Central	223	78	6	14	140	91	9	9	46	36	20	17	**445**	**245**
Retail	China – Eastern	149	53	21	29	140	91	9	9	33	33	20	17	**372**	**232**
Retail	China – South Central	85	19	30	46	140	91	9	9	36	35	20	17	**320**	**216**
Retail	China – Northeast	336	154	4	15	140	91	10	10	47	33	20	17	**557**	**319**
Retail	China – Northwest	336	154	4	15	140	91	10	10	47	33	20	17	**557**	**319**
Retail	China – Southern	40	1	54	85	140	91	9	9	36	39	20	17	**298**	**241**
Retail	Denmark	209	88	16	17	140	91	9	9	39	31	20	17	**432**	**253**
Retail	France	149	53	21	29	140	91	9	9	33	33	20	17	**372**	**232**
Retail	Germany	209	88	16	17	140	91	9	9	39	31	20	17	**432**	**253**
Retail	Italy	85	19	30	46	140	91	9	9	36	35	20	17	**320**	**216**
Retail	Japan	149	53	21	29	140	91	9	9	33	33	20	17	**372**	**232**
Retail	Netherlands	135	32	4	9	140	91	9	9	29	31	20	17	**336**	**189**
Retail	Spain	149	53	21	29	140	91	9	9	33	33	20	17	**372**	**232**
Retail	U.S. Midwest	106	9	18	25	140	91	9	9	33	41	20	17	**325**	**191**
Retail	U.S. Northeast	209	88	16	17	140	91	9	9	39	31	20	17	**432**	**253**
Retail	U.S. South	27	2	13	39	140	91	9	9	35	41	20	17	**244**	**198**
Retail	U.S. West	73	0	4	21	140	91	9	9	28	32	20	17	**272**	**170**
Retail	United Kingdom	149	53	21	29	140	91	9	9	33	33	20	17	**372**	**232**
School	Canada	215	38	21	11	58	11	8	11	17	13	37	41	**356**	**125**
School	China – North Central	142	20	21	9	58	12	7	10	16	12	37	41	**281**	**104**
School	China – Eastern	98	8	75	18	58	12	6	9	16	11	37	41	**290**	**100**
School	China – South Central	59	6	99	26	58	12	6	9	16	11	37	41	**275**	**105**
School	China – Northeast	215	38	21	11	58	11	8	11	17	13	37	41	**356**	**125**
School	China – Northwest	215	38	21	11	58	11	8	11	17	13	37	41	**356**	**125**
School	China – Southern	30	1	157	43	58	11	5	8	17	12	37	41	**304**	**117**
School	Denmark	133	16	0	0	58	12	7	10	16	11	37	41	**252**	**90**
School	France	98	8	0	0	58	12	6	9	16	11	37	41	**215**	**81**
School	Germany	133	16	0	0	58	12	7	10	16	11	37	41	**252**	**90**
School	Italy	59	6	99	26	58	12	6	9	16	11	37	41	**275**	**105**
School	Japan	98	8	75	18	58	12	6	9	16	11	37	41	**290**	**100**
School	Netherlands	95	17	22	8	58	12	6	9	15	11	37	41	**234**	**99**
School	Spain	98	8	75	18	58	12	6	9	16	11	37	41	**290**	**100**
School	U.S. Midwest	65	9	48	17	58	12	6	9	17	12	37	41	**231**	**101**
School	U.S. Northeast	133	16	57	12	58	12	7	10	16	11	37	41	**308**	**103**
School	U.S. South	18	5	80	24	58	12	5	8	16	12	37	41	**214**	**102**
School	U.S. West	51	3	36	18	58	12	6	9	15	10	37	41	**203**	**93**
School	United Kingdom	98	8	0	0	58	12	6	9	16	11	37	41	**215**	**81**

Local context on energies

Energy carbon intensities and costs also vary across regions. Moreover, they will also vary in time (to 2030). We have retrieved data for today and 2030[45]. We have assumed a baseline (ongoing policies) scenario for the decarbonization of the power system (more radical scenarios exist) and have taken no assumptions on grid-retailed energy cost evolutions at this stage, given the inherent uncertainties revolving around them[46].

Figure 20 – Local context on energy

Country	Electricity CO_2 intensity ($kgCO_2/kWh$)	Electricity CO_2 intensity 2030	Natural gas CO_2 intensity ($kgCO_2/kWh$)	Electricity cost (USD/kWh)	Natural gas cost (USD/kWh)
Canada	0.13	0.05	0.20	0.11	0.03
China – North Central	0.64	0.49	0.20	0.08	0.04
China – Eastern	0.64	0.49	0.20	0.09	0.06
China – South Central	0.64	0.49	0.20	0.09	0.04
China – Northeast	0.64	0.49	0.20	0.08	0.05
China – Northwest	0.64	0.49	0.20	0.07	0.04
China – Southern	0.64	0.49	0.20	0.08	0.06
Denmark	0.19	0.10	0.20	0.35	0.10
France	0.05	0.02	0.20	0.22	0.07
Germany	0.41	0.12	0.20	0.38	0.08
Italy	0.24	0.04	0.20	0.28	0.08
Japan	0.43	0.27	0.20	0.19	0.11
Netherlands	0.44	0.12	0.20	0.25	0.06
Spain	0.27	0.04	0.20	0.30	0.08
U.S. Midwest	0.39	0.25	0.20	0.12	0.02
U.S. Northeast	0.39	0.25	0.20	0.17	0.05
U.S. South	0.39	0.25	0.20	0.12	0.03
U.S. West	0.39	0.25	0.20	0.12	0.03
United Kingdom	0.25	0.04	0.20	0.19	0.04

Heating electrification

Heat pumps operational performance (relative to natural gas boilers) varies across regions. We have taken the following COP (Coefficient Of Performance) levels. We have not assumed any improvements by 2030 (a highly debatable assumption!), nor any change in performance across building archetypes.

Figure 21 – COP levels

	COP levels
Canada	2.4
China – Eastern	3.1
China – North Central	2.8
China – Northeast	2.2
China – Northwest	2.6
China – South Central	3.0
China – Southern	3.3
Denmark	2.8
France	3.0
Germany	2.8
Italy	3.2
Japan	3.0
Netherlands	2.9
Spain	3.3
US Midwest	2.5
US Northeast	2.7
US South	3.2
US West	2.8
United Kingdom	2.9

(45) BloombergNEF (2019), New Energy Outlook European Environmental Agency (2021) ©OECD/IEA (2021), World Energy Outlook.
(46) We have assumed costs for natural gas and electricity consistent with H1 2021 data, prior to the recent spike in energy prices. We have also run our model assuming a 50% increase in cost for natural gas and 20% on electricity cost (consistent with the German case as of Q1 2022). Results show an increase in savings, but which translate only in a few additional points (the savings associated to energy efficiency and onsite solar show a much larger impact across the stock). Wehrmann, 2022, German consumers experience biggest rise ever in gas and power prices in 2021.

Active energy efficiency

The performance of active energy efficiency per building archetype, region, and date of construction has been reviewed in a previous study(47) from the Schneider Electric™ Sustainability Research Institute. This study was based on EU.bac standards, which consider different levels of granularity in digital controls. In this report, we have assumed the highest degree of energy savings (Category A) for buildings with heating systems running on heat pumps(48). We reproduce in Figure 22 the corresponding impacts on overall energy demand. These savings are already normalized to the full energy profile of the building (i.e. they apply on total energy demand, inclusive of all types of demand, including those that are not controllable, e.g. appliances).

Figure 22 – Digital controls impact on energy efficiency

Energy Efficiency from Digital (category A)	1980						2018					
	Residential	Hospital	Hotel	Office	Retail	Education	Residential	Hospital	Hotel	Office	Retail	Education
Canada	-21%	-17%	-16%	-21%	-31%	-20%	-16%	-5%	-9%	-6%	-5%	-9%
China – North Central	-18%	-16%	-14%	-17%	-24%	-17%	-13%	-4%	-8%	-6%	-4%	-7%
China – Eastern	-16%	-18%	-15%	-22%	-22%	-19%	-11%	-4%	-8%	-6%	-4%	-8%
China – South Central	-14%	-18%	-16%	-23%	-22%	-20%	-10%	-4%	-8%	-7%	-4%	-9%
China – Northeast	-21%	-17%	-17%	-22%	-32%	-21%	-16%	-5%	-10%	-6%	-5%	-9%
China – Northwest	-20%	-16%	-16%	-20%	-29%	-19%	-15%	-4%	-9%	-6%	-4%	-8%
China – Southern	-13%	-19%	-18%	-25%	-24%	-23%	-10%	-5%	-10%	-8%	-5%	-11%
Denmark	-18%	-17%	-15%	-20%	-25%	-16%	-12%	-4%	-8%	-6%	-4%	-6%
France	-16%	-18%	-15%	-22%	-23%	-15%	-10%	-4%	-8%	-6%	-4%	-6%
Germany	-18%	-17%	-15%	-20%	-25%	-16%	-12%	-4%	-8%	-6%	-4%	-6%
Italy	-14%	-18%	-16%	-23%	-21%	-20%	-9%	-4%	-8%	-7%	-4%	-9%
Japan	-16%	-18%	-15%	-22%	-23%	-19%	-11%	-4%	-8%	-6%	-4%	-8%
Netherlands	-15%	-17%	-13%	-17%	-21%	-16%	-9%	-3%	-7%	-5%	-3%	-7%
Spain	-16%	-18%	-15%	-21%	-22%	-18%	-11%	-4%	-8%	-6%	-4%	-8%
U.S. Midwest	-15%	-17%	-15%	-19%	-22%	-18%	-11%	-4%	-8%	-7%	-4%	-8%
U.S. Northeast	-18%	-17%	-15%	-20%	-25%	-19%	-13%	-4%	-8%	-6%	-4%	-8%
U.S. South	-13%	-18%	-15%	-22%	-18%	-20%	-9%	-4%	-8%	-7%	-4%	-9%
U.S. West	-12%	-17%	-13%	-17%	-18%	-17%	-8%	-4%	-8%	-6%	-4%	-8%
United Kingdom	-17%	-18%	-15%	-22%	-23%	-15%	-10%	-4%	-8%	-6%	-4%	-6%

Onsite solar

The potential of onsite solar in buildings has been reviewed in detail in a previous report(49) from the Schneider Electric™ Sustainability Research Institute.

This report evaluates first the potential of rooftop space available for onsite solar provisions, as a function of the rooftop surface (a share of floor area, contingent to the number of floors and the shape of roofs), and of suitable rooftop surface (a share of the roof area, dependent on other equipment being already installed, as well as other contingencies such as location of the building, e.g. presence of shaded areas, etc.). Based on that report, a number of assumptions have been taken for each building archetype (Figure 23). In new constructions, we assume a significant rise of suitable roof space available for onsite solar, given compelling economics(50).

Figure 23 – Suitable roof space for onsite solar

Suitable roof space	Floor to Roof		Suitable Roof space	
	Existing	New build	Existing	New build
Residential	50%	50%	50%	70%
Hospital	17%	17%	30%	70%
Hotel	25%	25%	30%	70%
Office	10%	10%	10%	70%
Retail	100%	100%	50%	70%
Education	33%	33%	30%	70%

The production of onsite solar then depends on the performance of photovoltaic panels, which obviously varies across regions, as a function of solar irradiation. We assume also these levels constant, discarding any potential breakthrough on photovoltaic technologies.

(47) Schneider Electric (2021), Cracking the Energy Efficiency Case in Buildings.
(48) Savings are higher for buildings running on conventional heating systems (e.g. natural gas), as a switch to heat pumps already embeds significant efficiency.
(49) Schneider Electric (2022), The unexpected disruption: distributed generation.
(50) Schneider Electric (2022), The unexpected disruption: distributed generation.

Figure 24 – Onsite solar potential

Distributed Generation Potential	kWh/m²/y
Canada	197
China – Eastern	154
China – North Central	144
China – Northeast	144
China – Northwest	144
China – South Central	154
China – Southern	154
Denmark	149
France	169
Germany	149
Italy	185
Japan	143
Netherlands	149
Spain	185
US Midwest	197
US Northeast	197
US South	230
US West	230
United Kingdom	149

The potential of onsite solar is maximized in the Buildings of the Future use cases, and the model also assumes 100% of it is self-consumed, which implies a proper dimensioning for energy storage, which is evaluated in the Capex module.

Sensitivity analysis

We also performed simulations when accounting for the benefit of implementing only active energy efficiency, heat electrification, or onsite solar. To do this, we ran our model including only one solution at the time, in order to get a better understanding of what are the key contributors to carbon abatement or energy spend savings(51).

Capex module

The Capex module consolidates all capex inputs for the various parts of the Buildings of the Future, and compares them to the current situation. Here, we review these assumptions one by one.

Capex of heating

In the Buildings of the Future, conventional (natural gas) heating systems are switched to electric heat pumps (we consider air-sourced heat pumps in our model). We use two different sources of inputs for residential and service buildings.

Residential

We leverage datasets from the BloombergNEF Heating Unit Economics Calculator(52), also used in a previous study(53) from the Schneider Electric™ Sustainability Research Institute. Given that these values are for specific residential types, we adjust the heating cost per square meter retrieved from the Calculator to the actual energy intensities for our residential use cases with specific assumptions that account for higher or lower energy needs.

We have also taken the assumption to not include air-conditioning costs in the residential use cases. This is an important assumption, that ultimately degrades the competitiveness of heat pumps in residential (since a heat pump can provide for both heating and cooling with one equipment). According to our simulations, this typically increases paybacks by around two years on average (with significant differences across regions).

For our 2030 scenario, we assume costs of heat pumps reduce by 20%, due to increased demand leading to economies of scale and better structuring of the value chain.

Service

Retrieving costs for service buildings is less trivial and requires a greater level of modelling.

- We used the building archetypes identified above and leveraged the database for these archetypes to assess power capacity requirements for heating (and cooling, as all service buildings are assumed to be equipped with cooling) across all these buildings and the 19 regions reviewed(54).

(51) Benefits do not sum up. The solution that bundles all three approaches into one remains a specific modelling run with different results as these combine with one another.
(52) BloombergNEF (2020), Heating Unit Economics Calculator (HUEC 1.0.3).
(53) Schneider Electric (b) (2021), Building Heat Decarbonization.
(54) For each building archetype in each region, we retrieve heating and cooling loads accounting for all coils and zone conditioning (outside of electric heating when present) and we divide these values to the surface of the building to get a load in W/m².

Figure 25 – Heating and cooling power requirements in service buildings (1980 standards)

	Office		Hospital		Retail		Hotel		Education	
Load demand (1980) W/m²	Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating
Canada	180	137	199	214	235	441	110	84	119	264
China – Eastern	180	109	218	197	204	284	121	69	142	207
China – North Central	156	125	181	200	184	400	112	80	96	242
China – Northeast	180	137	199	214	235	441	110	84	119	264
China – Northwest	180	137	199	214	235	441	110	84	119	264
China – South Central	173	107	223	197	226	249	126	68	149	197
China – Southern	182	102	230	194	231	205	129	63	160	182
Denmark	180	125	216	210	226	375	121	80	138	244
France	180	109	218	197	204	284	121	69	142	207
Germany	180	125	216	210	226	375	121	80	138	244
Italy	173	107	223	197	226	249	126	68	149	197
Japan	180	109	218	197	204	284	121	69	142	207
Netherlands	180	101	192	185	151	220	115	60	125	181
Spain	180	109	218	197	204	284	121	69	142	207
U.S. Midwest	152	100	190	178	154	230	119	61	114	172
U.S. Northeast	180	125	216	210	226	375	121	80	138	244
U.S. South	187	88	212	179	201	129	122	65	161	150
U.S. West	174	90	189	177	142	156	113	64	172	170
United Kingdom	180	109	218	197	204	284	121	69	142	207

Figure 26 – Heating and cooling power requirements in service buildings (2018 standards)

	Office		Hospital		Retail		Hotel		Education	
Load demand (2018) W/m²	Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating
Canada	124	105	162	76	208	352	106	49	88	109
China – Eastern	122	92	172	89	225	278	110	38	89	85
China – North Central	108	103	151	67	198	320	107	45	83	100
China – Northeast	124	105	162	76	208	352	106	49	88	109
China – Northwest	124	105	162	76	208	352	106	49	88	109
China – South Central	120	86	171	79	235	263	110	35	88	76
China – Southern	122	69	175	59	274	254	112	28	90	60
Denmark	122	96	169	96	205	286	107	41	88	91
France	122	92	172	89	225	278	110	38	89	85
Germany	122	96	169	96	205	286	107	41	88	91
Italy	120	86	171	79	235	263	110	35	88	76
Japan	122	92	172	89	225	278	110	38	89	85
Netherlands	117	79	141	73	182	242	106	32	80	70
Spain	122	92	172	89	225	278	110	38	89	85
U.S. Midwest	120	82	154	71	215	251	109	33	86	69
U.S. Northeast	122	96	169	96	205	286	107	41	88	91
U.S. South	106	81	155	71	234	260	112	32	86	67
U.S. West	112	68	144	59	188	219	106	26	77	60
United Kingdom	122	92	172	89	225	278	110	38	89	85

- As a second step, we use these load demands to compute a cost per square meter, following the assumptions we explicated in a previous study[55].
  - Conventional solution: a heating boiler system at USD 200/kW and a chiller system at USD 510/kW.
  - Heat pump solution: a reversible system at USD 600/kW, dimensioned for the maximum power need between heating and cooling.
  - We also assume that:
    - Heat distribution systems are largely similar. As our model essentially computes differences in costs across the two systems (the extra capex required), we thus focus only on equipment capex.
    - Enough electrical capacity is in place (no upgrade of transformer substations for instance).
    - Similar COP levels for commercial heat pumps as for residential.
    - While our estimate on cost differences may overlook additional works to integrate a new system (e.g. a heat pump) within an existing setting (which will depend on the heating system architecture, and only apply to retrofit cases), it is worth noting that heat pumps are dimensioned for the full load, prior to any energy efficiency provisions, hence oversized relative to the ultimate need.

(55) Schneider Electric (b) (2021), Building Heat Decarbonization.

Figure 27 – Cost of heating (1980 standards)

	Office		Hospital		Retail		Hotel		Education	
Costs (1980) USD/m²	Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating
Canada	119	108	145	128	208	265	73	66	113	158
China – Eastern	113	108	150	131	160	170	76	73	114	124
China – North Central	104	93	133	120	174	240	73	67	97	145
China – Northeast	119	108	145	128	208	265	73	66	113	158
China – Northwest	119	108	145	128	208	265	73	66	113	158
China – South Central	110	104	153	134	165	149	78	75	115	118
China – Southern	113	109	156	138	159	138	79	78	118	109
Denmark	117	108	152	130	190	225	78	72	119	146
France	113	108	150	131	160	170	76	73	114	124
Germany	117	108	152	130	190	225	78	72	119	146
Italy	110	104	153	134	165	149	78	75	115	118
Japan	113	108	150	131	160	170	76	73	114	124
Netherlands	112	108	135	115	121	132	70	69	100	109
Spain	113	108	150	131	160	170	76	73	114	124
U.S. Midwest	98	91	132	114	124	138	73	71	92	103
U.S. Northeast	117	108	152	130	190	225	78	72	119	146
U.S. South	113	112	144	127	128	121	75	73	112	97
U.S. West	107	104	132	113	104	94	70	68	122	103
United Kingdom	113	108	150	131	160	170	76	73	114	124

Figure 28 – Cost of heating (2018 standards)

	Office		Hospital		Retail		Hotel		Education	
Costs (2018) USD/m²	Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating
Canada	84	74	98	97	176	211	64	64	67	66
China – Eastern	81	73	106	103	171	167	64	66	62	53
China – North Central	76	65	90	91	165	192	64	64	62	60
China – Northeast	84	74	98	97	176	211	64	64	67	66
China – Northwest	84	74	98	97	176	211	64	64	67	66
China – South Central	78	72	103	103	172	158	63	66	60	53
China – Southern	76	73	101	105	191	164	63	67	58	54
Denmark	81	73	105	101	162	172	63	64	63	55
France	81	73	106	103	171	167	64	66	62	53
Germany	81	73	105	101	162	172	63	64	63	55
Italy	78	72	103	103	172	158	63	66	60	53
Japan	81	73	106	103	171	167	64	66	62	53
Netherlands	76	70	87	85	141	145	60	64	55	48
Spain	81	73	106	103	171	167	64	66	62	53
U.S. Midwest	77	72	93	93	160	151	62	66	57	51
U.S. Northeast	81	73	105	101	162	172	63	64	63	55
U.S. South	70	64	93	93	171	156	63	67	57	52
U.S. West	71	67	85	87	140	131	59	63	51	46
United Kingdom	81	73	106	103	171	167	64	66	62	53

Finally, we take no assumption on cost improvements in our 2030 scenario.

Capex of active energy efficiency

The cost of active energy efficiency has been reviewed in a previous study[56] from the Schneider Electric™ Sustainability Research Institute. We consider here category A solutions, as explained in the Operational module chapter of this Annex. We assume those costs are:

- Similar across retrofit and new constructions.
- Similar across regions (a debatable assessment as installation costs vary across regions; the cost estimates assumed here come from European assessments, and they are likely to be lower in other regions, notably China).
- Similar in time, and do not vary to 2030.

Overall, these costs come as an extra in Buildings of the Future, compared to the conventional solution.

Figure 29 – cost of implementing active energy efficiency in buildings

	Category of Digital Solution			
Capex USD/m²	D	C	B	A
Residential	0	5	NA	25
Hotel	0	20	30	45
Retail	0	17	25	35
Office	0	20	30	40
Hospital	0	20	30	40
Education	0	20	30	45

Capex of onsite solar

The National Renewable Energy Laboratory[57] (NREL) and the IRENA[58] (2020) have realized detailed estimates on the cost of deploying onsite solar on building premises, which we use in this report.

- For retrofit: we used the data available for both residential and service buildings[59].
- For new build: we considered a lower level of cost, considering inherent savings associated to overhead and installation costs.
- For 2030: we assumed a further decline in hardware costs and in installation costs (between 20-40% across regions).

Figure 30 – Cost of deploying onsite solar (USD/W)

Cost of onsite solar without storage (USD/W)	Office		Hospital		Retail		Hotel		Education		Residential		
	Retrofit	New	Retrofit	New	Retrofit	New	Retrofit	New	Retrofit	New	Retrofit	New	Savings to 2030
Canada	1.7	1.3	1.7	1.3	1.7	1.3	1.7	1.3	1.7	1.3	2.7	1.3	40%
China – Eastern	0.7	0.5	0.7	0.5	0.7	0.5	0.7	0.5	0.7	0.5	0.8	0.5	20%
China – North Central	0.7	0.5	0.7	0.5	0.7	0.5	0.7	0.5	0.7	0.5	0.8	0.5	20%
China – Northeast	0.7	0.5	0.7	0.5	0.7	0.5	0.7	0.5	0.7	0.5	0.8	0.5	20%
China – Northwest	0.7	0.5	0.7	0.5	0.7	0.5	0.7	0.5	0.7	0.5	0.8	0.5	20%
China – South Central	0.7	0.5	0.7	0.5	0.7	0.5	0.7	0.5	0.7	0.5	0.8	0.5	20%
China – Southern	0.7	0.5	0.7	0.5	0.7	0.5	0.7	0.5	0.7	0.5	0.8	0.5	20%
Denmark	1.3	1.0	1.3	1.0	1.3	1.0	1.3	1.0	1.3	1.0	1.8	1.0	30%
France	1.3	1.0	1.3	1.0	1.3	1.0	1.3	1.0	1.3	1.0	1.8	1.0	30%
Germany	1.1	0.8	1.1	0.8	1.1	0.8	1.1	0.8	1.1	0.8	1.6	0.8	30%
Italy	1.0	0.8	1.0	0.8	1.0	0.8	1.0	0.8	1.0	0.8	1.4	0.8	20%
Japan	1.7	1.3	1.7	1.3	1.7	1.3	1.7	1.3	1.7	1.3	2.2	1.3	40%
Netherlands	1.3	1.0	1.3	1.0	1.3	1.0	1.3	1.0	1.3	1.0	1.8	1.0	30%
Spain	0.8	0.6	0.8	0.6	0.8	0.6	0.8	0.6	0.8	0.6	1.4	0.6	30%
U.S. Midwest	1.7	1.3	1.7	1.3	1.7	1.3	1.7	1.3	1.7	1.3	2.7	1.3	40%
U.S. Northeast	1.7	1.3	1.7	1.3	1.7	1.3	1.7	1.3	1.7	1.3	2.7	1.3	40%
U.S. South	1.7	1.3	1.7	1.3	1.7	1.3	1.7	1.3	1.7	1.3	2.7	1.3	40%
U.S. West	1.7	1.3	1.7	1.3	1.7	1.3	1.7	1.3	1.7	1.3	2.7	1.3	40%
United Kingdom	1.5	1.1	1.5	1.1	1.5	1.1	1.5	1.1	1.5	1.1	2.2	1.1	30%

These cost levels can then be applied to the different building archetypes, considering the capacity of onsite solar effectively deployed. The costs are higher for retail and residential given the share of onsite solar installed in those building archetypes, relative to others. The costs also tend to be higher in new constructions given the higher capacity deployed, but this is also compensated by lower costs per unit of installed capacity.

(56) Schneider Electric (2021), Cracking the Energy Efficiency Case in Buildings.
(57) NREL (2021), US Solar Photovoltaic System and Energy Storage Cost benchmark: Q1 2020.
(58) IRENA (2020), Renewable Power Generation Costs in 2020.
(59) The data was not available for some countries (Canada, Denmark, the Netherlands). We assumed costs similar to those of the US (Canada) and France (Denmark, the Netherlands).

Figure 31 – Cost of deploying onsite solar (USD/m²)

Cost of onsite solar without storage (USD/m²) – Current	Office		Hospital		Retail		Hotel		Education		Residential	
	Retrofit	New	Retrofit	New	Retrofit	New	Retrofit	New	Retrofit	New	Retrofit	New
Canada	3	15	14	25	142	152	21	38	28	51	113	76
China – Eastern	1	6	6	10	58	62	9	15	12	21	31	31
China – North Central	1	6	6	10	58	62	9	15	12	21	31	31
China – Northeast	1	6	6	10	58	62	9	15	12	21	31	31
China – Northwest	1	6	6	10	58	62	9	15	12	21	31	31
China – South Central	1	6	6	10	58	62	9	15	12	21	31	31
China – Southern	1	6	6	10	58	62	9	15	12	21	31	31
Denmark	2	12	11	19	108	116	16	29	22	39	75	58
France	2	12	11	19	108	116	16	29	22	39	75	58
Germany	2	10	9	16	92	98	14	25	18	33	67	49
Italy	2	9	8	15	83	89	13	22	17	30	58	45
Japan	3	15	14	25	142	152	21	38	28	51	92	76
Netherlands	2	12	11	19	108	116	16	29	22	39	75	58
Spain	1	7	7	12	67	71	10	18	13	24	58	36
U.S. Midwest	3	15	14	25	142	152	21	38	28	51	113	76
U.S. Northeast	3	15	14	25	142	152	21	38	28	51	113	76
U.S. South	3	15	14	25	142	152	21	38	28	51	113	76
U.S. West	3	15	14	25	142	152	21	38	28	51	113	76
United Kingdom	3	13	13	22	125	134	19	33	25	45	92	67

Cost of onsite solar without storage (USD/m²) – 2030	Office		Hospital		Retail		Hotel		Education		Residential	
	Retrofit	New	Retrofit	New	Retrofit	New	Retrofit	New	Retrofit	New	Retrofit	New
Canada	2	9	9	15	85	91	13	23	17	30	68	46
China – Eastern	1	5	5	8	46	49	7	12	9	16	25	25
China – North Central	1	5	5	8	46	49	7	12	9	16	25	25
China – Northeast	1	5	5	8	46	49	7	12	9	16	25	25
China – Northwest	1	5	5	8	46	49	7	12	9	16	25	25
China – South Central	1	5	5	8	46	49	7	12	9	16	25	25
China – Southern	1	5	5	8	46	49	7	12	9	16	25	25
Denmark	2	8	8	14	76	81	11	20	15	27	53	41
France	2	8	8	14	76	81	11	20	15	27	53	41
Germany	1	7	6	11	64	69	10	17	13	23	47	34
Italy	1	7	7	12	67	71	10	18	13	24	47	36
Japan	2	9	9	15	85	91	13	23	17	30	55	46
Netherlands	2	8	8	14	76	81	11	20	15	27	53	41
Spain	1	5	5	8	47	50	7	12	9	17	41	25
U.S. Midwest	2	9	9	15	85	91	13	23	17	30	68	46
U.S. Northeast	2	9	9	15	85	91	13	23	17	30	68	46
U.S. South	2	9	9	15	85	91	13	23	17	30	68	46
U.S. West	2	9	9	15	85	91	13	23	17	30	68	46
United Kingdom	2	9	9	16	88	94	13	23	18	31	64	47

Capex of storage

To properly assess the capex for storage, the first step is to assess the actual volume of storage required. We define it in this paper as a share of total onsite solar generated over a day[60]. Since onsite solar may produce in excess of demand at a given point in time (particularly when buildings run with low demand, e.g. an unoccupied household in the middle of a working week), the volume of storage required corresponds to the energy that is produced in excess of demand during the time of peak production. In certain buildings (e.g. offices or hospitals), the maximum peak generation of PV never exceeds the maximum demand at a point in time, leading to zero need for storage. In others, it does, and therefore requires storage. To size this, we subtract the total PV generation during a day in Summer (maximized output) to the corresponding energy demand during the same period of time. In this report, we have made raw evaluations assuming a stepwise profile for load demand and evaluated the peak demand at times of PV generation[61]. The volume of storage required is higher in new buildings given the greater capacity of onsite solar. It is also higher in regions with higher PV output.

Figure 32 – Dimensioning of storage (kWh)

	Office		Hospital		Retail		Hotel		Education		Residential	
Storage in kWh	Retrofit	New	Retrofit	New	Retrofit	New	Retrofit	New	Retrofit	New	Retrofit	New
Canada	0	0	0	0	31	614	0	0	0	658	22	35
China – Eastern	0	0	0	0	0	0	0	0	0	0	14	23
China – North Central	0	0	0	0	204	863	0	0	0	1575	29	45
China – Northeast	0	0	0	0	0	338	0	0	0	0	17	27
China – Northwest	0	0	0	0	53	643	0	0	0	762	23	36
China – South Central	0	0	0	0	81	768	0	0	0	605	25	40
China – Southern	0	0	0	0	0	448	0	0	0	0	19	32
Denmark	0	0	0	0	0	183	0	0	0	0	13	22
France	0	0	0	0	0	459	0	0	0	509	18	29
Germany	0	0	0	0	0	183	0	0	0	0	13	22
Italy	0	0	0	0	0	478	0	0	0	0	20	32
Japan	0	0	0	0	0	525	0	0	0	279	21	34
Netherlands	0	0	0	0	0	239	0	0	0	0	13	22
Spain	0	0	0	0	177	703	0	0	0	1109	28	43
U.S. Midwest	0	0	0	0	59	635	0	0	0	505	22	36
U.S. Northeast	0	0	0	0	0	525	0	0	0	529	22	34
U.S. South	0	0	0	0	220	728	0	0	0	947	27	44
U.S. West	0	0	0	0	270	832	0	0	0	1160	28	44
United Kingdom	0	0	0	0	0	218	0	0	0	0	13	22

Then comes the actual evaluation of the cost of storage. We assume here battery storage only, though other storage solutions (notably leveraging thermal storage solutions) could ultimately be more competitive. Our estimates for storage costs are thus on the higher-end and could ultimately be much lower than often anticipated. We leverage the same report from NREL mentioned above to retrieve costs for storage systems in both residential and service buildings, to which we apply a discount for new constructions (overhead and installation costs), and assume a decline of 50% in hardware costs (and a minor decline in installation costs) by 2030.

Figure 33 – Cost of storage (USD/kWh)

	Current situation		2030	
Storage costs USD/kWh	Retrofit	New	Retrofit	New
Residential	800	450	500	250
Hotel	450	390	250	200
Retail	450	390	250	200
Office	450	390	250	200
Hospital	450	390	250	200
Education	450	390	250	200

Applying these figures to the building archetypes studied in this paper provides us with a cost per square meter. Similar to the evaluation of the costs of onsite solar, those of storage depend on the costs of hardware and installation (which vary between retrofits and new constructions, and are lower in 2030), as well as the actual volume of storage required (which is increased in new constructions).

(60) In this paper, we consider an installation which maximizes self-consumption, which is an important assumption and obviously highly debatable. Many retail schemes indeed exist around the world to monetize this excess energy over the course of a day by reselling it to the grid. Here, we design storage system to store the generation in excess of demand, hence maximize self-consumption. For more on reselling schemes, see BloombergNEF (2021), Realizing the potential of customer-sited solar.

(61) Typically, we have estimated for commercial buildings (outside of hotels) a load profile with a 12-hour step-up of load demand eight times that of the nightshift. For hotels, we have used 1.5 times peak. For residential households, on the contrary, daylight demand is 70% of nighttime demand. We have also assumed a 10-hour window for PV generation. A further study will be published in 2022 refining those estimates.

Figure 34 – Cost of storage (USD/m²)

Cost of Storage (USD/m²) Current	Office		Hospital		Retail		Hotel		Education		Residential	
	Retrofit	New	Retrofit	New	Retrofit	New	Retrofit	New	Retrofit	New	Retrofit	New
Canada	0	0	0	0	7	120	0	0	0	13	120	106
China – Eastern	0	0	0	0	0	0	0	0	0	0	73	70
China – North Central	0	0	0	0	46	168	0	0	0	31	155	134
China – Northeast	0	0	0	0	0	66	0	0	0	0	89	81
China – Northwest	0	0	0	0	12	125	0	0	0	15	124	109
China – South Central	0	0	0	0	18	150	0	0	0	12	135	121
China – Southern	0	0	0	0	0	87	0	0	0	0	100	96
Denmark	0	0	0	0	0	36	0	0	0	0	71	66
France	0	0	0	0	0	89	0	0	0	10	98	88
Germany	0	0	0	0	0	36	0	0	0	0	71	66
Italy	0	0	0	0	0	93	0	0	0	0	104	97
Japan	0	0	0	0	0	102	0	0	0	5	113	101
Netherlands	0	0	0	0	0	47	0	0	0	0	68	66
Spain	0	0	0	0	40	137	0	0	0	22	149	129
U.S. Midwest	0	0	0	0	13	124	0	0	0	10	119	107
U.S. Northeast	0	0	0	0	0	102	0	0	0	10	115	102
U.S. South	0	0	0	0	49	142	0	0	0	18	146	131
U.S. West	0	0	0	0	61	162	0	0	0	23	150	131
United Kingdom	0	0	0	0	0	43	0	0	0	0	71	67

Cost of Storage (USD/m²) 2030	Office		Hospital		Retail		Hotel		Education		Residential	
	Retrofit	New	Retrofit	New	Retrofit	New	Retrofit	New	Retrofit	New	Retrofit	New
Canada	0	0	0	0	4	61	0	0	0	7	75	59
China – Eastern	0	0	0	0	0	0	0	0	0	0	46	39
China – North Central	0	0	0	0	25	86	0	0	0	16	97	74
China – Northeast	0	0	0	0	0	34	0	0	0	0	55	45
China – Northwest	0	0	0	0	7	64	0	0	0	8	78	61
China – South Central	0	0	0	0	10	77	0	0	0	6	85	67
China – Southern	0	0	0	0	0	45	0	0	0	0	63	53
Denmark	0	0	0	0	0	18	0	0	0	0	44	37
France	0	0	0	0	0	46	0	0	0	5	61	49
Germany	0	0	0	0	0	18	0	0	0	0	44	37
Italy	0	0	0	0	0	48	0	0	0	0	65	54
Japan	0	0	0	0	0	53	0	0	0	3	71	56
Netherlands	0	0	0	0	0	24	0	0	0	0	43	37
Spain	0	0	0	0	22	70	0	0	0	11	93	72
U.S. Midwest	0	0	0	0	7	63	0	0	0	5	75	60
U.S. Northeast	0	0	0	0	0	53	0	0	0	5	72	57
U.S. South	0	0	0	0	27	73	0	0	0	9	91	73
U.S. West	0	0	0	0	34	83	0	0	0	12	94	73
United Kingdom	0	0	0	0	0	22	0	0	0	0	45	37

Capex consolidation

The total capex increases from deploying provisions for Buildings of the Future can then be consolidated from all of the above.

Figure 35 – Capex for Buildings of the Future (USD/m²), current situation, retrofit case

	Office		Hospital		Retail		Hotel		Education		Residential	
TOTAL Costs (1980) USD/m²	Today	Future	Today	Future	Today	Future	Today	Future	Today	Future	Today	Future
Canada	119	151	145	183	208	449	73	132	113	232	25	300
China – Eastern	113	149	150	176	160	263	76	126	114	181	10	168
China – North Central	104	135	133	166	174	378	73	121	97	202	10	250
China – Northeast	119	149	145	174	208	357	73	120	113	215	10	184
China – Northwest	119	149	145	174	208	369	73	120	113	215	10	219
China – South Central	110	145	153	179	165	260	78	129	115	175	10	230
China – Southern	113	150	156	184	159	231	79	131	118	166	10	195
Denmark	117	150	152	181	190	368	78	134	119	213	30	307
France	113	150	150	181	160	313	76	134	114	191	73	301
Germany	117	150	152	179	190	352	78	131	119	210	91	328
Italy	110	146	153	182	165	268	78	133	115	180	22	274
Japan	113	151	150	185	160	347	76	139	114	197	49	331
Netherlands	112	150	135	166	121	275	70	130	100	175	42	244
Spain	113	149	150	177	160	312	76	128	114	182	27	297
U.S. Midwest	98	134	132	168	124	328	73	138	92	177	29	307
U.S. Northeast	117	151	152	184	190	402	78	139	119	220	34	307
U.S. South	113	155	144	181	128	347	75	139	112	170	29	325
U.S. West	107	147	132	168	104	331	70	134	122	176	25	334
United Kingdom	113	150	150	183	160	330	76	137	114	194	33	273

Figure 36 – Capex for Buildings of the Future (USD/m²), current situation, new constructions case

	Office		Hospital		Retail		Hotel		Education		Residential	
TOTAL Costs (2018) USD/m²	Today	Future	Today	Future	Today	Future	Today	Future	Today	Future	Today	Future
Canada	84	130	98	163	176	517	64	147	67	174	19	240
China – Eastern	81	120	106	154	171	264	64	126	62	119	7	156
China – North Central	76	111	90	141	165	457	64	125	62	156	7	219
China – Northeast	84	121	98	148	176	373	64	124	67	131	7	167
China – Northwest	84	121	98	148	176	433	64	124	67	146	7	195
China – South Central	78	118	103	153	172	404	63	127	60	130	7	207
China – Southern	76	120	101	156	191	348	63	127	58	120	7	182
Denmark	81	125	105	161	162	358	63	138	63	139	23	253
France	81	125	106	163	171	407	64	140	62	147	56	250
Germany	81	123	105	158	162	341	63	134	63	133	70	267
Italy	78	121	103	158	172	375	63	133	60	127	16	227
Japan	81	129	106	169	171	456	64	149	62	154	37	280
Netherlands	76	122	87	144	141	343	60	138	55	132	31	206
Spain	81	121	106	155	171	410	64	129	62	144	24	248
U.S. Midwest	77	127	93	158	160	461	62	148	57	157	21	243
U.S. Northeast	81	129	105	166	162	461	63	147	63	161	25	243
U.S. South	70	119	93	158	171	484	63	150	57	166	21	261
U.S. West	71	122	85	152	140	480	59	146	51	165	21	270
United Kingdom	81	127	106	166	171	378	64	144	62	143	23	218

Figure 37 – Capex for Buildings of the Future (USD/m²), 2030 situation, retrofit case

	Office		Hospital		Retail		Hotel		Education		Residential	
TOTAL Costs (1980) USD/m²	Today	Future	Today	Future	Today	Future	Today	Future	Today	Future	Today	Future
Canada	119	150	145	177	208	389	73	124	113	220	25	202
China – Eastern	113	149	150	175	160	251	76	125	114	178	10	127
China – North Central	104	134	133	165	174	346	73	119	97	199	10	178
China – Northeast	119	149	145	173	208	346	73	118	113	213	10	137
China – Northwest	119	149	145	173	208	353	73	118	113	213	10	159
China – South Central	110	145	153	178	165	240	78	127	115	172	10	166
China – Southern	113	150	156	183	159	219	79	130	118	164	10	144
Denmark	117	149	152	177	190	336	78	129	119	207	30	230
France	113	149	150	178	160	281	76	129	114	184	73	221
Germany	117	149	152	176	190	324	78	127	119	204	91	248
Italy	110	145	153	180	165	251	78	130	115	176	22	206
Japan	113	149	150	179	160	290	76	131	114	186	49	232
Netherlands	112	149	135	163	121	243	70	125	100	169	42	181
Spain	113	149	150	175	160	274	76	125	114	178	27	211
U.S. Midwest	98	133	132	163	124	265	73	129	92	165	29	207
U.S. Northeast	117	150	152	178	190	345	78	130	119	208	34	208
U.S. South	113	154	144	176	128	268	75	131	112	159	29	217
U.S. West	107	146	132	162	104	247	70	125	122	165	25	223
United Kingdom	113	150	150	179	160	293	76	131	114	187	33	202

Figure 38 – Capex for Buildings of the Future (USD/m²), 2030 situation, new constructions case

	Office		Hospital		Retail		Hotel		Education		Residential	
TOTAL Costs (2018) USD/m²	Today	Future	Today	Future	Today	Future	Today	Future	Today	Future	Today	Future
Canada	84	123	98	152	176	398	64	132	67	148	19	156
China – Eastern	81	118	106	151	171	251	64	123	62	115	7	112
China – North Central	76	110	90	139	165	363	64	122	62	137	7	148
China – Northeast	84	119	98	145	176	329	64	121	67	127	7	119
China – Northwest	84	119	98	145	176	360	64	121	67	135	7	134
China – South Central	78	117	103	151	172	319	63	123	60	120	7	141
China – Southern	76	118	101	153	191	293	63	124	58	115	7	127
Denmark	81	121	105	155	162	306	63	130	63	127	23	186
France	81	122	106	157	171	329	64	131	62	131	56	177
Germany	81	120	105	153	162	294	63	127	63	123	70	198
Italy	78	119	103	155	172	312	63	129	60	121	16	163
Japan	81	122	106	158	171	346	64	133	62	132	37	189
Netherlands	76	119	87	138	141	285	60	129	55	120	31	147
Spain	81	118	106	152	171	322	64	123	62	126	24	168
U.S. Midwest	77	121	93	148	160	340	62	133	57	132	21	158
U.S. Northeast	81	122	105	156	162	350	63	132	63	135	25	159
U.S. South	70	113	93	148	171	355	63	135	57	137	21	166
U.S. West	71	116	85	142	140	340	59	131	51	133	21	174
United Kingdom	81	123	106	159	171	318	64	134	62	130	23	156

Economic performance consolidation

Both the Operational and the Capex modules are then connected together to measure the total economic performance of the solution. The annual savings from deploying Buildings of the Future can be compared to the upfront cost of access to these services. We use, however, two different methodologies to compare results depending on whether we look at a retrofit or a new construction case.

- For retrofits, we evaluate the payback of the solution in years. This is realized by simply dividing the upfront cost by the volume of annual savings. For the sake of simplicity, we take no assumption on discount rates in this review.
- For new acquisitions (both new constructions and retrofits that happen at times of ownership transfer), we consider paybacks are unlikely to be the main driver of adoption. Rather, we look at the impact of the upfront cost on total cost of acquisition (how much more expensive is it to acquire a Building of the Future, compared to a conventional one?). To do that, we use three average costs of acquisition of USD 2,000/m², USD 3,000/m², and USD 5,000/m². These costs integrate both the cost of construction and the cost of land acquisition.
  - We find that USD 2,000/m² is well representative of average costs in rural areas and/or low-quality constructions, while USD 5,000/m² is more representative of what can be found around city-centers (notably for residential). The average assumption is more representative of the average stock and is our central assumption for the outlook delivered in the body of the report.
  - The closer to city-centers, the higher the cost of land, notably for residential (land acquisition costs are typically lower for service buildings, well below USD 1,000/m²).
  - The costs of construction typically range around USD 1,000-1,500/m² for residential (they can also exceed these levels for luxury constructions) but will often be higher for new service buildings.

Limitations

There are obviously a few limitations to the exercise. Among them, worth mentioning:

- The results outlined in this report correspond to selected building archetypes and should not be considered as perfect averages of a given region. However, they provide a good first understanding of the magnitude of the benefits associated with those solutions in different building premises across different regions.
- Similarly, the potential of onsite solar is highly dependent on the building archetype, as well as its location, but also how it has been built. The most difficult element to assess (and most prone to variations) is the actual share of rooftop truly suitable for photovoltaic installations (e.g. other equipment installed on rooftops, shaded areas, etc.). We have taken key assumptions here that we consider representative of average conditions.
- A key assumption in the model is the maximization of self-consumption from onsite solar provisions. Self-consumption is, however, dependent on patterns of energy use in different building types, as well as the total generation (here maximized to its full potential).
  - Simple assumptions have been taken on how much onsite solar is consumed instantaneously, leaning toward a general conservative (over)sizing of storage systems[62].
  - Storage is also primarily assumed to be made with batteries, while other solutions, notably thermal storage, which are possibly more competitive, also exist. However, a more granular analysis of those different options goes beyond the boundaries of this report.
  - Alternative monetization schemes (such as reselling excess generation over the grid) have not been considered in these simulations, although they still form the bulk of incentives today. As well, we have simply considered fixed energy prices, while in several geographies, variable prices (notably for electricity) may change the picture.
- Key assumptions have also been made on capex:
  - The exact sizing of heating and cooling loads, while relatively simple to assess in residential households, is less straightforward in service buildings. We have taken here key assumptions that will be further refined over time.
  - In general, we have taken regional assumptions for costs of installation, to the exception of digital controls for which we have assumed similar costs across regions, an obviously debatable assumption.

Detailed tables

Following are the detailed results from the research.

Operational performance

We look here at detailed results for the six building archetypes in terms of CO_2 emissions and energy spend savings, for the current and the 2030 scenarios, and for both retrofit and new constructions.

Figure 39 – Residential operational performance (Building of the Future vs conventional)

	CO_2				Energy Cost			
Residential	Current Existing	Current New	2030 Existing	2030 New	Current Existing	2030 Existing	Current New	2030 New
Canada	-80%	-93%	-86%	-95%	-27%	-27%	-62%	-62%
US Midwest	-62%	-76%	-87%	-91%	-44%	-44%	-83%	-83%
US Northeast	-61%	-75%	-81%	-88%	-44%	-44%	-76%	-76%
US South	-74%	-84%	-100%	-100%	-68%	-68%	-100%	-100%
US West	-82%	-89%	-100%	-100%	-78%	-78%	-100%	-100%
China – North Central	-37%	-52%	-59%	-68%	-53%	-53%	-66%	-66%
China – Eastern	-45%	-58%	-68%	-76%	-65%	-65%	-76%	-76%
China – South Central	-48%	-60%	-71%	-78%	-55%	-55%	-73%	-73%
China – Northeast	-18%	-37%	-42%	-56%	-50%	-50%	-60%	-60%
China – Northwest	-28%	-45%	-50%	-62%	-53%	-53%	-63%	-63%
China – Southern	-53%	-64%	-70%	-77%	-61%	-61%	-74%	-74%
Denmark	-75%	-87%	-80%	-90%	-36%	-36%	-61%	-61%
France	-93%	-97%	-96%	-98%	-51%	-51%	-79%	-79%
Germany	-55%	-87%	-70%	-91%	-25%	-25%	-58%	-58%
Italy	-73%	-95%	-88%	-98%	-56%	-56%	-84%	-84%
Netherlands	-56%	-88%	-76%	-93%	-41%	-41%	-71%	-71%
Spain	-72%	-96%	-86%	-98%	-50%	-50%	-80%	-80%
UK	-70%	-95%	-80%	-97%	-32%	-32%	-66%	-66%
Japan	-53%	-70%	-68%	-79%	-59%	-59%	-70%	-70%

(62) Such paradigm, however, offers the potential to provide additional services to the grid, a trend which is expected to be further monetized in time, and what is generally referred to as demand-response.

Figure 40 – Hotel operational performance (Building of the Future vs conventional)

Hotel	CO_2				Energy Cost			
	Current Existing	Current New	2030 Existing	2030 New	Current Existing	2030 Existing	Current New	2030 New
Canada	-50%	-81%	-59%	-85%	-17%	-17%	-26%	-26%
US Midwest	-24%	-52%	-36%	-59%	-18%	-18%	-27%	-27%
US Northeast	-26%	-53%	-38%	-61%	-20%	-20%	-31%	-31%
US South	-25%	-53%	-41%	-63%	-22%	-22%	-37%	-37%
US West	-24%	-52%	-40%	-62%	-20%	-20%	-35%	-35%
China – North Central	-18%	-37%	-25%	-42%	-23%	-23%	-31%	-31%
China – Eastern	-20%	-39%	-27%	-45%	-27%	-27%	-37%	-37%
China – South Central	-21%	-40%	-27%	-45%	-23%	-23%	-31%	-31%
China – Northeast	-15%	-35%	-19%	-38%	-27%	-27%	-33%	-33%
China – Northwest	-17%	-37%	-23%	-41%	-27%	-27%	-34%	-34%
China – Southern	-23%	-41%	-28%	-45%	-27%	-27%	-35%	-35%
Denmark	-36%	-66%	-46%	-72%	-18%	-18%	-24%	-24%
France	-61%	-84%	-72%	-89%	-21%	-21%	-29%	-29%
Germany	-24%	-78%	-32%	-80%	-16%	-16%	-21%	-21%
Italy	-30%	-88%	-42%	-90%	-22%	-22%	-31%	-31%
Netherlands	-21%	-78%	-30%	-81%	-16%	-16%	-24%	-24%
Spain	-30%	-90%	-42%	-91%	-20%	-20%	-31%	-31%
UK	-29%	-89%	-39%	-90%	-17%	-17%	-23%	-23%
Japan	-23%	-51%	-30%	-56%	-25%	-25%	-33%	-33%

Figure 41 – Retail operational performance (Building of the Future vs conventional)

Retail	CO_2				Energy Cost			
	Current Existing	Current New	2030 Existing	2030 New	Current Existing	2030 Existing	Current New	2030 New
Canada	-80%	-92%	-81%	-93%	-52%	-52%	-62%	-62%
US Midwest	-63%	-77%	-76%	-85%	-57%	-57%	-72%	-72%
US Northeast	-63%	-77%	-77%	-85%	-57%	-57%	-75%	-75%
US South	-71%	-82%	-86%	-91%	-70%	-70%	-85%	-85%
US West	-73%	-83%	-81%	-88%	-70%	-70%	-77%	-77%
China – North Central	-47%	-60%	-49%	-61%	-54%	-54%	-56%	-56%
China – Eastern	-52%	-63%	-50%	-62%	-60%	-60%	-50%	-50%
China – South Central	-52%	-63%	-61%	-70%	-54%	-54%	-63%	-63%
China – Northeast	-44%	-57%	-53%	-65%	-58%	-58%	-58%	-58%
China – Northwest	-46%	-59%	-55%	-65%	-58%	-58%	-60%	-60%
China – Southern	-53%	-64%	-59%	-69%	-56%	-56%	-62%	-62%
Denmark	-67%	-83%	-66%	-82%	-48%	-48%	-57%	-57%
France	-85%	-94%	-88%	-95%	-54%	-54%	-77%	-77%
Germany	-55%	-87%	-60%	-88%	-45%	-45%	-56%	-56%
Italy	-64%	-94%	-77%	-96%	-58%	-58%	-76%	-76%
Netherlands	-55%	-88%	-61%	-89%	-49%	-49%	-56%	-56%
Spain	-66%	-95%	-72%	-96%	-57%	-57%	-72%	-72%
UK	-61%	-94%	-68%	-95%	-47%	-47%	-67%	-67%
Japan	-53%	-70%	-58%	-73%	-56%	-56%	-60%	-60%

Figure 42 – Office operational performance (Building of the Future vs conventional)

Office	CO_2				Energy Cost			
	Current Existing	2030 Existing	Current New	2030 New	Current Existing	2030 Existing	Current New	2030 New
Canada	-50%	-81%	-27%	-72%	-16%	-16%	-15%	-15%
US Midwest	-22%	-50%	-17%	-47%	-17%	-17%	-16%	-16%
US Northeast	-25%	-52%	-18%	-48%	-19%	-19%	-16%	-16%
US South	-24%	-52%	-19%	-49%	-23%	-23%	-18%	-18%
US West	-21%	-50%	-19%	-48%	-18%	-18%	-18%	-18%
China – North Central	-17%	-37%	-13%	-34%	-22%	-22%	-16%	-16%
China – Eastern	-22%	-41%	-14%	-35%	-28%	-28%	-16%	-16%
China – South Central	-24%	-42%	-15%	-35%	-25%	-25%	-15%	-15%
China – Northeast	-16%	-36%	-12%	-33%	-28%	-28%	-16%	-16%
China – Northwest	-18%	-37%	-13%	-33%	-28%	-28%	-16%	-16%
China – Southern	-26%	-43%	-16%	-36%	-28%	-28%	-16%	-16%
Denmark	-35%	-66%	-19%	-57%	-19%	-19%	-13%	-13%
France	-56%	-82%	-30%	-72%	-23%	-23%	-15%	-15%
Germany	-24%	-78%	-15%	-75%	-17%	-17%	-13%	-13%
Italy	-29%	-88%	-18%	-86%	-24%	-24%	-16%	-16%
Netherlands	-20%	-78%	-14%	-77%	-16%	-16%	-13%	-13%
Spain	-29%	-89%	-18%	-88%	-22%	-22%	-16%	-16%
UK	-29%	-89%	-16%	-87%	-21%	-21%	-13%	-13%
Japan	-25%	-52%	-14%	-46%	-26%	-26%	-15%	-15%

Figure 43 – Hospital operational performance (Building of the Future vs conventional)

Hospital	CO_2				Energy Cost			
	Current Existing	Current New	2030 Existing	2030 New	Current Existing	2030 Existing	Current New	2030 New
Canada	-43%	-78%	-43%	-78%	-14%	-14%	-6%	-6%
US Midwest	-21%	-50%	-15%	-46%	-14%	-14%	-10%	-10%
US Northeast	-23%	-51%	-16%	-47%	-17%	-17%	-11%	-11%
US South	-24%	-52%	-17%	-47%	-18%	-18%	-14%	-14%
US West	-23%	-51%	-17%	-47%	-17%	-17%	-14%	-14%
China – North Central	-16%	-36%	-9%	-30%	-21%	-21%	-15%	-15%
China – Eastern	-19%	-38%	-11%	-32%	-27%	-27%	-17%	-17%
China – South Central	-19%	-38%	-11%	-32%	-22%	-22%	-12%	-12%
China – Northeast	-14%	-34%	-4%	-27%	-23%	-23%	-17%	-17%
China – Northwest	-15%	-35%	-7%	-29%	-23%	-23%	-18%	-18%
China – Southern	-20%	-39%	-11%	-32%	-27%	-27%	-15%	-15%
Denmark	-34%	-65%	-24%	-60%	-17%	-17%	-9%	-9%
France	-61%	-84%	-50%	-80%	-19%	-19%	-11%	-11%
Germany	-22%	-77%	-14%	-75%	-15%	-15%	-7%	-7%
Italy	-29%	-88%	-19%	-86%	-19%	-19%	-12%	-12%
Netherlands	-21%	-79%	-13%	-76%	-16%	-16%	-9%	-9%
Spain	-28%	-89%	-20%	-88%	-19%	-19%	-12%	-12%
UK	-29%	-89%	-18%	-87%	-16%	-16%	-8%	-8%
Japan	-22%	-51%	-13%	-45%	-25%	-25%	-15%	-15%

Figure 44 – Education operational performance (Building of the Future vs conventional)

Education	CO_2				Energy Cost			
	Current Existing	Current New	2030 Existing	2030 New	Current Existing	2030 Existing	Current New	2030 New
Canada	-65%	-87%	-72%	-89%	-17%	-17%	-53%	-53%
US Midwest	-32%	-57%	-61%	-75%	-22%	-22%	-58%	-58%
US Northeast	-34%	-58%	-63%	-76%	-24%	-24%	-60%	-60%
US South	-34%	-58%	-67%	-79%	-31%	-31%	-66%	-66%
US West	-34%	-58%	-72%	-82%	-28%	-28%	-71%	-71%
China – North Central	-22%	-41%	-46%	-59%	-33%	-33%	-50%	-50%
China – Eastern	-25%	-43%	-49%	-61%	-36%	-36%	-52%	-52%
China – South Central	-27%	-44%	-47%	-59%	-29%	-29%	-48%	-48%
China – Northeast	-14%	-35%	-38%	-53%	-36%	-36%	-47%	-47%
China – Northwest	-19%	-38%	-41%	-55%	-37%	-37%	-48%	-48%
China – Southern	-29%	-46%	-43%	-57%	-32%	-32%	-45%	-45%
Denmark	-53%	-75%	-63%	-80%	-20%	-20%	-52%	-52%
France	-80%	-92%	-80%	-92%	-25%	-25%	-62%	-62%
Germany	-33%	-80%	-55%	-87%	-14%	-14%	-51%	-51%
Italy	-37%	-90%	-58%	-93%	-28%	-28%	-54%	-54%
Netherlands	-30%	-81%	-51%	-87%	-20%	-20%	-48%	-48%
Spain	-39%	-91%	-60%	-94%	-26%	-26%	-57%	-57%
UK	-43%	-91%	-60%	-94%	-17%	-17%	-54%	-54%
Japan	-30%	-55%	-47%	-67%	-33%	-33%	-48%	-48%

Sensitivity analysis

As discussed above, we also performed simulations by accounting for the implementation of one solution at the time (active energy efficiency, heat electrification, onsite solar), in order to weigh the impact of each in consolidated results. The following graphs show the results for both existing buildings (e.g., retrofits) and new constructions, in the current context.

Figure 10 – CO_2 abatement per segment, and per key contribution, retrofits

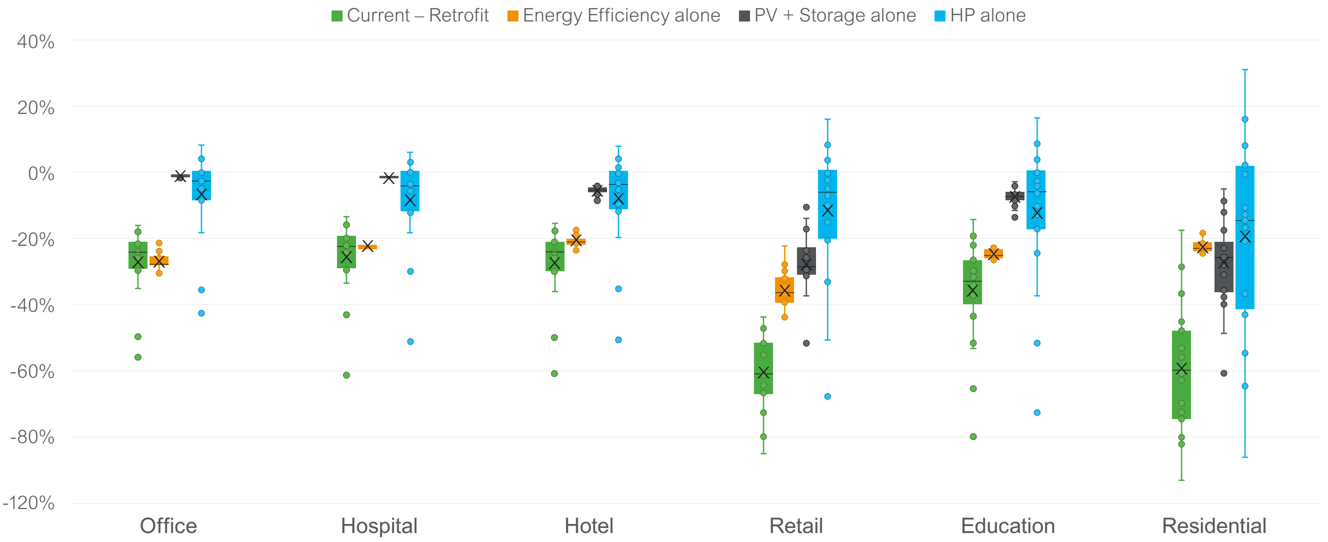


Figure 45 – CO_2 abatement per segment, and per key contribution, new constructions

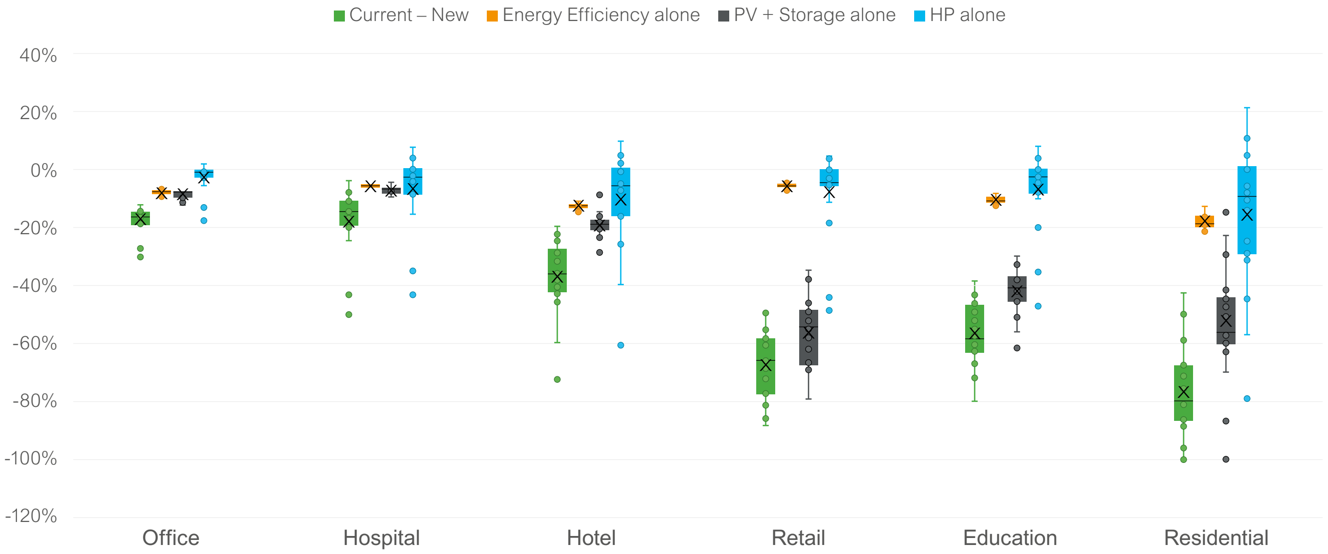


Figure 11 – Energy spend savings per segment, and per key contribution, retrofits

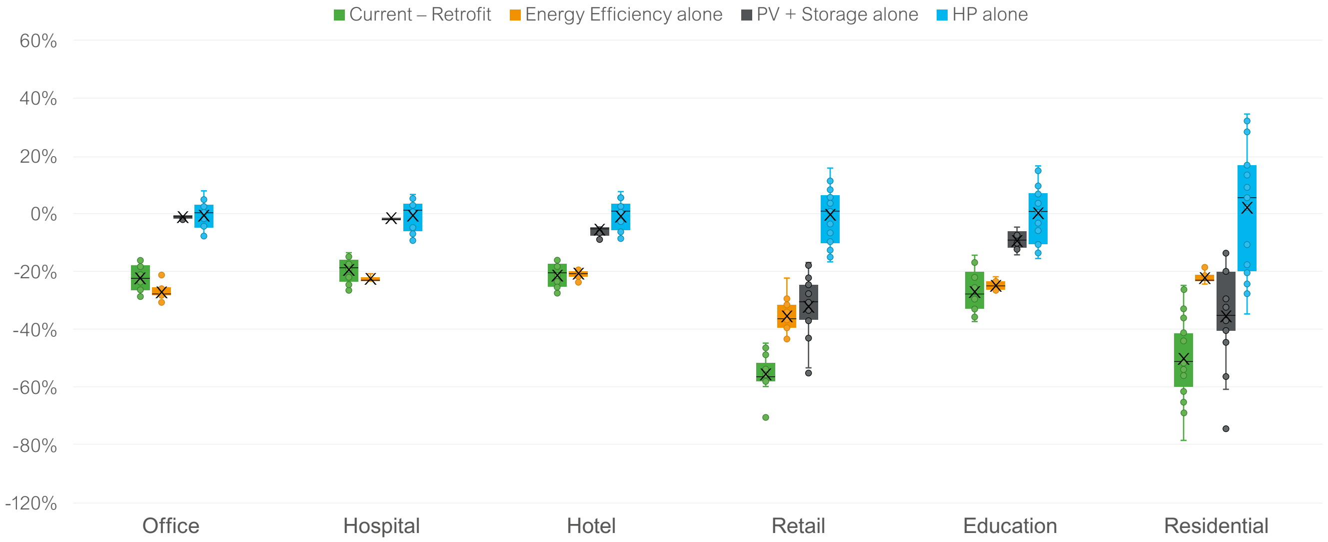
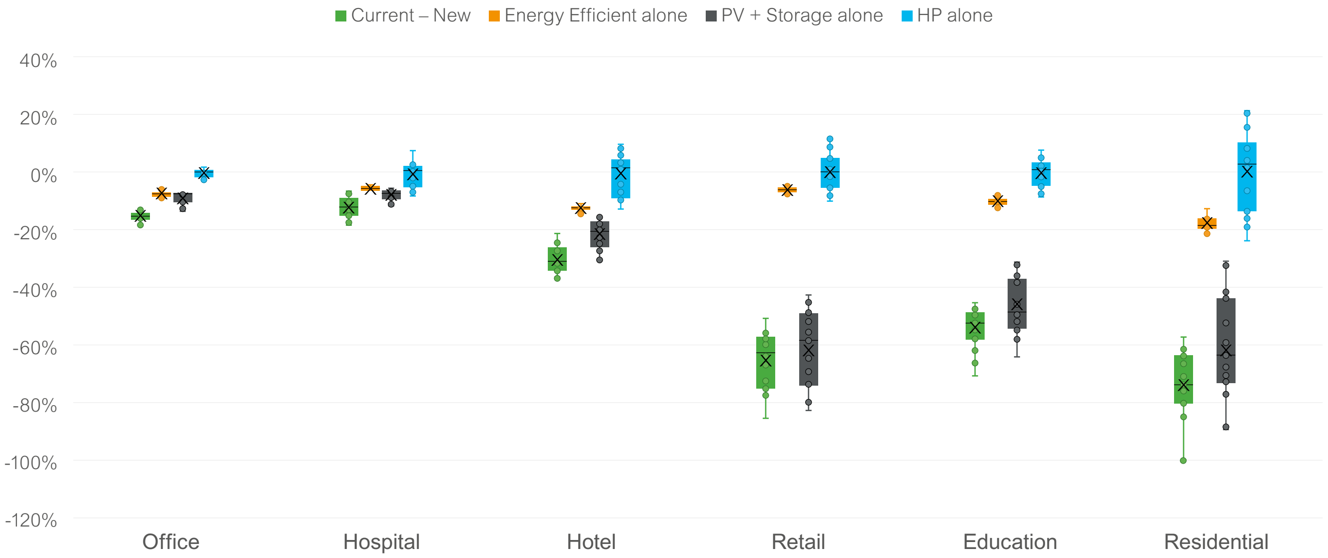


Figure 46 – Energy spend savings per segment, and per key contribution, new constructions



Economic performance

We look here at paybacks for retrofits and the impact of Buildings of the Future on total costs of acquisition for new acquisitions (new constructions, as well as retrofits happening at times of ownership transfer).

Paybacks in retrofits (years)

Figure 47 – Paybacks in years for retrofits, current scenario

Current	Office Retrofit	Hospital Retrofit	Retail Retrofit	Hotel Retrofit	Education Retrofit	Residential Retrofit
Canada	12.9	5.3	13.9	15.2	33.3	60.8
China – Eastern	8.4	1.7	6.1	8.7	8.0	13.9
China – North Central	12.0	4.1	14.6	11.4	19.4	29.8
China – Northeast	7.8	2.9	7.6	8.5	12.8	15.6
China – Northwest	9.4	3.4	9.8	9.9	15.0	21.6
China – South Central	9.5	2.2	7.4	11.0	9.5	36.7
China – Southern	9.2	1.9	5.7	9.5	6.2	32.7
Denmark	3.5	0.9	3.9	4.2	8.8	17.7
France	4.6	1.3	4.9	5.9	9.5	17.5
Germany	3.6	0.9	3.7	4.3	11.8	23.5
Italy	3.4	0.9	2.5	4.1	3.6	15.6
Japan	4.5	1.2	5.8	5.7	5.4	14.1
Netherlands	7.3	1.6	5.6	7.7	9.6	21.4
Spain	3.4	0.9	3.5	4.0	4.2	15.6
U.S. Midwest	13.5	4.7	13.0	15.0	18.8	60.6
U.S. Northeast	7.1	2.0	8.0	8.4	11.7	27.4
U.S. South	10.2	3.2	12.0	11.8	7.8	37.9
U.S. West	14.4	3.5	12.9	13.8	10.1	42.4
United Kingdom	6.1	1.9	7.7	8.8	18.7	41.3

Figure 48 – Paybacks in years for retrofits, 2030 scenario

2030	Office Retrofit	Hospital Retrofit	Retail Retrofit	Hotel Retrofit	Education Retrofit	Residential Retrofit
Canada	12.5	4.5	10.4	13.0	30.1	39.0
China – Eastern	8.3	1.7	5.4	8.4	7.8	10.2
China – North Central	11.9	3.9	12.3	11.0	18.9	20.9
China – Northeast	7.8	2.8	7.1	8.1	12.5	11.4
China – Northwest	9.3	3.3	8.8	9.6	14.6	15.4
China – South Central	9.4	2.1	5.9	10.6	9.1	26.0
China – Southern	9.1	1.8	4.8	9.2	5.9	23.6
Denmark	3.4	0.8	3.2	3.8	8.2	12.8
France	4.5	1.2	3.9	5.4	8.7	11.3
Germany	3.6	0.8	3.1	4.0	11.0	15.6
Italy	3.3	0.9	2.1	4.0	3.5	11.4
Japan	4.3	1.0	4.1	4.9	4.7	9.1
Netherlands	7.2	1.4	4.4	7.0	8.8	14.7
Spain	3.4	0.8	2.6	3.7	3.9	10.6
U.S. Midwest	13.0	4.0	9.0	13.0	16.3	38.8
U.S. Northeast	6.8	1.7	5.8	7.3	10.4	17.4
U.S. South	9.9	2.7	7.7	10.2	6.3	24.0
U.S. West	14.0	2.9	8.2	11.9	8.0	27.3
United Kingdom	5.9	1.7	6.0	8.0	16.9	29.1

Residential sensitivity analysis

In the following figure, we compare current results for our baseline residential case to two additional use cases, looking at the sensitivity when accounting for lower provisions of onsite solar (and consequently storage). In our baseline retrofit case, around 6kW of PV is deployed on the household's rooftop. We assess corresponding levels when accounting for 3kW and 1kW of PV (partial realization of the total potential) with their relevant storage system.

- Both CO_2 and energy spend savings tend to diminish; a natural outcome.
- The lower the carbon intensity of the grid electricity, the lower the impact on CO_2 savings; another expected outcome.
- A key finding is that while in some regions the reduced level of onsite solar and storage provisions tends to improve payback levels, this is not applicable across all geographies. This has to do with the complex equation of energy spend savings and actual upfront cost of deploying distributed solutions. The case is typically positive in China, but negative elsewhere.
- In general, however, the payback often remains unattractive, whatever the volume of onsite solar (and storage).

Figure 49 – Residential retrofit sensitivity analysis

Residential sensitivity	Current use case (6kW PV) CO_2	Current use case (6kW PV) Energy spend	Current use case (6kW PV) Paybacks	3kW PV CO_2	3kW PV Energy spend	3kW PV Paybacks	1kW PV CO_2	1kW PV Energy spend	1kW PV Paybacks	TREND
Canada	-80%	-27%	60.8	-76%	-11%	67.8	-73%	0%	No payback	-
China – Eastern	-45%	-65%	13.9	-30%	-55%	7.5	-20%	-49%	6.9	+
China – North Central	-37%	-53%	29.8	-24%	-44%	17.1	-15%	-37%	10.4	+
China – Northeast	-18%	-50%	15.6	-7%	-43%	8.4	0%	-39%	6.8	+
China – Northwest	-28%	-53%	21.6	-18%	-46%	11.7	-11%	-42%	7.8	+
China – South Central	-48%	-55%	36.7	-30%	-39%	23.5	-18%	-28%	19.0	+
China – Southern	-53%	-61%	32.7	-33%	-44%	19.1	-19%	-33%	19.0	+
Denmark	-75%	-36%	17.7	-69%	-21%	19.0	-65%	-11%	30.1	-
France	-93%	-51%	17.5	-91%	-33%	13.1	-89%	-21%	12.6	+
Germany	-55%	-25%	23.5	-44%	-7%	46.0	-37%	4%	No payback	-
Italy	-73%	-56%	15.6	-59%	-33%	13.8	-50%	-18%	18.5	-
Japan	-53%	-59%	14.1	-42%	-49%	8.7	-34%	-43%	6.4	+
Netherlands	-56%	-41%	21.4	-41%	-21%	20.5	-31%	-7%	42.1	-
Spain	-72%	-50%	15.6	-61%	-30%	12.6	-54%	-17%	12.5	=
U.S. Midwest	-62%	-44%	60.6	-43%	-16%	76.2	-31%	3%	No payback	-
U.S. Northeast	-61%	-44%	27.4	-47%	-25%	21.4	-39%	-13%	21.1	+
U.S. South	-74%	-68%	37.9	-50%	-38%	28.8	-34%	-18%	26.9	+
U.S. West	-82%	-78%	42.4	-52%	-41%	36.8	-32%	-16%	42.1	=
United Kingdom	-70%	-32%	41.3	-61%	-13%	55.9	-55%	0%	No payback	-

Impact on total cost of acquisition for both existing buildings and new constructions (% of total cost)(63)

Figure 50 – Share of additional cost, current scenario, USD 3,000/m² cost of acquisition

Current	Share of additional cost of acquisition – 3,000USD/m² TCO											
	Office Existing	Office New	Hospital Existing	Hospital New	Retail Existing	Retail New	Hotel Existing	Hotel New	Education Existing	Education New	Residential Existing	Residential New
Canada	1.1%	1.5%	1.3%	2.2%	8.0%	11.4%	2.0%	2.8%	3.9%	3.6%	9.2%	7.4%
China – Eastern	1.2%	1.3%	0.9%	1.6%	3.4%	3.1%	1.7%	2.1%	2.2%	1.9%	5.3%	4.9%
China – North Central	1.0%	1.2%	1.1%	1.7%	6.8%	9.7%	1.6%	2.0%	3.5%	3.1%	8.0%	7.1%
China – Northeast	1.0%	1.2%	1.0%	1.7%	5.0%	6.6%	1.6%	2.0%	3.4%	2.2%	5.8%	5.3%
China – Northwest	1.0%	1.2%	1.0%	1.7%	5.4%	8.6%	1.6%	2.0%	3.4%	2.6%	7.0%	6.3%
China – South Central	1.2%	1.3%	0.9%	1.7%	3.2%	7.7%	1.7%	2.1%	2.0%	2.3%	7.4%	6.7%
China – Southern	1.2%	1.4%	0.9%	1.8%	2.4%	5.3%	1.8%	2.2%	1.6%	2.1%	6.2%	5.8%
Denmark	1.1%	1.4%	0.9%	1.8%	5.9%	6.6%	1.9%	2.5%	3.1%	2.5%	9.2%	7.7%
France	1.2%	1.5%	1.0%	1.9%	5.1%	7.9%	1.9%	2.5%	2.6%	2.8%	7.6%	6.4%
Germany	1.1%	1.4%	0.9%	1.7%	5.4%	6.0%	1.8%	2.4%	3.0%	2.3%	7.9%	6.6%
Italy	1.2%	1.4%	1.0%	1.8%	3.4%	6.8%	1.8%	2.3%	2.2%	2.3%	8.4%	7.0%
Japan	1.2%	1.6%	1.1%	2.1%	6.2%	9.5%	2.1%	2.8%	2.8%	3.1%	9.4%	8.1%
Netherlands	1.3%	1.5%	1.0%	1.9%	5.1%	6.7%	2.0%	2.6%	2.5%	2.6%	6.8%	5.8%
Spain	1.2%	1.3%	0.9%	1.7%	5.0%	8.0%	1.7%	2.2%	2.3%	2.7%	9.0%	7.5%
U.S. Midwest	1.2%	1.6%	1.2%	2.2%	6.8%	10.0%	2.2%	2.9%	2.8%	3.3%	9.2%	7.4%
U.S. Northeast	1.1%	1.6%	1.1%	2.0%	7.1%	10.0%	2.0%	2.8%	3.3%	3.3%	9.1%	7.3%
U.S. South	1.4%	1.6%	1.2%	2.2%	7.3%	10.4%	2.1%	2.9%	1.9%	3.6%	9.8%	8.0%
U.S. West	1.3%	1.7%	1.2%	2.2%	7.6%	11.3%	2.1%	2.9%	1.8%	3.8%	10.3%	8.3%
United Kingdom	1.2%	1.5%	1.1%	2.0%	5.7%	6.9%	2.0%	2.7%	2.7%	2.7%	8.0%	6.5%

(63) For existing buildings retrofitted at time of ownership transfer, we compute the impact in terms of cost of acquisition.

Figure 51 – Share of additional cost, 2030 scenario, USD 3,000/m² cost of acquisition

	Share of additional cost of acquisition – 3,000USD/m² TCO											
2030	Office Existing	Office New	Hospital Existing	Hospital New	Retail Existing	Retail New	Hotel Existing	Hotel New	Education Existing	Education New	Residential Existing	Residential New
Canada	1.0%	1.3%	1.1%	1.8%	6.0%	7.4%	1.7%	2.3%	3.6%	2.7%	5.9%	4.6%
China – Eastern	1.2%	1.3%	0.8%	1.5%	3.0%	2.7%	1.6%	2.0%	2.1%	1.7%	3.9%	3.5%
China – North Central	1.0%	1.1%	1.1%	1.6%	5.8%	6.6%	1.5%	1.9%	3.4%	2.5%	5.6%	4.7%
China – Northeast	1.0%	1.2%	0.9%	1.6%	4.6%	5.1%	1.5%	1.9%	3.3%	2.0%	4.2%	3.7%
China – Northwest	1.0%	1.2%	0.9%	1.6%	4.8%	6.1%	1.5%	1.9%	3.3%	2.3%	5.0%	4.2%
China – South Central	1.2%	1.3%	0.8%	1.6%	2.5%	4.9%	1.7%	2.0%	1.9%	2.0%	5.2%	4.5%
China – Southern	1.2%	1.4%	0.9%	1.7%	2.0%	3.4%	1.7%	2.1%	1.5%	1.9%	4.5%	4.0%
Denmark	1.1%	1.3%	0.8%	1.7%	4.9%	4.8%	1.7%	2.2%	2.9%	2.1%	6.7%	5.4%
France	1.2%	1.4%	0.9%	1.7%	4.0%	5.3%	1.8%	2.3%	2.3%	2.3%	4.9%	4.0%
Germany	1.1%	1.3%	0.8%	1.6%	4.5%	4.4%	1.6%	2.1%	2.8%	2.0%	5.2%	4.3%
Italy	1.2%	1.4%	0.9%	1.7%	2.9%	4.7%	1.8%	2.2%	2.0%	2.1%	6.1%	4.9%
Japan	1.2%	1.4%	1.0%	1.8%	4.3%	5.8%	1.8%	2.3%	2.4%	2.3%	6.1%	5.1%
Netherlands	1.2%	1.4%	0.9%	1.7%	4.1%	4.8%	1.8%	2.3%	2.3%	2.2%	4.6%	3.9%
Spain	1.2%	1.3%	0.8%	1.5%	3.8%	5.1%	1.6%	2.0%	2.1%	2.1%	6.1%	4.8%
U.S. Midwest	1.2%	1.4%	1.0%	1.8%	4.7%	6.0%	1.9%	2.4%	2.4%	2.5%	5.9%	4.6%
U.S. Northeast	1.1%	1.4%	0.9%	1.7%	5.2%	6.3%	1.8%	2.3%	3.0%	2.4%	5.8%	4.5%
U.S. South	1.4%	1.4%	1.1%	1.8%	4.7%	6.1%	1.9%	2.4%	1.6%	2.6%	6.2%	4.9%
U.S. West	1.3%	1.5%	1.0%	1.9%	4.8%	6.7%	1.8%	2.4%	1.4%	2.7%	6.6%	5.1%
United Kingdom	1.2%	1.4%	1.0%	1.8%	4.4%	4.9%	1.8%	2.4%	2.4%	2.2%	5.6%	4.4%

Figure 52 – Share of additional cost, current scenario, USD 2,000/m² cost of acquisition

	Share of additional cost of acquisition – 2,000USD/m² TCO											
Current	Office Existing	Office New	Hospital Existing	Hospital New	Retail Existing	Retail New	Hotel Existing	Hotel New	Education Existing	Education New	Residential Existing	Residential New
Canada	1.6%	2.3%	1.9%	3.2%	12.0%	17.1%	3.0%	4.1%	5.9%	5.4%	13.8%	11.0%
China – Eastern	1.8%	1.9%	1.3%	2.4%	5.1%	4.7%	2.5%	3.1%	3.3%	2.8%	7.9%	7.4%
China – North Central	1.5%	1.8%	1.7%	2.5%	10.2%	14.6%	2.4%	3.0%	5.2%	4.7%	12.0%	10.6%
China – Northeast	1.5%	1.8%	1.5%	2.5%	7.5%	9.9%	2.3%	3.0%	5.1%	3.2%	8.7%	8.0%
China – Northwest	1.5%	1.8%	1.5%	2.5%	8.1%	12.8%	2.3%	3.0%	5.1%	4.0%	10.5%	9.4%
China – South Central	1.8%	2.0%	1.3%	2.5%	4.7%	11.6%	2.6%	3.2%	3.0%	3.5%	11.0%	10.0%
China – Southern	1.9%	2.2%	1.4%	2.7%	3.6%	7.9%	2.6%	3.2%	2.4%	3.1%	9.3%	8.7%
Denmark	1.7%	2.2%	1.4%	2.8%	8.9%	9.8%	2.8%	3.8%	4.7%	3.8%	13.8%	11.5%
France	1.8%	2.2%	1.5%	2.9%	7.6%	11.8%	2.9%	3.8%	3.8%	4.2%	11.4%	9.7%
Germany	1.6%	2.1%	1.3%	2.6%	8.1%	8.9%	2.7%	3.6%	4.5%	3.5%	11.8%	9.9%
Italy	1.8%	2.1%	1.5%	2.7%	5.1%	10.1%	2.8%	3.5%	3.2%	3.4%	12.6%	10.5%
Japan	1.9%	2.4%	1.7%	3.2%	9.3%	14.3%	3.2%	4.3%	4.2%	4.6%	14.1%	12.2%
Netherlands	1.9%	2.3%	1.6%	2.9%	7.7%	10.1%	3.0%	3.9%	3.8%	3.8%	10.1%	8.7%
Spain	1.8%	2.0%	1.3%	2.5%	7.6%	12.0%	2.6%	3.3%	3.4%	4.1%	13.5%	11.2%
U.S. Midwest	1.8%	2.5%	1.8%	3.2%	10.2%	15.1%	3.2%	4.3%	4.2%	5.0%	13.9%	11.1%
U.S. Northeast	1.7%	2.4%	1.6%	3.1%	10.6%	14.9%	3.1%	4.2%	5.0%	4.9%	13.6%	10.9%
U.S. South	2.1%	2.4%	1.9%	3.2%	10.9%	15.7%	3.2%	4.3%	2.9%	5.4%	14.8%	12.0%
U.S. West	2.0%	2.6%	1.8%	3.3%	11.4%	17.0%	3.2%	4.4%	2.7%	5.7%	15.4%	12.5%
United Kingdom	1.8%	2.3%	1.6%	3.0%	8.5%	10.4%	3.0%	4.0%	4.0%	4.0%	12.0%	9.7%

Figure 53 – Share of additional cost, 2030 scenario, USD 2,000/m² cost of acquisition

	Share of additional cost of acquisition – 2,000USD/m² TCO											
2030	Office Existing	Office New	Hospital Existing	Hospital New	Retail Existing	Retail New	Hotel Existing	Hotel New	Education Existing	Education New	Residential Existing	Residential New
Canada	1.5%	2.0%	1.6%	2.7%	9.0%	11.1%	2.5%	3.4%	5.3%	4.0%	8.9%	6.8%
China – Eastern	1.8%	1.9%	1.2%	2.3%	4.5%	4.0%	2.5%	3.0%	3.2%	2.6%	5.9%	5.3%
China – North Central	1.5%	1.7%	1.6%	2.4%	8.6%	9.9%	2.3%	2.9%	5.1%	3.7%	8.4%	7.0%
China – Northeast	1.5%	1.8%	1.4%	2.4%	6.9%	7.6%	2.2%	2.9%	5.0%	3.0%	6.3%	5.6%
China – Northwest	1.5%	1.8%	1.4%	2.4%	7.2%	9.2%	2.2%	2.9%	5.0%	3.4%	7.5%	6.4%
China – South Central	1.8%	1.9%	1.3%	2.4%	3.8%	7.3%	2.5%	3.0%	2.9%	3.0%	7.8%	6.7%
China – Southern	1.8%	2.1%	1.3%	2.6%	3.0%	5.1%	2.5%	3.1%	2.3%	2.9%	6.7%	6.0%
Denmark	1.6%	2.0%	1.3%	2.5%	7.3%	7.2%	2.6%	3.3%	4.4%	3.2%	10.0%	8.1%
France	1.8%	2.0%	1.4%	2.6%	6.0%	7.9%	2.7%	3.4%	3.5%	3.4%	7.4%	6.1%
Germany	1.6%	1.9%	1.2%	2.4%	6.7%	6.6%	2.5%	3.2%	4.2%	3.0%	7.8%	6.4%
Italy	1.8%	2.0%	1.4%	2.6%	4.3%	7.0%	2.6%	3.3%	3.1%	3.1%	9.2%	7.3%
Japan	1.8%	2.1%	1.4%	2.6%	6.5%	8.8%	2.7%	3.5%	3.6%	3.5%	9.2%	7.6%
Netherlands	1.9%	2.1%	1.4%	2.6%	6.1%	7.2%	2.7%	3.4%	3.4%	3.3%	7.0%	5.8%
Spain	1.8%	1.9%	1.2%	2.3%	5.7%	7.6%	2.5%	3.0%	3.2%	3.2%	9.2%	7.2%
U.S. Midwest	1.8%	2.2%	1.5%	2.7%	7.0%	9.0%	2.8%	3.6%	3.7%	3.7%	8.9%	6.9%
U.S. Northeast	1.6%	2.0%	1.3%	2.6%	7.7%	9.4%	2.6%	3.5%	4.5%	3.6%	8.7%	6.7%
U.S. South	2.1%	2.1%	1.6%	2.7%	7.0%	9.2%	2.8%	3.6%	2.3%	4.0%	9.4%	7.3%
U.S. West	2.0%	2.3%	1.5%	2.8%	7.2%	10.0%	2.8%	3.6%	2.2%	4.1%	9.9%	7.7%
United Kingdom	1.8%	2.1%	1.4%	2.7%	6.6%	7.4%	2.8%	3.5%	3.6%	3.4%	8.5%	6.7%

Figure 54 – Share of additional cost, current scenario, USD 5,000/m² cost of acquisition

	Share of additional cost of acquisition – 5,000USD/m² TCO											
Current	Office Existing	Office New	Hospital Existing	Hospital New	Retail Existing	Retail New	Hotel Existing	Hotel New	Education Existing	Education New	Residential Existing	Residential New
Canada	0.6%	0.9%	0.8%	1.3%	4.8%	6.8%	1.2%	1.7%	2.4%	2.1%	5.5%	4.4%
China – Eastern	0.7%	0.8%	0.5%	1.0%	2.0%	1.9%	1.0%	1.3%	1.3%	1.1%	3.2%	3.0%
China – North Central	0.6%	0.7%	0.7%	1.0%	4.1%	5.8%	1.0%	1.2%	2.1%	1.9%	4.8%	4.2%
China – Northeast	0.6%	0.7%	0.6%	1.0%	3.0%	3.9%	0.9%	1.2%	2.0%	1.3%	3.5%	3.2%
China – Northwest	0.6%	0.7%	0.6%	1.0%	3.2%	5.1%	0.9%	1.2%	2.0%	1.6%	4.2%	3.8%
China – South Central	0.7%	0.8%	0.5%	1.0%	1.9%	4.6%	1.0%	1.3%	1.2%	1.4%	4.4%	4.0%
China – Southern	0.7%	0.9%	0.6%	1.1%	1.4%	3.2%	1.1%	1.3%	1.0%	1.2%	3.7%	3.5%
Denmark	0.7%	0.9%	0.6%	1.1%	3.6%	3.9%	1.1%	1.5%	1.9%	1.5%	5.5%	4.6%
France	0.7%	0.9%	0.6%	1.1%	3.1%	4.7%	1.2%	1.5%	1.5%	1.7%	4.6%	3.9%
Germany	0.7%	0.8%	0.5%	1.0%	3.2%	3.6%	1.1%	1.4%	1.8%	1.4%	4.7%	3.9%
Italy	0.7%	0.8%	0.6%	1.1%	2.0%	4.1%	1.1%	1.4%	1.3%	1.4%	5.0%	4.2%
Japan	0.7%	1.0%	0.7%	1.3%	3.7%	5.7%	1.3%	1.7%	1.7%	1.8%	5.7%	4.9%
Netherlands	0.8%	0.9%	0.6%	1.2%	3.1%	4.0%	1.2%	1.5%	1.5%	1.5%	4.1%	3.5%
Spain	0.7%	0.8%	0.5%	1.0%	3.0%	4.8%	1.0%	1.3%	1.4%	1.6%	5.4%	4.5%
U.S. Midwest	0.7%	1.0%	0.7%	1.3%	4.1%	6.0%	1.3%	1.7%	1.7%	2.0%	5.5%	4.4%
U.S. Northeast	0.7%	0.9%	0.6%	1.2%	4.2%	6.0%	1.2%	1.7%	2.0%	2.0%	5.5%	4.4%
U.S. South	0.8%	1.0%	0.7%	1.3%	4.4%	6.3%	1.3%	1.7%	1.2%	2.2%	5.9%	4.8%
U.S. West	0.8%	1.0%	0.7%	1.3%	4.5%	6.8%	1.3%	1.7%	1.1%	2.3%	6.2%	5.0%
United Kingdom	0.7%	0.9%	0.7%	1.2%	3.4%	4.2%	1.2%	1.6%	1.6%	1.6%	4.8%	3.9%

Figure 55 – Share of additional cost, 2030 scenario, USD 5,000/m² cost of acquisition

	Share of additional cost of acquisition – 5,000USD/m² TCO											
2030	Office Existing	Office New	Hospital Existing	Hospital New	Retail Existing	Retail New	Hotel Existing	Hotel New	Education Existing	Education New	Residential Existing	Residential New
Canada	0.6%	0.8%	0.6%	1.1%	3.6%	4.4%	1.0%	1.4%	2.1%	1.6%	3.5%	2.7%
China – Eastern	0.7%	0.8%	0.5%	0.9%	1.8%	1.6%	1.0%	1.2%	1.3%	1.0%	2.3%	2.1%
China – North Central	0.6%	0.7%	0.6%	1.0%	3.5%	4.0%	0.9%	1.2%	2.0%	1.5%	3.4%	2.8%
China – Northeast	0.6%	0.7%	0.6%	1.0%	2.8%	3.1%	0.9%	1.1%	2.0%	1.2%	2.5%	2.2%
China – Northwest	0.6%	0.7%	0.6%	1.0%	2.9%	3.7%	0.9%	1.1%	2.0%	1.4%	3.0%	2.5%
China – South Central	0.7%	0.8%	0.5%	1.0%	1.5%	2.9%	1.0%	1.2%	1.1%	1.2%	3.1%	2.7%
China – Southern	0.7%	0.8%	0.5%	1.0%	1.2%	2.1%	1.0%	1.2%	0.9%	1.2%	2.7%	2.4%
Denmark	0.7%	0.8%	0.5%	1.0%	2.9%	2.9%	1.0%	1.3%	1.7%	1.3%	4.0%	3.3%
France	0.7%	0.8%	0.6%	1.0%	2.4%	3.2%	1.1%	1.4%	1.4%	1.4%	3.0%	2.4%
Germany	0.6%	0.8%	0.5%	0.9%	2.7%	2.6%	1.0%	1.3%	1.7%	1.2%	3.1%	2.6%
Italy	0.7%	0.8%	0.5%	1.0%	1.7%	2.8%	1.1%	1.3%	1.2%	1.2%	3.7%	2.9%
Japan	0.7%	0.8%	0.6%	1.1%	2.6%	3.5%	1.1%	1.4%	1.4%	1.4%	3.7%	3.0%
Netherlands	0.7%	0.9%	0.6%	1.0%	2.4%	2.9%	1.1%	1.4%	1.4%	1.3%	2.8%	2.3%
Spain	0.7%	0.8%	0.5%	0.9%	2.3%	3.0%	1.0%	1.2%	1.3%	1.3%	3.7%	2.9%
U.S. Midwest	0.7%	0.9%	0.6%	1.1%	2.8%	3.6%	1.1%	1.4%	1.5%	1.5%	3.6%	2.7%
U.S. Northeast	0.7%	0.8%	0.5%	1.0%	3.1%	3.8%	1.1%	1.4%	1.8%	1.5%	3.5%	2.7%
U.S. South	0.8%	0.8%	0.6%	1.1%	2.8%	3.7%	1.1%	1.4%	0.9%	1.6%	3.7%	2.9%
U.S. West	0.8%	0.9%	0.6%	1.1%	2.9%	4.0%	1.1%	1.4%	0.9%	1.6%	4.0%	3.1%
United Kingdom	0.7%	0.8%	0.6%	1.1%	2.6%	2.9%	1.1%	1.4%	1.5%	1.3%	3.4%	2.7%

Additional data on energy efficiency

The model also consolidates, as an intermediary output, the levels of energy efficiency across the different building archetypes and regions discussed above. While this study has focused on carbon abatement and economic performance, we also reproduce key results in terms of energy efficiency.

Figure 56 – Levels of energy efficiency, across buildings and regions

	Office		Hospital		Retail		Hotel		Education		Residential	
Energy Efficiency	Existing	New	Existing	New	Existing	New	Existing	New	Existing	New	Existing	New
Canada	-39%	-13%	-32%	-26%	-55%	-33%	-35%	-33%	-49%	-30%	-60%	-51%
US Midwest	-26%	-10%	-28%	-12%	-38%	-24%	-25%	-24%	-33%	-18%	-48%	-35%
US Northeast	-34%	-11%	-31%	-17%	-49%	-20%	-31%	-30%	-42%	-23%	-60%	-48%
US South	-25%	-10%	-31%	-11%	-24%	-12%	-23%	-24%	-26%	-17%	-45%	-31%
US West	-24%	-8%	-31%	-11%	-33%	-35%	-24%	-23%	-32%	-15%	-41%	-27%
China – North Central	-32%	-15%	-30%	-24%	-49%	-36%	-31%	-30%	-45%	-25%	-61%	-48%
China – Eastern	-31%	-10%	-31%	-16%	-44%	-6%	-29%	-28%	-38%	-19%	-59%	-45%
China – South Central	-30%	-9%	-30%	-13%	-36%	-28%	-26%	-25%	-33%	-18%	-50%	-36%
China – Northeast	-38%	-13%	-32%	-24%	-54%	-18%	-34%	-32%	-47%	-28%	-57%	-48%
China – Northwest	-39%	-13%	-33%	-27%	-56%	-27%	-36%	-34%	-50%	-30%	-62%	-52%
China – Southern	-29%	-10%	-30%	-11%	-31%	-13%	-25%	-23%	-29%	-15%	-34%	-27%
Denmark	-34%	-11%	-32%	-17%	-49%	-20%	-31%	-30%	-46%	-23%	-61%	-50%
France	-31%	-10%	-31%	-15%	-44%	-18%	-29%	-28%	-42%	-19%	-61%	-46%
Germany	-34%	-11%	-32%	-17%	-49%	-20%	-31%	-30%	-46%	-24%	-61%	-50%
Italy	-30%	-9%	-31%	-13%	-36%	-10%	-26%	-25%	-33%	-18%	-51%	-36%
Netherlands	-29%	-10%	-32%	-15%	-42%	-28%	-27%	-26%	-40%	-23%	-55%	-42%
Spain	-31%	-10%	-32%	-16%	-44%	-7%	-29%	-29%	-39%	-19%	-60%	-46%
UK	-31%	-10%	-31%	-15%	-44%	-7%	-28%	-28%	-42%	-19%	-60%	-46%
Japan	-31%	-10%	-31%	-15%	-44%	-21%	-28%	-28%	-38%	-19%	-59%	-45%

Bibliography

1. Birol F. (2021). COP26 climate pledges could help limit global warming to 1.8°C, but implementing them will be the key. © OECD/IEA. Accessed: January 2022.
https://www.iea.org/commentaries/cop26-climate-pledges-could-help-limit-global-warming-to-1-8-c-but-implementing-them-will-be-the-key

2. BloombergNEF (2019). New Energy Outlook. Accessed: November 2019.
https://about.bnef.com/product/

3. BloombergNEF (2020). Heating Unit Economics Calculator (HUEC 1.0.3). Accessed: January 2021
https://www.bnef.com/insights/23797

4. BloombergNEF (2021). Realizing the potential of customer-sited solar. Accessed: September 2021.
https://about.bnef.com/blog/careful-policy-design-could-unlock-massive-rooftop-solar-market-around-the-world/

5. Energiesprong (2022). This Dutch construction innovation shows it's possible to quickly retrofit every building. Accessed: March 2022.
https://energiesprong.org/this-dutch-construction-innovation-shows-its-possible-to-quickly-retrofit-every-building/

6. European Commission (2022). Energy Poverty. Accessed: May 2022.
https://ec.europa.eu/energy/eu-buildings-factsheets-topics-tree/energy-poverty_en

7. European Environment Agency (2021). Greenhouse gas emission intensity of electricity generation in Europe. Accessed: September 2021.
https://www.eea.europa.eu/data-and-maps/indicators/overview-of-the-electricity-production-3/assessment

8. Gates B. (2021). How to avoid a climate disaster: the solutions we have and the breakthroughs we need. Random House Large Print

9. IPCC (2022). 6th assessment report. Accessed: April 2022.
https://www.ipcc.ch/assessment-report/ar6/

10. IRENA (2020). Renewable Power Generation Costs in 2020. Accessed: January 2022.
https://www.irena.org/publications/2021/Jun/Renewable-Power-Costs-in-2020

11. Keiner D., Ram M., De Souza Noel Simas Barbosa L., Bogdanov D., Breyer C. (2019). Cost optimal self-consumption of PV prosumers with stationary batteries, heat pumps, thermal energy storage and electric vehicles across the world up to 2050. Elsevier. Accessed: May 2020.
https://www.semanticscholar.org/paper/Cost-optimal-self-consumption-of-PV-prosumers-with-Keiner-Ram/e461099b8788776a7070118e67f6862baaf947d5

12. Nossent P. (2019). Un bâtiment durable certifié rapporte plus, à plus de monde et plus longtemps. La Tribune. Based on analysis from MSCI IPD index.
https://www.latribune.fr/opinions/tribunes/un-batiment-durable-certifie-rapporte-plus-a-plus-de-monde-et-plus-longtemps-834939.html

13. NREL (2011). U.S. Department of Energy Commercial Reference Building Models of the National Building Stock. Technical report NREL/TP-5500-46861. Accessed: May 2021.
https://www.nrel.gov/docs/fy11osti/46861.pdf

14. NREL (2021), US Solar Photovoltaic System and Energy Storage Cost benchmark: Q1 2020. Accessed: May 2021.
https://www.nrel.gov/docs/fy21osti/77324.pdf

15. ©OECD/IEA (2021). World Energy Outlook. Accessed: November 2021.
https://www.iea.org/reports/world-energy-outlook-2021

16. Shell (2018). Sky scenario.
https://www.shell.com/energy-and-innovation/the-energy-future/scenarios/shell-scenario-sky.html

17. Schneider Electric (2021). Cracking the Energy Efficiency Case in Buildings. Schneider Electric™ Sustainability Research Institute. Accessed: October 2021.
https://www.se.com/ww/en/insights/sustainability/sustainability-research-institute/

18. Schneider Electric (b) (2021). Building Heat Decarbonization. Schneider Electric™ Sustainability Research Institute. Accessed: September 2021.
https://www.se.com/ww/en/insights/sustainability/sustainability-research-institute/

19. Schneider Electric (c) (2021). Electric Vehicle Smart Charging in Buildings. Schneider Electric™ Sustainability Research Institute. Accessed: November 2021.
https://www.se.com/ww/en/insights/sustainability/sustainability-research-institute/

20. Schneider Electric (2022). The unexpected disruption: distributed generation. Schneider Electric™ Sustainability Research Institute. Accessed: January 2022.
https://www.se.com/ww/en/insights/sustainability/sustainability-research-institute/

21. US Department of Energy (2021). Commercial Reference Buildings. Office of Energy Efficiency and Renewable Energy. Accessed: May 2021.
https://www.energy.gov/eere/buildings/commercial-reference-buildings

22. US Department of Energy (b) (2021). Prototype Building Models. Building Energy Codes Program. Accessed: May 2021.
https://www.energy.gov/eere/buildings/commercial-reference-buildings

23. US Department of Energy (2022). Low-income community energy solutions. Accessed: May 2022.
https://www.energy.gov/eere/slsc/low-income-community-energy-solutions

24. Wehrmann B. (2022) German consumers experience biggest rise ever in gas and power prices in 2021. Accessed: March 2022.
https://www.cleanenergywire.org/news/german-consumers-experience-biggest-rise-ever-gas-and-power-prices-2021

25. World Green Building Council (2016). About Green Building. Accessed: January 2022.
https://www.worldgbc.org/benefits-green-buildings

Author

Vincent Petit, SVP Climate and Energy Transition Research, head of the Sustainability Research Institute, Schneider Electric

Remi Paccou, Director Sustainability Research, Schneider Electric

Vincent Minier, VP Energy Transition Research, Schneider Electric

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