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Sustainability Research Institute

Cracking the Energy Efficiency case in Buildings

How to rapidly tame carbon emissions in buildings around the world?

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In this white paper, we take a second look at alternative ways to provide significant and rapid carbon abatement within the building stock. Traditionally considered a key lever to decarbonization, energy efficiency efforts have often fallen short in recent decades. Fortunately, digital technologies offer a new toolbox which, according to our modelling, can bring 20-30 percent carbon abatement, with highly competitive paybacks, below 8 years in average, removing some of the major hurdles which have hampered the development of energy efficiency measures so far.

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Executive summary

Energy efficiency is widely considered a critical option to accelerate the decarbonization of the economy by 2050. Despite this, efforts to accelerate building renovations have often fallen short globally, and results have generally been disappointing (with some notable exceptions in select countries).

There are several reasons to this, ranging from lack of data and monitoring, proper standards, financing and rebound effects on demand. In this report, we take stock of these issues and explore to which extent digital technologies could help remove some of the largest roadblocks identified and provide an alternative pathway to rapid efficiency gains, and secure the collective effort toward a net-zero building stock by 2050.

Through a detailed modelling analysis assessing different building archetypes in 19 regions of the world (and over 1,300 simulations), we find that digital technologies can bring 20-30 percent carbon abatement across the entire existing building stock with paybacks generally well below 8 years and no rebound effect, a compelling proposition for rapid adoption. Moreover, these paybacks could in fact be even lower as we consider the already ongoing digitalization of building premises for other purposes than energy efficiency.

This reports thus concludes that digital solutions are key to the rapid decarbonization of buildings, and could bring significant benefits, often underestimated by conventional research. In short, there is a way to decarbonize faster and in a more affordable manner than often suggested, and it implies to embrace modern solutions to crack modern issues.

Building decarboniza-tion: there is a problem to crack

A big issue, possibly getting bigger

The current global building stock stands at around 224 billion square meters, a figure which is expected to nearly double to around 415 billion square meters by 2050[1].

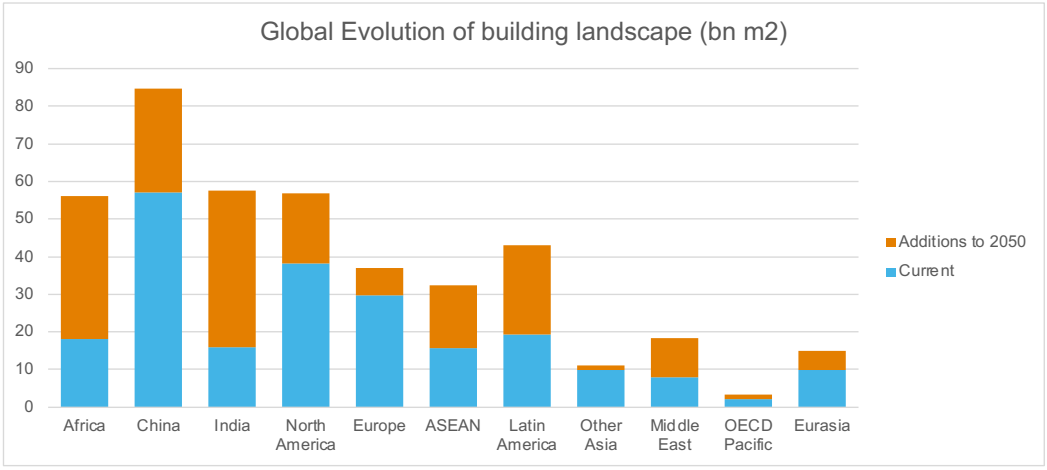


Figure 1 – Global evolution of building landscape

In terms of global emissions, the current building stock accounts for around 20 percent of global greenhouse gas emissions, or around 10GtCO2e/y, if we focus on the use phase only. This figure increases to around 30 percent when accounting for emissions from upstream activities[2].

Not only these emissions need to be zeroed by 2050 for the world to stay on a course consistent with a 1.5-degree pathway, but the significant expected growth of the stock should also come with net-zero additional emissions[3].

The building sector therefore faces a major challenge going forward, aggravated by the natural fragmentation of the sector, the variety of situations and starting points in different geographies, which have so far led this industry to limited progress and productivity gains globally[4].

Why energy efficiency is key, and why it did not work so far

The widely agreed pathway to decarbonize buildings revolves around two key transformations: clean electrification of building uses (e.g. heating) ; and a more efficient building stock[5].

The International Energy Agency, in its net zero emission scenario for 2050, estimates both to contribute around 80 percent of the total effort, the remainder stemming from the switch to bioenergy and other forms of renewable sources. Such a transition would require above 85 percent of the existing building stock to be retrofitted by 2050, and all new buildings to be zero-carbon from 2030 onwards. This would lead to 10 times

1 FEMM (2019), Roadmap to 2050 ; © OECD/IEA (2013), Technology Roadmap Energy Efficient Building envelopes ; © OECD/IEA (b) (2013), Transition to Sustainable Buildings ; UN Environment Program (2016), Towards zero-emission efficient and resilient buildings. Global Status Report ; Schneider Electric Research

2 Climate Watch (2021), greenhouse gas emissions ; Schneider Electric Research. If we focus on energy-related emissions only, buildings represent around 40 percent of total.

3 The Net Zero Emissions scenario from the International Energy Agency plans on a reduction of 95 percent of building emissions by 2050 (direct emissions only, not accounting for electricity and construction). © OECD/IEA (2021), Net Zero by 2050.

4 Cilia J. (2019), The Construction Labor Shortage: Will Developers Deploy Robotics? ; McKinsey (2017), Reinventing construction: a route to higher productivity

5 IPCC (2014), Synthesis Report AR5 ; © OECD/IEA (2021), Net Zero by 2050 ; Schneider Electric (2021), The 2030 Imperative ; Schneider Electric (b) (2021), Building Heat Decarbonization

more heat pumps installed than today, and over 7,500TWh of electricity generated from rooftop solar[6].

Energy efficiency, the topic of this report, is thus expected to play a major role in overall decarbonization of the building stock. In fact, the International Energy Agency estimates that overall building energy demand could be in 2050 20-30 percent lower than today, despite significant growth of the stock.

All this is widely acknowledged and takes another dimension when considering that such massive growth would lead to significant additional investments on the supporting energy infrastructure (potentially further aggravated by increases in peak demand stemming from electrification[7]).

While building energy efficiency is key, one could argue however that most attempts have so far shown little success at global level. The European Union is an interesting example, with significant policy efforts over the last decades, culminating with the recent Building Renovation Wave Strategy in 2020[8].

There are several reasons for this. First, there has been generally a lack of data and monitoring over a fragmented sector, combined with lagging standards on renovation, even though the global building stock would be today 30 percent more efficient than two decades ago[9].

A second issue has to do with lack of performance standards, a problem highly recognized at the European Union level, since it has remained to date a national competency, leading to misallocations of funds[10]. In this regard, some countries such as Ireland, Portugal or Spain have typically performed much better than others, with up to 4 times the annual energy intensity improvement of laggards.

A third issue relates to costs and availability of financing for such renovations. Traditional renovations show indeed paybacks in excess of 15 years in average, a non-starter for most private investors and household owners[11]. Public financing appears thus to be paramount. At the EU level, an annual 185 billion euros financing gap has been identified. Despite analyses showing the theoretical high level of return on investment, the sheer size of the funds required has generally prevented its implementation by public authorities[12]. Some studies show that the funds made available as a result of the Covid-19 pandemic offer a new opportunity to trigger such policy, with over 600 billion euros made available across the European Union for climate actions, but again the effective allocation of this budget to building renovation remains to be confirmed in many countries, as it competes against other priorities, and there are both concerns and disagreements over how best to use it[13].

6 Ibid

7 See for instance NREL (2018), Electrification Futures Study: Scenarios of Electric Technology Adoption and Power Consumption for the United States. The topic of increased peak demand remains however controversial, given the variety of solutions to mitigate it and different patterns of load profiles across regions, a topic which is out of the focus of this report.

8 European Commission (2020), Renovation Wave

9 For households only. Voita (2020), The Renovation Wave. A make or break for the European Green Deal

10 European Commission (2020), Renovation Wave ; Keating (2020), EU renovation wave needs standards and cash

11 © OECD/IEA (2012), Building Shell and Thermal Insulation

12 Renovate Europe (2021), Building renovation : a kick starter for the EU economy. The analysis shows that 1 million Euros invested yields in average 18 jobs created, and that each euro invested provides 0.62 euros returns to the government within one year, not accounting for significant indirect benefits, notably on health spendings.

13 Keating (2020), EU renovation wave needs standards and cash ; Renovate Europe (2021), Building renovation : a kick starter for the EU economy ; Wehrmann (2020), German industry welcomes EU buildings renovation wave but houseowners lament high costs

As a result of such hurdles, the renovation effort on buildings has so far remained low. In the European Union, the weighted energy renovation rate is estimated to range around 1 percent, a very low annual improvement rate. Deep energy renovations, which provide over 60 percent energy savings, amount to less than 0.2-0.3 percent of stock turnover per year[14]. This figure should be an order of magnitude higher to meet climate goals by 2050. In short, despite commendable efforts and local successes, the renovation of buildings in one of the most committed regions of the world on the topic has so far fallen short.

There is also a more pernicious effect of traditional building renovations and their impact on energy efficiency: that of rebound of demand. The more efficient a building, the lower the costs of energy, the more the demand.

The issue is well-known and has been studied by researchers for a long time[15]. While there are still debates on key drivers and actual levels of rebound within the scientific community[16], recent examples, such as the last wave of renovations of households in Germany tend to indicate rebound is a key limiting factor of massive energy efficiency programs, at least in the residential sector[17].

From all this we can thus conclude the following: energy efficiency is a key driver of decarbonization, this is widely acknowledged. There are several hurdles to the proper deployment of energy efficiency measures in buildings, ranging from lack of data, standards, and financing, and the key limiting factor of rebound effects, which compensate part of the savings realized.

These issues help shed light on why the deployment of energy efficiency measures has so far shown little success globally and continue to hamper the route toward net-zero in buildings. In other words, a new approach is needed.

14 European Commission (2019), Comprehensive study of building energy renovation activities and the uptake of nearly zero-energy buildings in the EU

15 See for instance work from Frondel et al (2008), Identifying the Rebound: Evidence from a German Household Panel

16 Gillingham et al (2015), The Rebound Effect and Energy Efficiency Policy ; Colemares et al (2019), The rebound effect and its representation in energy and climate models

17 Federal Association of German Housing and Propterty Companies (2020), Annual Report

Why not crack modern problems with modern solutions?

A new toolbox for efficiency

A new approach to the problem of energy efficiency in buildings is thus required. Fortunately, the toolbox of solutions available has also improved, notably thanks to the growing penetration of digital technologies within building premises.

Digital efficiency solutions are of a different nature than conventional solutions, and in fact complement each other.

Conventional solutions (also referred to as passive efficiency) include works on envelopes (external, cavity or interior insulation works), on roofs and floors, as well as on windows, and appliances performance (notably for heating, cooling, ventilation or lighting). Paybacks are generally in excess of 15 years as they often imply large material works and long hours at job sites (in particular for works on envelopes)[18]. These solutions essentially focus on reducing the baseline energy demand (energy demand with similar patterns of use), by optimizing thermal exchanges between the building and the environment (reducing leakages, while still providing for the appropriate ventilation), and the efficiency of appliances installed (minimizing energy waste). With growing comfort and lower energy bills, these baseline reductions also tend – as discussed above – to yield rebound effects on demand.

Digital technologies focus on energy uses, not baseline demand. They adjust energy demand by defining setpoints and optimizing for space and time occupancy. The greater flexibility in building use, the more savings[19]. These technologies thus act on a different stream of energy inefficiencies than conventional solutions, that of final uses. More importantly, they help mitigate natural rebound effects (a key point!), by the real-time nature of their operation. Both approaches are thus largely complementary.

What is unfortunate however is that their deployment has attracted little attention so far, despite the key hurdles described above. Time thus to embrace this new set of technologies and understand what reasonably could be expected from them. In other words: crack modern problems with modern solutions.

A toolbox with a potential we can assess with precision

The purpose of this report is to provide quantified and credible evidence of the potential of these technologies, for the global community of corporate, investors and policymakers to use as a reference.

A lot has already been said on these technologies, but we have so far failed to develop a coherent set of reference points. Extravagant figures in terms of potential have been reported, both high and low. Most of the time, these figures have come from limited and truncated exercises, on specific use cases, in special conditions, with limited ability to extrapolate to global averages. A specific analysis on lighting controls efficiency (a small share of energy loads in a building) in a specific building (a 1980 office for instance) tells us little of the overall potential that can be reached across a variety of loads, for a variety of building types, of different ages.

Most studies have also generally relied on specific geographical analyses, while energy demand profiles (for a similar building) vary significantly across regions. Colder regions rely more on heat, warmer ones more on cooling, mild climates have less of both compared to appliances, etc.

18 EEFIG (2021), De-risking Energy Efficiency Platform ; © OECD/IEA (2012), Building Shell and Thermal Insulation

19 As an example, data shows that two-thirds of offices have utilization rates below 70 percent. It is also estimated that up to 25 percent of available office space is unoccupied at any point in time. JLL (2021), Workplace planning in the new world of work ; Bell T. (2021), How To Calculate And Optimize Your Office Space Utilization Rate

Finally, studies on the potential of digital solutions have spurred in the early 2010s, fueled by research programs from the European Union, but we lack up-to-date data, which can be translated at global level.

In short, we need a clear and up-to-date set of figures, assessed against a model which, though likely imperfect, provides enough transparency to contribute to the discussion at hand. Figure 2 summarizes the different steps of the modelling analysis (more details are available in annex).

This starts with defining specific use cases

- Typical building archetypes are defined, alongside their energy demand profile by key service, leveraging the rich databases from the US Department of Energy[20]. We have modelled 6 building types representing a broad range of different use cases.
- The same resources help further refine demand profiles by considering the age of construction (1980 and 2006 are considered), as performance standards have varied widely across time, and the overall building stock is a complex mix of different building types of different ages.
- We have also "localized" these standard demand profiles for 19 regions of the world, taking into account different weather patterns, hence different needs for different services (notably heating and cooling)[21].
- Since the standard set of building profiles considers natural gas as the main energy source for heating purposes (space, water), we have also created new demand profiles considering heat pumps to assess relative performance of all-electric buildings[22].

From these 450 use cases, we have then assessed the potential of energy savings from various digital solutions, following the European categorization[23]. Category D corresponds to no controls, category C to basic controls (e.g. thermostats), category A to advanced controls (e.g. building management systems, home automation, etc.), and category B is an intermediary range of solutions (similar to category A, but with lower granularity, see annex).

These 1,300 simulations give us a wide range of results on energy efficiency, which are further translated into

- Carbon emissions savings[24], accounting for different carbon intensities of fuels across regions.
- Cost savings[25], accounting for different costs of energy.
- Payback times of digital solutions[26], accounting for cost savings and initial upfront investments (see annex).

20 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

21 Ibid

22 For heat pumps, we have assumed current COP levels, applied equally to space/water heating, BloombergNEF (2020), Heating Unit Economics Calculator

23 EU.BAC (2021), Guidelines for the transposition of the new Energy Performance Buildings Directive ; European Standards (2021), BS EN 15232-1:2017 Energy Performance of Buildings Impact of Building Automation, Controls and Building Management

24 BloombergNEF (2019), New Energy Outlook ; European Environmental Agency (2021)

25 BloombergNEF (2020), Heating Unit Economics Calculator

26 Energie 3.0 (2013), Débat sur la transition énergétique : les solutions concrètes de la filière éco-électrique ; Eurovent (2020), Preparatory study for Building Automation and Control Systems (GEN - 1191.00)

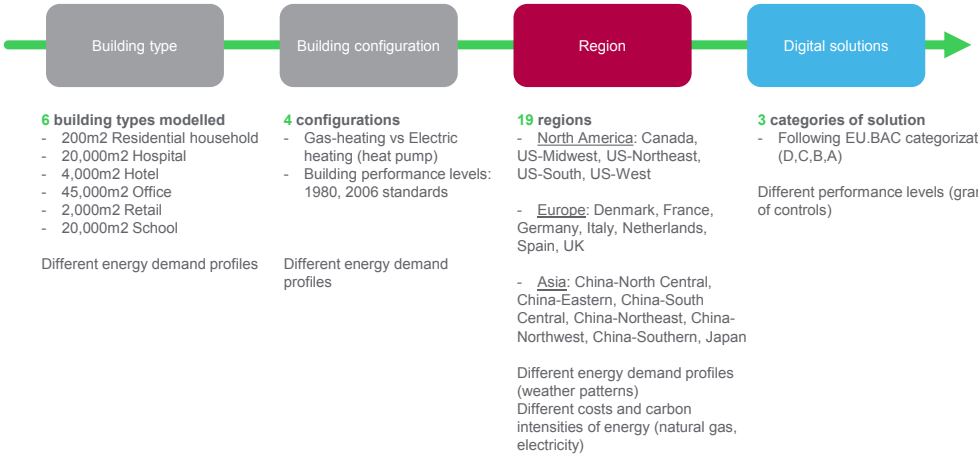


Figure 2 – Modelling efficiency for digital solutions

This tool thus provides us with a granular perspective of the energy, carbon emissions, cost and payback potential of different types of digital solutions, for 6 building types, with different ages and configurations, across 19 regions of the world.

Finding #1 – digital brings significant carbon abatement

In this part, we focus only on the 1980 building model (with heating provided by natural gas), which corresponds to the bulk of current stock[27] and is therefore more representative of the aggregated potential at a country level. Figure 3 shows the results of our modelling exercise in terms of energy efficiency for each type of building archetype across all 19 regions studied[28].

For clarity purposes, we look here only at category C (basic controls) and category A (advanced controls) (see annex for all details). Our modelling exercise yields energy savings between 8-20% for category C, and up to 20-35% for category A across sectors. Office and retail show higher efficiency gains from the deployment of digital solutions, compared to other sectors.

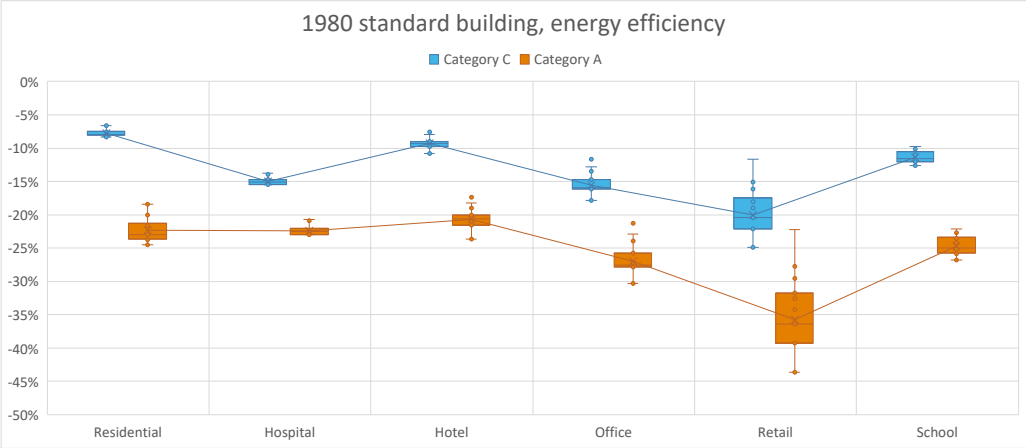


Figure 3 – 1980 standard building, energy efficiency

27 In the United States, half of the commercial stock was built before 1980, and the median age of housing is 39 years. Energy Information Agency (2015), Commercial Building Energy Consumption Survey ; Zhao (2021), Age of Housing Stock by State. In Europe, nearly 40 percent of the stock was built before 1960, and 80-85 percent before 1990. BPIE (2011), Europe's buildings under the microscope

28 Since we have 19 model results (for each type of building), this way of showing results cannot be considered as an accurate statistical representation of the reality of the stock at global level. Buildings of a same category obviously vary in age, characteristics, and distribution. This is however a handy representation of key results detailed in the tables in annex.

In terms of carbon emissions (Figure 4), the abatement potential reaches 7-17% for category C, and 20-30% for category A, with similar trends across sectors. As discussed earlier, these savings are also net of rebound effects due to the nature of digital efficiency solutions, hence sustainable over time[29].

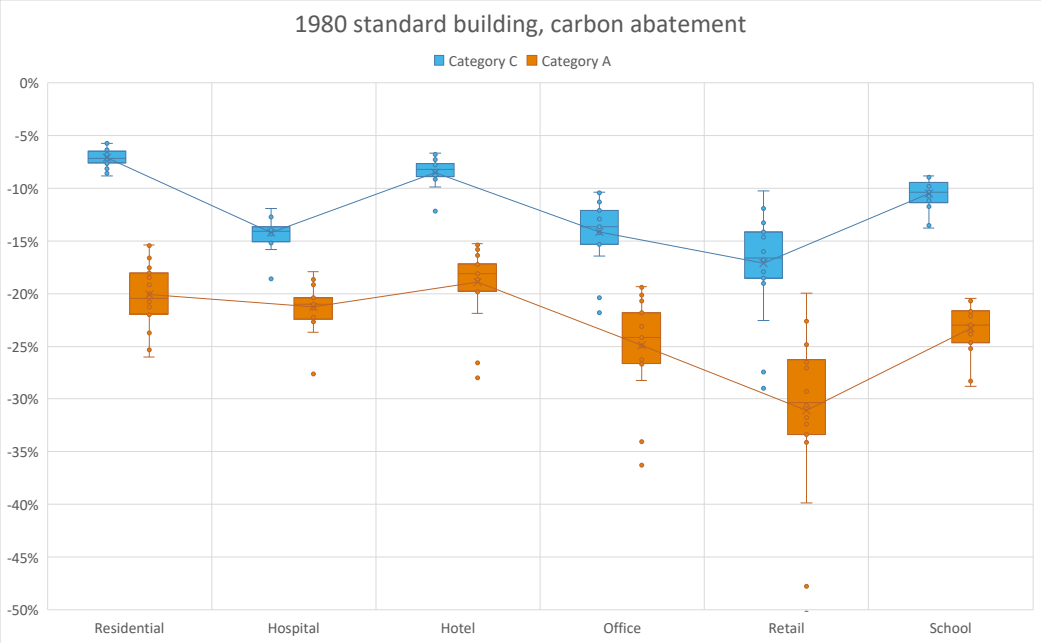


Figure 4 – 1980 standard building, carbon abatement

Key takeaway: digital solutions are a powerful option for carbon abatement of the building stock.

Finding #2 – digital comes at very competitive paybacks

The question that immediately comes up is that of the cost of deploying such solutions. We can assess it in terms of paybacks. Paybacks are defined by the savings realized on energy bills and the time it takes for these savings to pay for the upfront investment. They are expressed in years.

We can draw key conclusions from the results on Figure 5

- Most sectors enjoy paybacks in average below 8 years, with disparities across regions.
- The hospital and retail sectors offer the most attractive paybacks, well below 5 years.
- In general, paybacks for category C (basic controls) and category A (advanced controls) are very similar, to the exception of the residential sector where basic controls are more attractive, with paybacks ranging around 5 years.

29 Several concerns have as well emerged on the actual carbon footprint of deploying such solutions (the emissions associated to their manufacturing and own energy demand). See annex for more information.

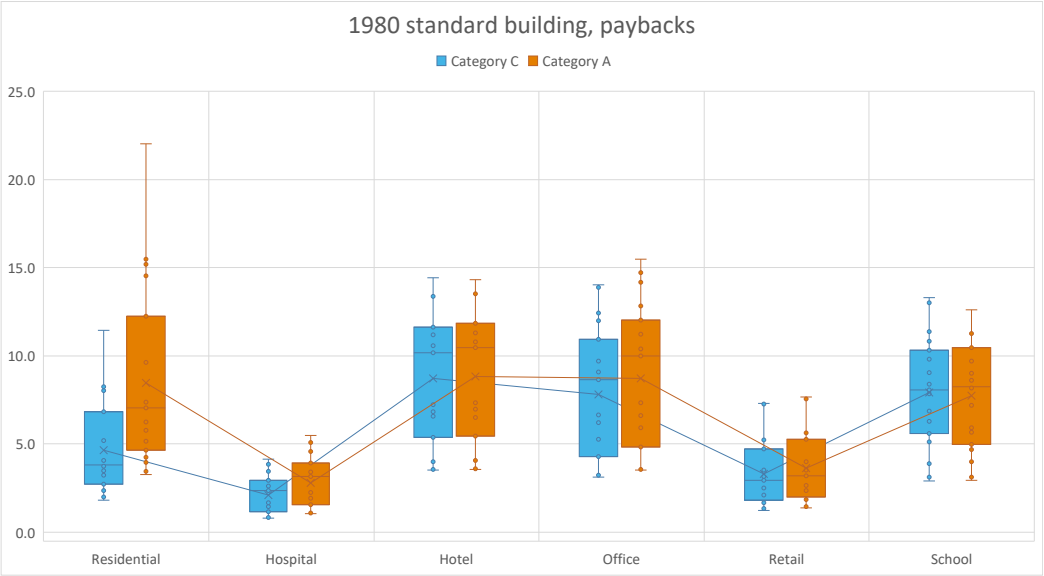


Figure 5 – 1980 standard building, paybacks

The deployment of digital solutions also brings cost savings, i.e. reduction of consumers' bills, across electricity and natural gas demand. These savings range around 7-15 percent for basic controls and between 15-30 percent for advanced solutions (category A).

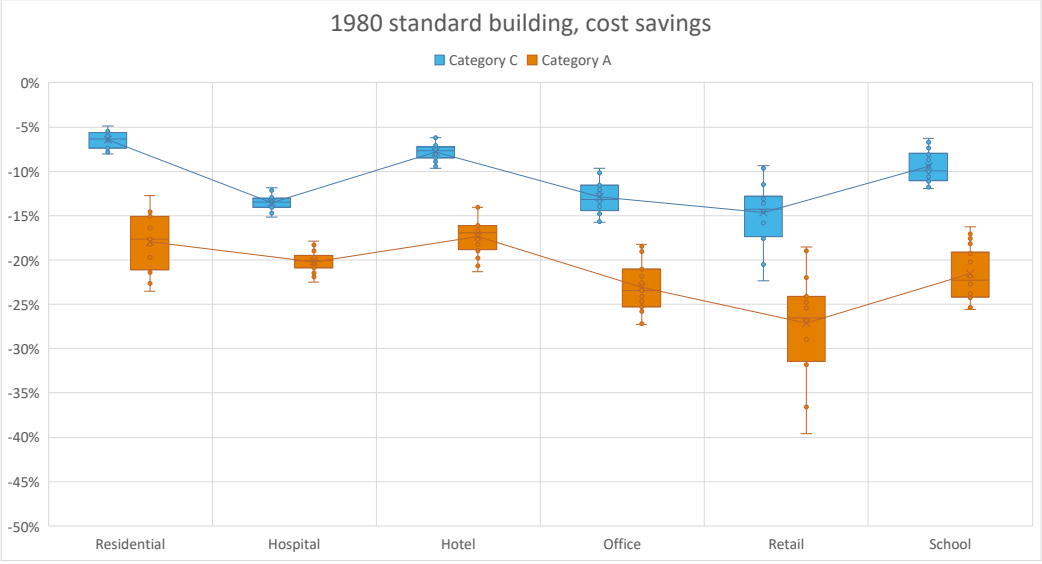


Figure 6 – 1980 standard building, cost savings

Key takeaway: digital technologies enjoy very competitive paybacks and net savings for consumers, a very compelling proposition to rapidly turn around the corner on energy efficiency gains within the building stock.

Finding #3 – digital shows potential across the entire stock

The age and associated performance of buildings have a strong impact on the carbon abatement potential of digital solutions. The more the building is efficient, the less there is to save. Figures 7 and 8 provide a perspective on carbon abatement and paybacks considering 2 building performance levels aligned with 1980 and 2006 construction standards[30].

These results highlight few key findings

- Obviously, the carbon abatement potential is lower for more efficient envelopes since the baseline energy demand is lower (though embodied emissions might be higher in current context). Consequently, paybacks are higher.
- The difference is however not significant. The share of existing stock eligible to digital solutions for efficiency is therefore considerable.
- While carbon abatement potential drops with efficiency in envelopes, making the case less attractive for newer constructions, it is worth to note that the integration of these solutions is more affordable for new build (better paybacks since lower installation costs), continues to offer cost savings, and helps mitigate rebound effects, as discussed above.

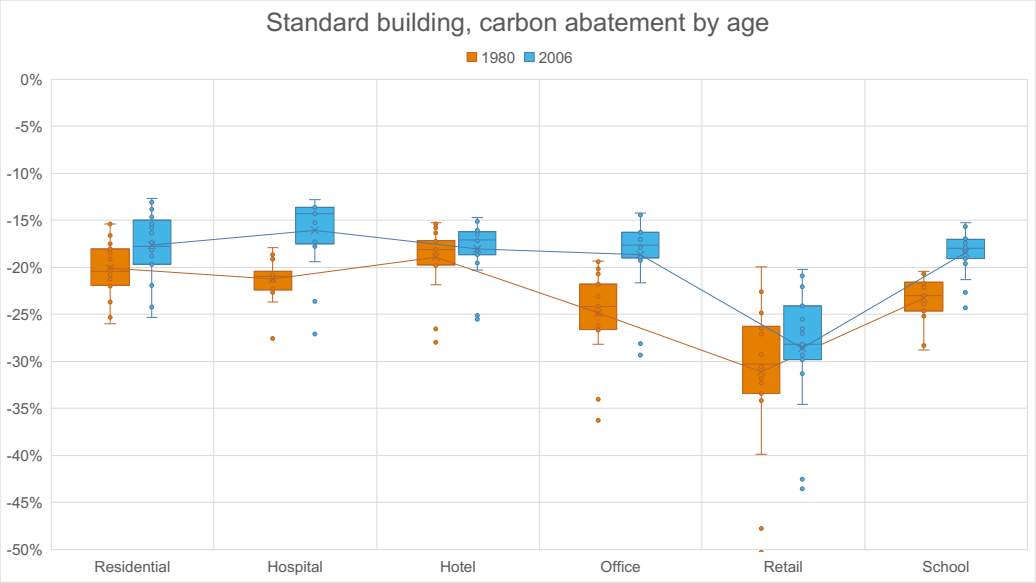


Figure 7 – Carbon abatement, by age (category A)

30 For clarity purposes, we only display here results for category A solutions. The full set of results is available in annex.

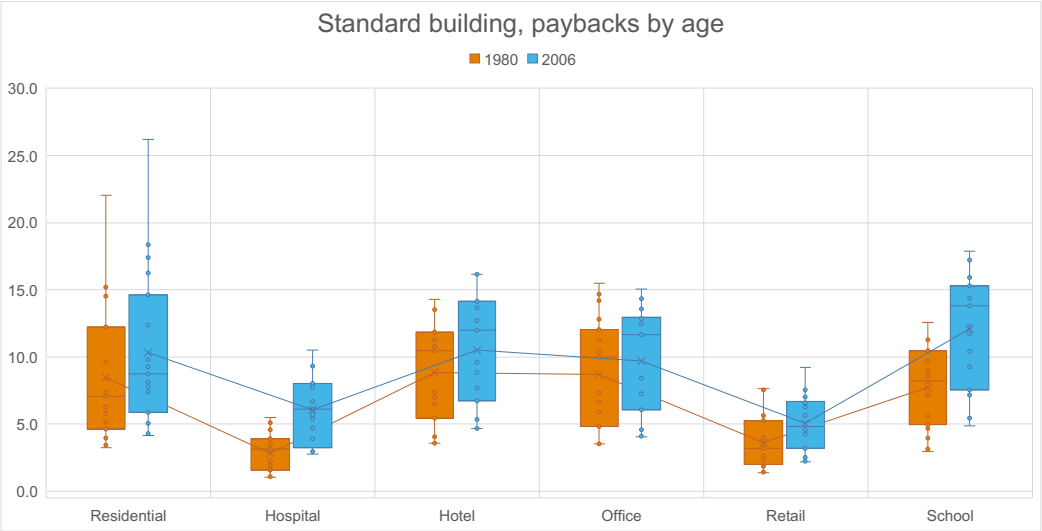


Figure 8 – Paybacks, by age (category A)

We also compare the relative performance of digital efficiency solutions in all-electric buildings, where heating is provided by heat pumps, a natural development of the building stock following decarbonization policies and cost competitiveness[31].

The main finding of Figures 8 and 9 is that, while carbon abatement potential is slightly lower for electrified heating systems (due in part to the greater efficiency of electrified heating solutions[32]), paybacks are however very similar, confirming the case for combined electrification and digital technologies deployment within the building stock.

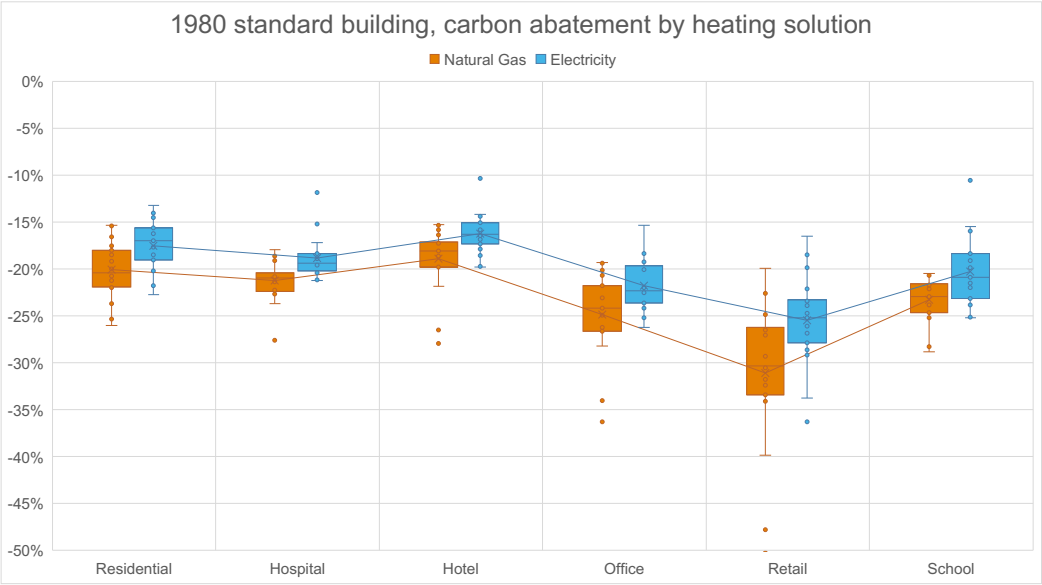


Figure 9 – 1980 standard building, carbon abatement by heating solution (category A)

31 It has been demonstrated that electrified heating can in many regions come at a net-saving for consumers, with a competitiveness likely to grow significantly over time. Schneider Electric (b) (2021), Building Heat Decarbonization

32 See details in annex on how we have chosen to compute carbon emissions of all-electric buildings in this report, a highly controversial topic, since all new power capacities (from electrification) could reasonably be assumed zero-carbon.

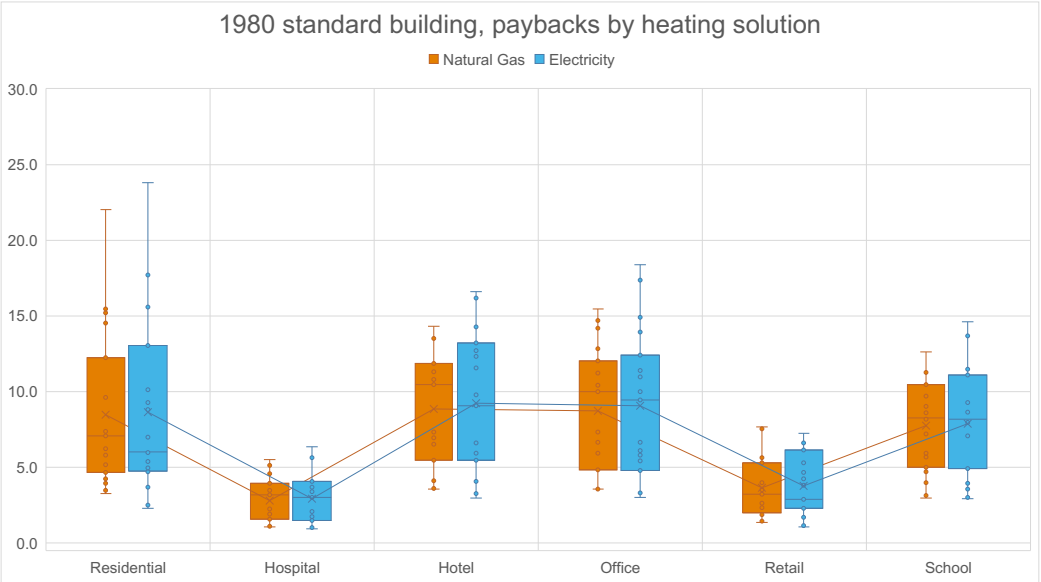


Figure 10 – 1980 standard building, paybacks by heating solution (category A)

Key takeaway: digital technologies hold their carbon abatement potential (and competitiveness) for the bulk of the existing stock and is a powerful complementary solution to heating electrification.

Finding #4 – all regions show significant potential

Regions show different patterns, depending on the actual building demand profile (weather patterns), carbon intensity and costs of energy[33].

Figure 10 provides a comparative view across regions for carbon abatement. The main finding is that results are generally similar across regions for all building types, with interesting exceptions for retail and offices in few countries (Canada, France and Denmark). This is in fact due to the lower baseline in emissions in those regions (due to lower carbon intensity of electricity generation), which makes savings on fossil fuels heating more apparent (see annex for more details).

33 Regional averages will depend on the actual distribution of different building types in a given region. Aggregation of results across building types from our model cannot therefore be presented in statistical terms here, since we use standard building archetypes while the reality is far more complex. Consequently, we show only here results for 1980 standard building types with category A solutions, to highlight key differences across regions. More details are available in annex.

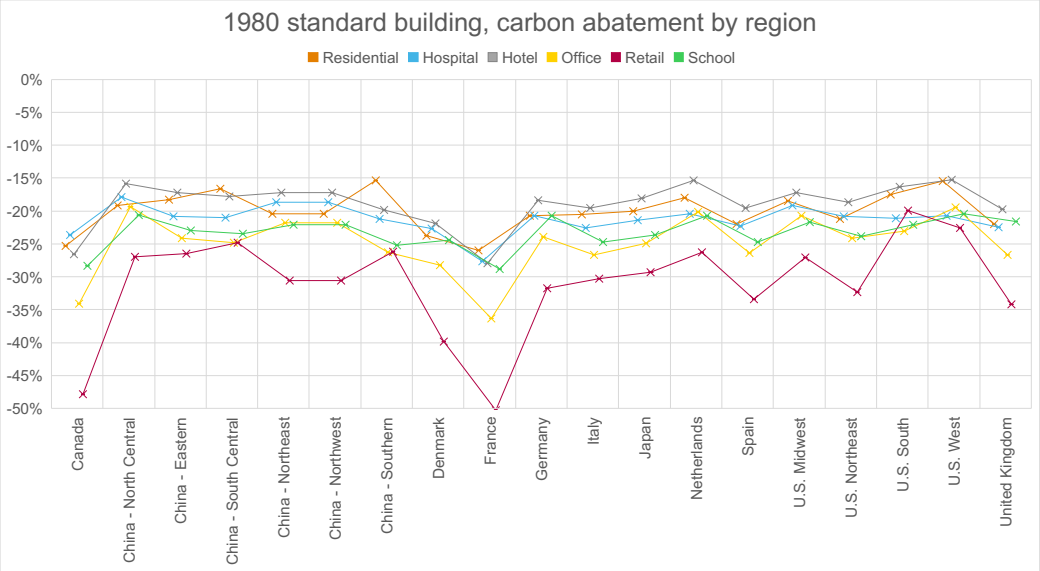


Figure 11 – 1980 standard building, carbon abatement by region (category A)

The analysis of paybacks shows a much stronger case overall for countries of Europe, compared to North America and China (Figure 11). This is due to higher costs of energy in Europe, which increases overall cost savings, hence makes the case more compelling for the deployment of digital solutions. In Europe, paybacks are generally closer to 5 years, a very compelling argument for adoption.

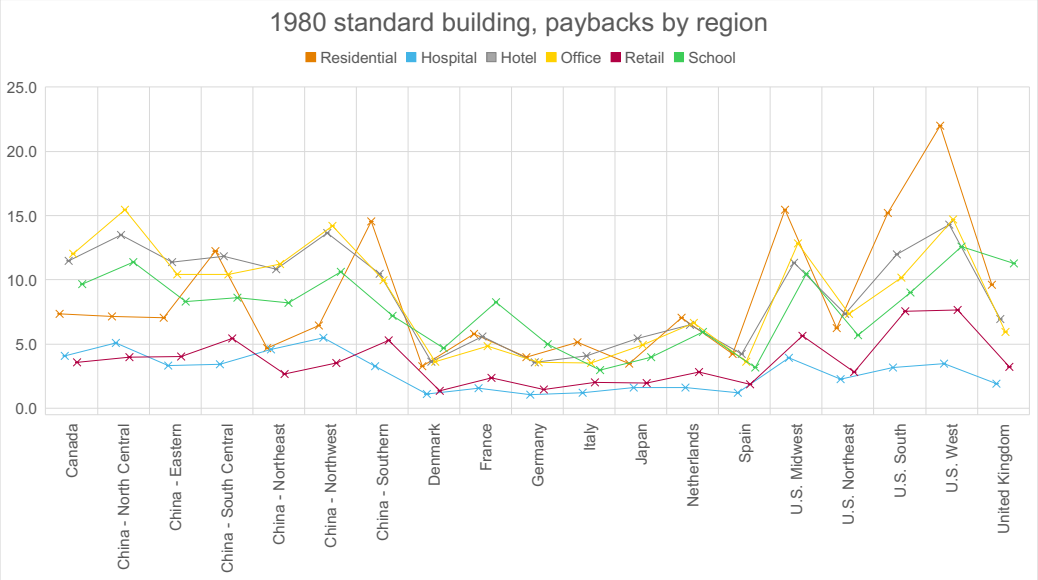


Figure 12 – 1980 standard building, paybacks by region (category A)

Key takeaway: all regions show significant potential and attractiveness, but current costs of energy make the case more compelling in Europe compared to other regions of the world.

Finding #5 – a potential which is underestimated

The International Energy Agency[34] estimated in its 2021 Net Zero scenario publication a potential for digital solutions of 0.35GtCO2/y abatement over the global building stock by 2050, focusing on direct emissions alone (heating and cooking, around 3GtCO2/y today), or around 10-12 percent of total abatement (the rest of energy efficiency savings coming from conventional works on building envelopes and equipment).

This figure is in the range of the global potential of basic controls (category C) discussed above and twice lower than the potential of advanced solutions (category A). In our analysis, digital solutions also apply beyond the scope of direct emissions alone and include indirect emissions from electricity demand (or a baseline of around 7GtCO2/y[35]), leading to a global potential of 1.4GtCO2/y. A 4-fold difference!

Requalifying this estimate is highly complex and would require several things to happen

- Analyze in detail the age of the building stock at global level and its evolution to 2050. How much of the current stock would still be standing by 2050?
- Analyze the new stock to come by 2050, its actual performance standards and fuels of choice, projections which are obviously based on significant assumptions.
- Estimate the actual pace of decarbonization of electricity by 2050 globally.
- Estimate penetration rates of digital technologies across the stock (both existing and new) by 2050.

It is not the purpose of this report to make a detailed estimate, but we can however provide initial insights for further research to happen at local level.

We take the following assumptions

- Two-third of the existing stock is still standing by 2050[36].
- New build is zero-carbon, an assumption broadly consistent with the Net Zero Emissions scenario from the International Energy Agency (all new build is zero carbon from 2030 onward).
- All additional electricity demand (for the new stock) is zero-carbon.
- 100 percent penetration of digital technologies[37].

This thought experiment provides a potential of around 1GtCO2/y. The discrepancy with the International Energy Agency forecast is due to the accounting of carbon abatement from electricity generation in our modelling. For direct emissions alone, the two approaches yield very similar results. These also both assume limited further growth in emissions from new constructions, a highly ambitious assumption, which digital technologies would help abate as well.

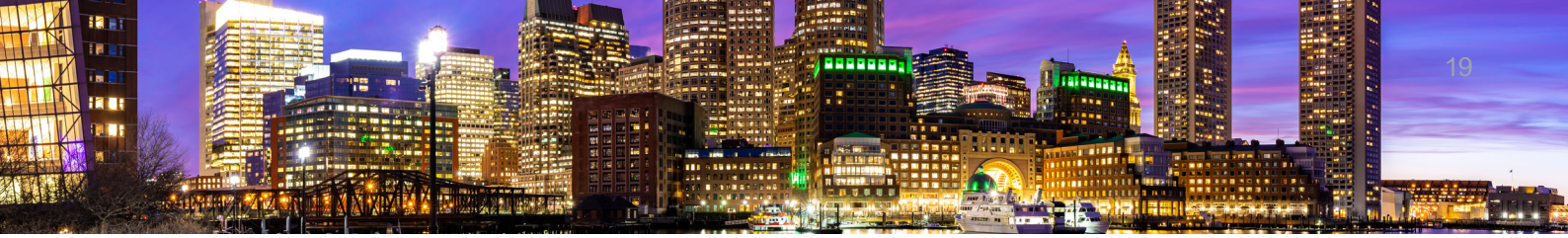
Key takeaway: the potential carbon abatement of digital solutions in the building stock is thus generally underestimated, particularly as it supports electricity decarbonization.

34 © OECD/IEA (2021), Net Zero by 2050

35 We have considered no efficiency savings on traditional appliances, outside of heating, cooling, ventilation and lighting (see annex). While the total baseline for emissions (direct and indirect) represents around 10GtCO2/y, we estimate the scope covered by digital solutions to represent around 7GtCO2/y. Schneider Electric Research.

36 The current stock stands at 224 billion square meters, and it is expected that 80 billion square meters will be demolished and rebuilt by 2050. © OECD/IEA (2013), Technology Roadmap Energy Efficient Building envelopes.

37 We also assume advanced solutions (category A) predominate over basic controls. We will see further down this assumption to be reasonable considering other changes at stake within the building sector.



Embrace the future… faster

Digital penetration is largely inevitable, the question is the pace of its development

The above analysis yields 5 main findings

- Digital efficiency solutions bring 20-30 percent carbon abatement across the building stock.
- They also bring highly competitive paybacks and cost savings for consumers, well below 8 years in average.
- They apply across all the current building stock.
- All regions show significant potential, even though the economic equation is more attractive in Europe (with paybacks ranging around 5 years in average).
- Their potential is generally underestimated.

There is more to it, however. 2 trends contribute to further accelerate their penetration and improve their economic potential

- The digitalization of our living environments is largely under way, be it for households or commercial buildings. The deployment of digital controls in commercial real-estate is notably widely acknowledged to bring significant benefits in terms of air quality, comfort, operational efficiency, and asset value[38]. Most new appliances now are also increasingly connected, further accelerating this trend.
- The increased penetration of distributed generation, mobility charging infrastructure, and stationary storage is redefining energy systems within buildings, and is a key driver for the further penetration of digital technologies within the building stock (both existing and new)[39].

These additional drivers of digital penetration change the actual paybacks calculation presented above, where we only computed savings stemming from cost efficiencies. In fact, the value is likely larger (stacked across multiple applications), leading to even more competitive paybacks. These paybacks are as well more complex to measure, a theme for further research.

Yet, we can argue **the penetration of digital efficiency solutions is ultimately inevitable**. The key question is therefore not to qualify or not their need, but rather create the right framework to accelerate their deployment across the board at rapid pace, given their multiple benefits.

Is there a better time to accelerate on no-brainers?

2030 is a critical milestone in the race toward decarbonizing the global economy. According to the Intergovernmental Panel for Climate Change[40], emissions need to be reduced by 30-50 percent globally by this time, for the world to stand a chance to remain on a course compatible with a 1.5-degree global warming trajectory.

Several scenarios have highlighted the need for significant efforts on energy efficiency, as a critical factor of success[41].

38 IDC (2020), The Business Value of Schneider Electric's EcoStruxure Solutions for Commercial Property

39 Distributed generation is projected to be competitive with retail electricity across all markets within the coming decade. BloombergNEF (2021), Realizing the Potential of Customer-Sited Solar.
The vast majority of EV charging is expected to occur within building premises. BloombergNEF (b) (2021), Electric Vehicle Outlook

40 IPCC (2018), Global Warming of 1.5°C

41 ©OECD/IEA (2021), Net Zero by 2050 ; Schneider Electric (2021), The 2030 imperative: a race against time. Both analyses suggest a contribution of 15-20 percent of total abatement by 2030 (without accounting for savings from behaviour and avoided demand).

In this context, digital solutions offer a clear path forward, as not only do they help achieve sizeable carbon abatement, but also at highly competitive paybacks, with net-savings for consumers, and without rebound effects. Their deployment is thus largely a no-brainer in any policy toolkit for rapid decarbonization of the building stock. While their unfolding is largely inevitable over the long run, accelerating their deployment in the decade to 2030 would create considerable benefits and prepare the ground for further decarbonization activities.

Doing so will require a clear set of policies, stemming around 2 main activities

- Mandates: develop clear objectives and milestones for the decarbonization of the existing stock, and drive adoption of digital efficiency solutions thru mandates.
- Metrics, Certification and Standards: develop standardized indicators of building performance which include this new technology toolkit at hand, both at regional level (e.g. European Performance Building Directive in Europe) and thru certification agencies (LEEDs, BREEAM, etc.)

JLL APAC Headquarters, Singapore

Global property services leader JLL has utilized digital technologies, to improve energy efficiency, at its new Asia-Pacific headquarters in Singapore.

With a single building energy management and environmental monitoring platform, JLL is now empowered to make better decisions and take advantage of condition-based maintenance. The implementation of digital solutions has led to a 30% reduction in energy use and operational costs at the site.

“A smart office starts with a smart system designed to help measure and manage energy usage and wellness conditions." - Darren Battle, JLL Asia-Pacific Head of Corporate Real Estate and Workplace.

Legal disclaimer

The contents of this publication are presented for information purposes only, and while effort has been made to ensure its accuracy, they are not to be construed as warranties or guarantees of any kind, express or implied. This publication should not be relied upon to make investment advice or other strategic decisions.

The assumptions and models and conclusions presented in the publication represent one possible scenario and are inherently dependent on many factors outside the control of any one company, including but not limited to governmental actions, evolution of climate conditions, geopolitical consideration and shifts in technology.

The scenarios and models are not intended to be projections of forecasts of the future and do not represent Schneider Electric's strategy of business plan.

Annex

Detailed assumptions

Building archetypes

Building demand profiles vary significantly

- Across regions depending on weather patterns, particularly as it relates to the share of space conditioning (heating/cooling).
- Across sectors depending on the use of the building (with notably a considerable impact from appliances in total energy demand).

The figures below have been retrieved from the US department of energy databases[42]

- For a given sector, a specific building archetype (in terms of size, energy performance) has been recovered as well as its corresponding energy demand profile, which varies for different weather pattern conditions.
- The same building with 1980 and 2006 performance characteristics (building construction codes) has also been retrieved to provide a comparable basis[43].

In some countries of Europe (Denmark, France, Germany, Netherlands, the United Kingdom), we have arbitrarily set the demand for cooling to zero in residential and schools.

Figure 13 summarizes

- Overall energy intensities used in this analysis.
- Share of loads (heating includes both space and water ; other corresponds to cooling, lighting and ventilation).

kWh/m2/y	1980			2006			2018		
	average	min	max	average	min	max	average	min	max
Residential	260	125	410	228	124	344	154	93	225
Hospital	649	564	691	482	423	552	293	261	352
Hotel	260	227	295	231	209	263	177	162	202
Office	176	142	198	200	169	228	142	134	152
Retail	380	236	548	239	170	319	NA	NA	NA
School	274	203	356	183	148	234	102	81	125

% of load (average)	1980			2006			2018		
	Heat	Appliance	Other	Heat	Appliance	Other	Heat	Appliance	Other
Residential	76%	13%	11%	69%	20%	10%	58%	30%	12%
Hospital	26%	15%	59%	41%	25%	33%	22%	41%	37%
Hotel	26%	29%	46%	29%	33%	38%	34%	41%	25%
Office	22%	29%	50%	16%	46%	38%	7%	62%	31%
Retail	44%	5%	51%	29%	7%	64%	NA	NA	NA
School	42%	14%	45%	23%	25%	53%	23%	40%	37%

Figure 13 – Building load profiles

42 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

43 The building profiles used here for 1980 and 2006 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, we however consider the impact on overall results to be minimal.

This yields interesting insights on building demand profiles

- In older buildings, the bulk of the energy demand comes from heating (76% of total energy needs in residential, around 25-40% in the commercial sector) and cooling (consolidated in other, important for the commercial sector).
- In newer buildings, the share of appliances becomes more sizeable, to the exception of retail, which continues to rely on heavy cooling loads (refrigeration).

In the following tables (Figures 14 to 16), we provide more regional details. For clarity purposes, we do not show results for all-electric buildings (where heating needs are supplied by heat pumps instead of gas boilers). We have simply translated these heating energy needs in corresponding electricity demand, applying current coefficient of performance (COP) levels, which differ across regions[44].

44 COP levels were retrieved from BloombergNEF (2020), Heating Unit Economics Calculator

		Space Heating			Cooling			Lighting (interior)			Water system			Ventilation			Appliances			Total	
Segment	Country	2006 Heat	1980 Heat	2018 Heat	2006 Cooling	1980 Cooling	2018 Cooling	2006 Lighting	1980 Lighting	2018 Lighting	2006 Water	1980 Water	2018 Water	2006 Ventilation	1980 Ventilation	2018 Ventilation	2006 Appliances	1980 Appliances	2018 Appliances	2006 TOTAL	1980 TOTAL
Residential	Canada	245	319	133	5	5	5	7	15	5	31	31	29	9	7	7	47	33	46	**344**	**410**
Residential	U.S. Midwest	76	98	34	13	13	12	7	15	5	24	24	22	8	6	6	47	33	46	**174**	**189**
Residential	U.S. Northeast	171	222	90	6	6	6	7	15	5	27	27	25	8	6	7	47	33	46	**266**	**309**
Residential	U.S. South	49	63	20	20	20	14	7	15	5	21	21	20	8	7	6	47	33	46	**152**	**158**
Residential	U.S. West	32	42	10	10	10	7	7	15	5	23	23	21	6	4	4	47	33	46	**124**	**125**
Hospital	Canada	264	188	116	30	160	16	52	104	41	18	11	18	66	60	42	123	98	120	**552**	**620**
Hospital	U.S. Midwest	132	114	22	32	177	25	52	104	41	16	9	15	68	63	43	123	98	120	**423**	**564**
Hospital	U.S. Northeast	192	166	48	34	212	24	52	104	41	17	10	16	66	63	40	123	98	120	**483**	**652**
Hospital	U.S. South	127	143	16	44	238	32	52	104	41	15	8	14	69	63	42	123	98	120	**429**	**653**
Hospital	U.S. West	145	155	18	38	210	29	52	104	41	15	9	15	66	58	39	123	98	120	**438**	**632**
Hotel	Canada	53	77	36	18	17	12	37	73	14	54	38	54	24	16	13	76	75	73	**263**	**295**
Hotel	U.S. Midwest	6	20	4	28	30	19	37	73	14	44	29	44	25	19	14	76	75	73	**216**	**245**
Hotel	U.S. Northeast	29	46	20	21	27	14	37	73	14	48	32	48	23	17	11	76	75	73	**235**	**269**
Hotel	U.S. South	2	6	2	37	32	24	37	73	14	40	26	39	25	18	12	76	75	73	**217**	**229**
Hotel	U.S. West	0	15	0	31	20	20	37	73	14	41	29	41	23	16	14	76	75	73	**209**	**227**
Office	Canada	63	77	14	20	12	10	31	51	16	4	2	4	18	7	14	91	50	88	**228**	**198**
Office	U.S. Midwest	11	21	5	26	20	15	31	51	15	3	1	3	22	8	17	91	50	88	**184**	**151**
Office	U.S. Northeast	39	47	7	21	23	13	31	51	15	4	2	4	18	7	14	91	50	88	**204**	**180**
Office	U.S. South	6	9	2	29	38	21	31	51	15	3	1	3	20	9	17	91	50	88	**180**	**157**
Office	U.S. West	3	16	0	23	18	13	31	51	15	3	1	3	19	6	14	91	50	88	**169**	**142**
Retail	Canada	154	336	0	15	4	0	91	140	0	10	0	0	33	47	0	17	20	0	**319**	**548**
Retail	U.S. Midwest	9	106	0	25	18	0	91	140	0	9	0	0	41	33	0	17	20	0	**191**	**316**
Retail	U.S. Northeast	88	209	0	17	16	0	91	140	0	9	0	0	31	39	0	17	20	0	**253**	**423**
Retail	U.S. South	2	27	0	39	13	0	91	140	0	9	0	0	41	35	0	17	20	0	**198**	**236**
Retail	U.S. West	0	73	0	21	4	0	91	140	0	9	0	0	32	28	0	17	20	0	**170**	**263**
School	Canada	89	215	38	19	21	11	47	58	11	11	8	11	24	17	13	45	37	41	**234**	**356**
School	U.S. Midwest	12	65	9	29	48	17	47	58	12	9	6	9	27	17	12	45	37	41	**169**	**231**
School	U.S. Northeast	37	133	16	22	57	12	47	58	12	10	7	10	22	16	11	45	37	41	**182**	**308**
School	U.S. South	4	18	5	37	80	24	47	58	12	8	5	8	23	16	12	45	37	41	**163**	**214**
School	U.S. West	3	51	3	30	36	18	47	58	12	9	6	9	22	15	10	45	37	41	**156**	**203**

Figure 14 – North America assumptions

		Space Heating			Cooling			Lighting (interior)			Water system			Ventilation			Appliances			Total	
Segment	Country	2006 Heat	1980 Heat	2018 Heat	2006 Cooling	1980 Cooling	2018 Cooling	2006 Lighting	1980 Lighting	2018 Lighting	2006 Water	1980 Water	2018 Water	2006 Ventilation	1980 Ventilation	2018 Ventilation	2006 Appliances	1980 Appliances	2018 Appliances	2006 TOTAL	1980 TOTAL
Residential	Denmark	171	222	90	0	0	0	7	15	5	27	27	25	8	6	7	47	33	46	**260**	**303**
Residential	France	134	174	63	0	0	0	7	15	5	25	25	23	6	5	5	47	33	46	**219**	**252**
Residential	Germany	171	222	90	0	0	0	7	15	5	27	27	25	8	6	7	47	33	46	**260**	**303**
Residential	Italy	74	96	33	17	17	12	7	15	5	22	22	21	7	6	5	47	33	46	**174**	**188**
Residential	Netherlands	91	118	46	0	4	0	7	15	5	26	26	24	7	5	6	47	33	46	**177**	**201**
Residential	Spain	134	174	63	11	11	9	7	15	5	25	25	23	6	5	5	47	33	46	**230**	**262**
Residential	United Kingdom	134	174	63	0	0	0	7	15	5	25	25	23	6	5	5	47	33	46	**219**	**252**
Hospital	Denmark	192	166	48	34	212	24	52	104	41	17	10	16	66	63	40	123	98	120	**483**	**652**
Hospital	France	176	154	36	48	252	31	52	104	41	16	9	15	68	63	39	123	98	120	**482**	**680**
Hospital	Germany	192	166	48	34	212	24	52	104	41	17	10	16	66	63	40	123	98	120	**483**	**652**
Hospital	Italy	149	144	23	60	264	39	52	104	41	15	8	14	71	66	41	123	98	120	**469**	**683**
Hospital	Netherlands	165	159	32	24	206	19	52	104	41	16	9	16	64	58	39	123	98	120	**444**	**635**
Hospital	Spain	176	154	36	48	252	31	52	104	41	16	9	15	68	63	39	123	98	120	**482**	**680**
Hospital	United Kingdom	176	154	36	48	252	31	52	104	41	16	9	15	68	63	39	123	98	120	**482**	**680**
Hotel	Denmark	29	46	20	21	27	14	37	73	14	48	32	48	23	17	11	76	75	73	**235**	**269**
Hotel	France	16	31	12	28	33	18	37	73	14	45	29	45	23	17	12	76	75	73	**226**	**258**
Hotel	Germany	29	46	20	21	27	14	37	73	14	48	32	48	23	17	11	76	75	73	**235**	**269**
Hotel	Italy	6	18	5	38	41	24	37	73	14	41	26	41	24	18	12	76	75	73	**223**	**252**
Hotel	Netherlands	8	26	6	20	17	13	37	73	14	46	31	46	23	16	14	76	75	73	**210**	**237**
Hotel	Spain	16	31	12	28	33	18	37	73	14	45	29	45	23	17	12	76	75	73	**226**	**258**
Hotel	United Kingdom	16	31	12	28	33	18	37	73	14	45	29	45	23	17	12	76	75	73	**226**	**258**
Office	Denmark	39	47	7	21	23	13	31	51	15	4	2	4	18	7	14	91	50	88	**204**	**180**
Office	France	25	31	4	28	38	14	31	51	15	4	1	3	21	10	14	91	50	88	**200**	**181**
Office	Germany	39	47	7	21	23	13	31	51	15	4	2	4	18	7	14	91	50	88	**204**	**180**
Office	Italy	16	22	2	31	44	19	31	51	15	3	1	3	22	10	15	91	50	88	**195**	**178**
Office	Netherlands	17	32	7	17	14	8	31	51	16	4	1	4	17	6	13	91	50	88	**177**	**155**
Office	Spain	25	31	4	28	38	14	31	51	15	4	1	3	21	10	14	91	50	88	**200**	**181**
Office	United Kingdom	25	31	4	28	38	14	31	51	15	4	1	3	21	10	14	91	50	88	**200**	**181**
Retail	Denmark	88	209	0	17	16	0	91	140	0	9	0	0	31	39	0	17	20	0	**253**	**423**
Retail	France	53	149	0	29	21	0	91	140	0	9	0	0	33	33	0	17	20	0	**232**	**363**
Retail	Germany	88	209	0	17	16	0	91	140	0	9	0	0	31	39	0	17	20	0	**253**	**423**
Retail	Italy	19	85	0	46	30	0	91	140	0	9	0	0	35	36	0	17	20	0	**216**	**311**
Retail	Netherlands	32	135		9	4		91	140		9	0		31	29		17	20		**189**	**327**
Retail	Spain	53	149	0	29	21	0	91	140	0	9	0	0	33	33	0	17	20	0	**232**	**363**
Retail	United Kingdom	53	149	0	29	21	0	91	140	0	9	0	0	33	33	0	17	20	0	**232**	**363**
School	Denmark	37	133	16	0	0	0	47	58	12	10	7	10	22	16	11	45	37	41	**160**	**252**
School	France	24	98	8	0	0	0	47	58	12	9	6	9	23	16	11	45	37	41	**148**	**215**
School	Germany	37	133	16	0	0	0	47	58	12	10	7	10	22	16	11	45	37	41	**160**	**252**
School	Italy	11	59	6	51	99	26	47	58	12	9	6	9	24	16	11	45	37	41	**186**	**275**
School	Netherlands	15	95	17	13	22	8	47	58	12	9	6	9	20	15	11	45	37	41	**149**	**234**
School	Spain	24	98	8	35	75	18	47	58	12	9	6	9	23	16	11	45	37	41	**183**	**290**
School	United Kingdom	24	98	8	0	0	0	47	58	12	9	6	9	23	16	11	45	37	41	**148**	**215**

Figure 15 – Europe assumptions

		Space Heating			Cooling			Lighting (interior)			Water system			Ventilation			Appliances			Total	
		2006	1980	2018	2006	1980	2018	2006	1980	2018	2006	1980	2018	2006	1980	2018	2006	1980	2018	2006	1980
Segment	Country	Heat	Heat	Heat	Cooling	Cooling	Cooling	Lighting	Lighting	Lighting	Water	Water	Water	Ventilation	Ventilation	Ventilation	Appliances	Appliances	Appliances	TOTAL	TOTAL
Residential	China - North Central	179	233	88	6	6	6	7	15	5	29	29	26	8	7	7	47	33	46	**276**	**321**
Residential	China - Eastern	134	174	63	11	11	9	7	15	5	25	25	23	6	5	5	47	33	46	**230**	**262**
Residential	China - South Central	74	96	33	17	17	12	7	15	5	22	22	21	7	6	5	47	33	46	**174**	**188**
Residential	China - Northeast	245	319	133	5	5	5	7	15	5	31	31	29	9	7	7	47	33	46	**344**	**410**
Residential	China - Northwest	245	319	133	5	5	5	7	15	5	31	31	29	9	7	7	47	33	46	**344**	**410**
Residential	China - Southern	21	28	14	28	28	22	7	15	5	19	19	17	8	6	7	47	33	46	**130**	**128**
Residential	Japan	134	174	63	11	11	9	7	15	5	25	25	23	6	5	5	47	33	46	**230**	**262**
Hospital	China - North Central	207	143	90	27	153	14	52	104	41	17	10	17	66	59	43	123	98	120	**492**	**567**
Hospital	China - Eastern	176	154	36	48	252	31	52	104	41	16	9	15	68	63	39	123	98	120	**482**	**680**
Hospital	China - South Central	149	144	23	60	264	39	52	104	41	15	8	14	71	66	41	123	98	120	**469**	**683**
Hospital	China - Northeast	264	188	116	30	160	16	52	104	41	18	11	18	66	60	42	123	98	120	**552**	**620**
Hospital	China - Northwest	264	188	116	30	160	16	52	104	41	18	11	18	66	60	42	123	98	120	**552**	**620**
Hospital	China - Southern	130	133	14	81	282	58	52	104	41	15	7	13	73	68	41	125	98	120	**475**	**691**
Hospital	Japan	176	154	36	48	252	31	52	104	41	16	9	15	68	63	39	123	98	120	**482**	**680**
Hotel	China - North Central	29	48	19	18	17	12	37	73	14	50	34	50	24	17	13	76	75	73	**236**	**265**
Hotel	China - Eastern	16	31	12	28	33	18	37	73	14	45	29	45	23	17	12	76	75	73	**226**	**258**
Hotel	China - South Central	6	18	5	38	41	24	37	73	14	41	26	41	24	18	12	76	75	73	**223**	**252**
Hotel	China - Northeast	53	77	36	18	17	12	37	73	14	54	38	54	24	16	13	76	75	73	**263**	**295**
Hotel	China - Northwest	53	77	36	18	17	12	37	73	14	54	38	54	24	16	13	76	75	73	**263**	**295**
Hotel	China - Southern	1	10	1	57	60	36	37	73	14	38	23	36	24	19	12	76	75	73	**232**	**259**
Hotel	Japan	16	31	12	28	33	18	37	73	14	45	29	45	23	17	12	76	75	73	**226**	**258**
Office	China - North Central	39	45	19	21	12	10	31	51	16	4	2	4	19	6	16	91	50	88	**205**	**165**
Office	China - Eastern	25	31	4	28	38	14	31	51	15	4	1	3	21	10	14	91	50	88	**200**	**181**
Office	China - South Central	16	22	2	31	44	19	31	51	15	3	1	3	22	10	15	91	50	88	**195**	**178**
Office	China - Northeast	63	77	14	20	12	10	31	51	16	4	2	4	18	7	14	91	50	88	**228**	**198**
Office	China - Northwest	63	77	14	20	12	10	31	51	16	4	2	4	18	7	14	91	50	88	**228**	**198**
Office	China - Southern	3	13	0	45	56	28	31	51	15	3	1	3	25	10	16	91	50	88	**198**	**182**
Office	Japan	25	31	4	28	38	14	31	51	15	4	1	3	21	10	14	91	50	88	**200**	**181**
Retail	China - North Central	78	223	0	14	6	0	91	140	0	9	0	0	36	46	0	17	20	0	**245**	**436**
Retail	China - Eastern	53	149	0	29	21	0	91	140	0	9	0	0	33	33	0	17	20	0	**232**	**363**
Retail	China - South Central	19	85	0	46	30	0	91	140	0	9	0	0	35	36	0	17	20	0	**216**	**311**
Retail	China - Northeast	154	336	0	15	4	0	91	140	0	10	0	0	33	47	0	17	20	0	**319**	**548**
Retail	China - Northwest	154	336	0	15	4	0	91	140	0	10	0	0	33	47	0	17	20	0	**319**	**548**
Retail	China - Southern	1	40	0	85	54	0	91	140	0	9	0	0	39	36	0	17	20	0	**241**	**290**
Retail	Japan	53	149	0	29	21	0	91	140	0	9	0	0	33	33	0	17	20	0	**232**	**363**
School	China - North Central	51	142	20	17	21	9	47	58	12	10	7	10	24	16	12	45	37	41	**194**	**281**
School	China - Eastern	24	98	8	35	75	18	47	58	12	9	6	9	23	16	11	45	37	41	**183**	**290**
School	China - South Central	11	59	6	51	99	26	47	58	12	9	6	9	24	16	11	45	37	41	**186**	**275**
School	China - Northeast	89	215	38	19	21	11	47	58	11	11	8	11	24	17	13	45	37	41	**234**	**356**
School	China - Northwest	89	215	38	19	21	11	47	58	11	11	8	11	24	17	13	45	37	41	**234**	**356**
School	China - Southern	3	30	1	88	157	43	47	58	11	8	5	8	29	17	12	45	37	41	**219**	**304**
School	Japan	24	98	8	35	75	18	47	58	12	9	6	9	23	16	11	45	37	41	**183**	**290**

Figure 16 – Asia assumptions

Carbon intensities

Carbon intensities have also been retrieved to compute carbon savings based on energy efficiency results per type of energy used (natural gas for heating, electricity for the rest)[45]. Figure 17 summarizes assumptions taken.

For all-electric buildings, we have considered similar carbon intensities for electrified heat than for other uses, a rather controversial assumption. Indeed, most of this new electricity demand could in theory be considered zero-carbon since these new uses will fuel new capacities, which, by way of regulation and natural market dynamics, are zero carbon sources[46]. Would we assume zero-carbon emissions for electrified heating instead, carbon abatement of digital solutions would thus be lower (as only applying to current electricity demand). Cost savings would however remain unchanged.

Carbon intensity (gCO2/kWh)	CO2 natural gas	CO2 electricity
Canada	0.2	0.13
China - North Central	0.2	0.64
Denmark	0.2	0.19
France	0.2	0.05
Germany	0.2	0.41
Italy	0.2	0.24
Japan	0.2	0.43
Netherlands	0.2	0.44
Spain	0.2	0.27
U.S. Midwest	0.2	0.39
United Kingdom	0.2	0.25

Figure 17 – Carbon intensities

Energy costs

The data on energy costs for key regions has been retrieved, enabling us to calculate cost savings from the deployment of digital solutions[47] (Figure 18).

	Energy costs	
Country	Elec costs USD/kWh	Gas costs USD/kWh
Canada	0.11	0.03
China - North Central	0.08	0.04
China - Eastern	0.09	0.06
China - South Central	0.09	0.04
China - Northeast	0.08	0.05
China - Northwest	0.07	0.04
China - Southern	0.08	0.06
Denmark	0.35	0.10
France	0.22	0.07
Germany	0.38	0.08
Italy	0.28	0.08
Japan	0.19	0.11
Netherlands	0.25	0.06
Spain	0.30	0.08
U.S. Midwest	0.12	0.02
U.S. Northeast	0.17	0.05
U.S. South	0.12	0.03
U.S. West	0.12	0.03
United Kingdom	0.19	0.04

Figure 18 – Energy costs

45 BloombergNEF (2019), New Energy Outlook ; European Environmental Agency (2021)
46 Ibid. Over 90 percent of projected new capacities are zero carbon.
47 BloombergNEF (2019), New Energy Outlook ; European Environmental Agency (2021)

Digital solutions

We have 3 categories of digital solutions as per European regulations. Category C corresponds to basic controls, while category A includes most advanced digital control systems. Category B is an intermediate solution with lower granularity of controls (Figure 19).

Control level	Category of Control			
	T1 - No time mgt	T2 - Presence days	T3 - Presence hours	T4 - Real-time detection
S1 - One Zone	D	C	C	B
S2 - Control by Zone	D	C	B	B
S3 - Control by Room	D	B	B	A

Figure 19 – Categorization of digital controls

There is no category B for the residential sector.

Figure 20 shows the various levels of savings of each category of digital solutions, in each type of building (EU.BAC, 2021).

Individual Residential	Heating/Cooling	Water Heating	Lighting/Ventilation	Appliances
D	*100%*	*100%*	*100%*	*100%*
C	91%	90%	93%	100%
B	80%	81%	86%	100%
A	73%	72%	85%	100%
Healthcare	**Heating/Cooling**	**Water Heating**	**Lighting/Ventilation**	**Appliances**
D	*100%*	*100%*	*100%*	*100%*
C	76%	90%	95%	100%
B	69%	81%	93%	100%
A	66%	72%	91%	100%
Hotel	**Heating/Cooling**	**Water Heating**	**Lighting/Ventilation**	**Appliances**
D	*100%*	*100%*	*100%*	*100%*
C	76%	90%	93%	100%
B	65%	81%	89%	100%
A	52%	72%	84%	100%
Office	**Heating/Cooling**	**Water Heating**	**Lighting/Ventilation**	**Appliances**
D	*100%*	*100%*	*100%*	*100%*
C	66%	90%	91%	100%
B	53%	81%	85%	100%
A	46%	72%	79%	100%
Retail	**Heating/Cooling**	**Water Heating**	**Lighting/Ventilation**	**Appliances**
D	*100%*	*100%*	*100%*	*100%*
C	64%	90%	93%	100%
B	47%	81%	88%	100%
A	38%	72%	84%	100%
School	**Heating/Cooling**	**Water Heating**	**Lighting/Ventilation**	**Appliances**
D	*100%*	*100%*	*100%*	*100%*
C	83%	90%	93%	100%
B	73%	81%	87%	100%
A	67%	72%	80%	100%

Figure 20 – Efficiency gains from digital solutions

We have taken as well key assumptions for the upfront costs of digital solutions, helping us to derive payback times in years from the cost savings associated to the deployment of digital solutions.

These costs vary across solutions. Typically, they range between 5 and 25 USD/m2 for residential, and 17-20 (category C) and 35-45USD/m2 (category A) for commercial buildings (Figure 20).

These costs also vary across segments, and this is due to the granularity of control required in commercial spaces compared to more simple residential settings. While we estimate costs are lower in retail (limited fragmentation of space), they are higher in schools and hotels.

Data is also only available for category C and A, and we have estimated category B with a slight downgrading factor[48].

We have estimated that these costs would equally apply across regions. This is an important assumption as they could in fact vary, depending on product costs and more importantly installation costs. Further research would however be required to get a refined understanding of such differences across key regions.

We consider however this base to be a reasonable proxy to assess paybacks of digital solutions, as they are generally consistent with current known ranges of technology costs. Note however that variations of capex may have significant impacts on paybacks. A +/-20% evolution on capex has a +/-0.5 year impact on a 3 years payback (minor), but this translates into a +/-1.5 year impact on a 8 years payback, and up to +/-3 year impact on a 15 years payback.

Capex USD/m2	Category of Digital Solution			
	D	C	B	A
Individual residential	0	5	NA	25
Hotel	0	20	30	45
Retail	0	17	25	35
Office	0	20	30	40
Healthcare	0	20	30	40
School	0	20	30	45

Figure 21 – Upfront costs of digital technologies

The footprint of digital solutions on energy demand

A recent concern has emerged on the actual energy and carbon footprint of digital technologies.

There has been limited study on the impact of the sector as a whole on energy demand and carbon emissions. In a 2021 report, Schneider Electric[49] has provided such a forecast to 2030. One of the findings of this report is that IoT, or the scope of digital technologies here under review, represents less than 5% of global electricity demand today, and will remain below 10% by 2030 (accounting only for energy use, not manufacturing). Our conclusion, therefore, is that benefits dwarf the impacts.

Detailed result tables

We provide here full detailed tables of results from our modelling exercise by region (Figures 22 to 27).

48 Energie 3.0 (2013), Débat sur la transition énergétique : les solutions concrètes de la filière éco-électrique ; Eurovent (2020), Preparatory study for Building Automation and Control Systems (GEN - 1191.00)

49 Schneider Electric (c) (2021), Digital Economy and Climate Impact

		1980 standard building (fossil fuel heating)												2006 standard building (fossil fuel heating)												2018 standard building (fossil fuel heating)											
		EE %			CO2 %			$ savings			Payback Y			EE %			CO2 %			$ savings			Payback Y			EE %			CO2 %			$ savings			Payback Y		
	Category	C	B	A	C	B	A	C	B	A	C	B	A	C	B	A	C	B	A	C	B	A	C	B	A	C	B	A	C	B	A	C	B	A	C	B	A
Segment	Country																																				
Residential	Canada	-8%	NA	-24%	-9%	NA	-25%	-7%	NA	-20%	4.2	NA	7.4	-8%	NA	-23%	-8%	NA	-24%	-6%	NA	-17%	5.3	NA	9.3	-7%	-15%	-21%	-8%	-17%	-23%	-5%	-11%	-14%	8.4	NA	14.9
Hospital	Canada	-15%	-19%	-22%	-16%	-21%	-24%	-12%	-16%	-18%	3.1	3.5	4.1	-14%	-18%	-21%	-16%	-21%	-24%	-9%	-11%	-13%	6.0	6.8	7.7	0%	-4%	-7%	0%	-5%	-8%	0%	-2%	-4%	NA	42.1	32.9
Hotel	Canada	-11%	-17%	-24%	-12%	-19%	-27%	-7%	-12%	-17%	11.3	10.7	11.5	-10%	-16%	-23%	-11%	-18%	-25%	-7%	-11%	-16%	13.6	12.7	13.7	0%	-7%	-14%	0%	-8%	-16%	0%	-4%	-9%	NA	44.7	32.4
Office	Canada	-18%	-26%	-30%	-20%	-29%	-34%	-12%	-17%	-21%	11.0	11.0	12.0	-14%	-21%	-25%	-17%	-24%	-28%	-10%	-14%	-17%	10.4	10.6	11.7	0%	-5%	-8%	0%	-6%	-9%	0%	-4%	-6%	NA	53.3	42.8
Retail	Canada	-25%	-37%	-44%	-27%	-41%	-48%	-16%	-24%	-29%	3.2	3.1	3.6	-22%	-33%	-39%	-25%	-37%	-44%	-15%	-23%	-27%	5.1	4.9	5.7	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
School	Canada	-13%	-21%	-27%	-14%	-22%	-28%	-9%	-16%	-21%	9.8	8.6	9.7	-10%	-17%	-23%	-11%	-19%	-24%	-7%	-13%	-18%	14.8	12.6	13.8	0%	-7%	-12%	0%	-8%	-13%	0%	-5%	-9%	NA	59.6	49.3
Residential	U.S. Midwest	-7%	NA	-21%	-7%	NA	-18%	-5%	NA	-15%	8.3	NA	15.5	-7%	NA	-19%	-6%	NA	-16%	-4%	NA	-12%	9.9	NA	18.3	-6%	-12%	-16%	-5%	-10%	-13%	-4%	-8%	-10%	14.0	NA	26.0
Hospital	U.S. Midwest	-14%	-18%	-21%	-13%	-17%	-19%	-12%	-16%	-18%	3.0	3.4	3.9	-11%	-14%	-17%	-9%	-11%	-13%	-6%	-9%	-10%	8.3	9.3	10.5	0%	-3%	-5%	0%	-2%	-4%	0%	-2%	-3%	NA	53.4	40.7
Hotel	U.S. Midwest	-8%	-14%	-19%	-8%	-12%	-17%	-7%	-11%	-16%	11.2	10.5	11.3	-8%	-13%	-18%	-7%	-12%	-16%	-7%	-11%	-15%	13.7	12.9	13.9	0%	-6%	-11%	0%	-5%	-10%	0%	-4%	-8%	NA	46.9	33.8
Office	U.S. Midwest	-13%	-19%	-23%	-11%	-17%	-21%	-10%	-15%	-19%	12.0	11.9	12.8	-9%	-14%	-17%	-9%	-13%	-16%	-8%	-12%	-15%	11.4	11.4	12.5	0%	-5%	-8%	0%	-4%	-7%	0%	-4%	-7%	NA	43.6	35.2
Retail	U.S. Midwest	-18%	-27%	-33%	-15%	-22%	-27%	-11%	-18%	-22%	5.2	5.0	5.6	-12%	-19%	-23%	-11%	-18%	-22%	-11%	-17%	-21%	7.1	6.7	7.6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
School	U.S. Midwest	-11%	-18%	-23%	-10%	-16%	-22%	-9%	-15%	-20%	10.8	9.4	10.4	-7%	-13%	-18%	-7%	-13%	-17%	-7%	-12%	-17%	15.9	13.3	14.4	0%	-6%	-10%	0%	-5%	-9%	0%	-5%	-9%	NA	59.2	49.0
Residential	U.S. Northeast	-8%	NA	-24%	-7%	NA	-21%	-7%	NA	-18%	3.5	NA	6.2	-7%	NA	-22%	-7%	NA	-19%	-5%	NA	-15%	4.4	NA	7.8	-7%	-14%	-19%	-6%	-12%	-16%	-5%	-9%	-12%	6.7	NA	12.1
Hospital	U.S. Northeast	-15%	-20%	-23%	-14%	-18%	-21%	-13%	-17%	-20%	1.7	1.9	2.2	-13%	-17%	-19%	-10%	-13%	-15%	-8%	-10%	-12%	4.4	5.0	5.7	0%	-3%	-6%	0%	-3%	-5%	0%	-2%	-4%	NA	32.4	25.0
Hotel	U.S. Northeast	-10%	-15%	-22%	-8%	-13%	-19%	-8%	-12%	-17%	7.2	6.8	7.3	-9%	-14%	-20%	-8%	-12%	-17%	-7%	-11%	-15%	9.6	8.9	9.6	0%	-6%	-13%	0%	-5%	-10%	0%	-4%	-9%	NA	32.0	23.2
Office	U.S. Northeast	-16%	-23%	-28%	-14%	-20%	-24%	-12%	-18%	-22%	6.6	6.7	7.3	-12%	-18%	-21%	-10%	-15%	-18%	-9%	-13%	-16%	7.6	7.7	8.4	0%	-5%	-7%	0%	-4%	-7%	0%	-4%	-6%	NA	34.1	27.5
Retail	U.S. Northeast	-22%	-33%	-39%	-18%	-27%	-32%	-14%	-22%	-27%	2.5	2.4	2.8	-19%	-29%	-34%	-15%	-24%	-29%	-13%	-20%	-25%	4.1	3.9	4.5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
School	U.S. Northeast	-12%	-20%	-26%	-11%	-18%	-24%	-10%	-17%	-22%	5.6	5.0	5.7	-8%	-15%	-20%	-7%	-13%	-18%	-7%	-12%	-17%	11.5	9.6	10.4	0%	-6%	-11%	0%	-5%	-9%	0%	-5%	-8%	NA	44.6	36.6
Residential	U.S. South	-7%	NA	-20%	-6%	NA	-18%	-6%	NA	-15%	8.1	NA	15.2	-6%	NA	-18%	-5%	NA	-15%	-5%	NA	-12%	9.5	NA	17.4	-5%	-11%	-15%	-4%	-9%	-12%	-4%	-8%	-10%	14.1	NA	26.2
Hospital	U.S. South	-15%	-20%	-23%	-14%	-18%	-21%	-13%	-18%	-20%	2.4	2.7	3.2	-11%	-15%	-17%	-9%	-12%	-14%	-7%	-10%	-11%	7.3	8.2	9.3	0%	-3%	-5%	0%	-2%	-4%	0%	-2%	-4%	NA	49.3	38.1
Hotel	U.S. South	-8%	-12%	-17%	-7%	-12%	-16%	-7%	-11%	-16%	11.8	11.1	12.0	-8%	-13%	-18%	-8%	-12%	-17%	-7%	-12%	-16%	12.5	11.8	12.7	0%	-6%	-11%	0%	-5%	-10%	0%	-4%	-9%	NA	43.2	31.1
Office	U.S. South	-13%	-20%	-24%	-13%	-19%	-23%	-13%	-19%	-23%	9.1	9.2	10.2	-9%	-14%	-17%	-9%	-13%	-16%	-9%	-13%	-16%	11.5	11.5	12.6	0%	-5%	-8%	0%	-5%	-8%	0%	-5%	-8%	NA	38.6	31.6
Retail	U.S. South	-12%	-18%	-22%	-10%	-16%	-20%	-9%	-15%	-19%	7.3	6.8	7.5	-13%	-20%	-24%	-13%	-20%	-24%	-13%	-20%	-24%	6.1	5.8	6.6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
School	U.S. South	-10%	-17%	-23%	-10%	-17%	-22%	-10%	-16%	-22%	9.0	8.0	9.0	-7%	-13%	-18%	-7%	-13%	-18%	-7%	-13%	-17%	15.6	13.2	14.5	0%	-6%	-11%	0%	-6%	-10%	0%	-5%	-10%	NA	52.5	43.9
Residential	U.S. West	-7%	NA	-18%	-6%	NA	-15%	-5%	NA	-13%	11.4	NA	22.0	-6%	NA	-16%	-5%	NA	-13%	-4%	NA	-10%	13.9	NA	26.2	-5%	-9%	-13%	-4%	-7%	-10%	-3%	-6%	-8%	21.0	NA	39.9
Hospital	U.S. West	-15%	-20%	-22%	-14%	-18%	-21%	-13%	-17%	-20%	2.6	3.0	3.5	-11%	-15%	-18%	-9%	-12%	-14%	-7%	-10%	-11%	7.4	8.4	9.5	0%	-3%	-5%	0%	-2%	-4%	0%	-2%	-4%	NA	52.2	40.2
Hotel	U.S. West	-7%	-12%	-17%	-7%	-11%	-15%	-6%	-10%	-14%	14.4	13.4	14.3	-7%	-12%	-17%	-7%	-12%	-16%	-7%	-11%	-15%	14.1	13.2	14.2	0%	-5%	-11%	0%	-5%	-9%	0%	-4%	-9%	NA	48.3	34.9
Office	U.S. West	-12%	-17%	-21%	-10%	-16%	-19%	-10%	-15%	-18%	13.9	13.7	14.7	-8%	-12%	-15%	-8%	-12%	-14%	-8%	-11%	-14%	14.0	13.9	15.1	0%	-4%	-6%	0%	-4%	-6%	0%	-4%	-6%	NA	53.5	43.0
Retail	U.S. West	-15%	-23%	-28%	-12%	-18%	-23%	-10%	-15%	-19%	7.3	6.8	7.7	-10%	-16%	-20%	-10%	-16%	-20%	-10%	-16%	-20%	8.8	8.2	9.2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
School	U.S. West	-10%	-17%	-22%	-9%	-15%	-20%	-8%	-14%	-19%	13.3	11.4	12.6	-7%	-13%	-17%	-7%	-12%	-17%	-7%	-12%	-17%	17.5	14.7	16.0	0%	-5%	-10%	0%	-5%	-9%	0%	-5%	-9%	NA	64.9	53.7

Figure 22 – North America simulation results

		1980 building with electric heat pumps												2006 building with electric heat pumps												2018 building with electric heat pumps											
		EE %			CO2 %			$ savings			Payback Y			EE %			CO2 %			$ savings			Payback Y			EE %			CO2 %			$ savings			Payback Y		
	Category	C	B	A	C	B	A	C	B	A	C	B	A	C	B	A	C	B	A	C	B	A	C	B	A	C	B	A	C	B	A	C	B	A	C	B	A
Segment	Country																																				
Residential	Canada	-7%	NA	-21%	-7%	NA	-20%	-8%	NA	-23%	2.7	NA	4.8	-6%	NA	-18%	-6%	NA	-18%	-7%	NA	-20%	3.4	NA	6.0	-5%	-11%	-16%	-5%	-11%	-15%	-6%	-13%	-17%	5.6	NA	9.8
Hospital	Canada	-11%	-15%	-17%	-10%	-13%	-15%	-13%	-18%	-20%	2.6	3.0	3.5	-9%	-12%	-14%	-9%	-12%	-13%	-11%	-14%	-16%	4.3	4.9	5.6	0%	-3%	-5%	0%	-3%	-4%	0%	-3%	-5%	NA	31.4	24.8
Hotel	Canada	-7%	-12%	-16%	-7%	-11%	-15%	-9%	-14%	-19%	8.9	8.4	9.0	-7%	-11%	-16%	-6%	-10%	-14%	-8%	-13%	-19%	10.7	10.0	10.7	0%	-5%	-9%	0%	-4%	-9%	0%	-5%	-11%	NA	33.4	24.2
Office	Canada	-12%	-17%	-21%	-11%	-16%	-19%	-14%	-20%	-25%	8.4	8.6	9.4	-10%	-14%	-17%	-9%	-13%	-16%	-11%	-16%	-20%	8.4	8.6	9.6	0%	-4%	-6%	0%	-4%	-6%	0%	-4%	-7%	NA	47.6	38.5
Retail	Canada	-17%	-26%	-31%	-17%	-25%	-29%	-20%	-30%	-35%	2.2	2.1	2.5	-15%	-23%	-27%	-14%	-21%	-25%	-18%	-27%	-33%	3.8	3.6	4.2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
School	Canada	-9%	-15%	-20%	-9%	-14%	-18%	-11%	-19%	-25%	7.0	6.2	7.1	-7%	-12%	-16%	-7%	-11%	-15%	-9%	-15%	-20%	11.6	10.0	11.1	0%	-5%	-9%	0%	-4%	-8%	0%	-6%	-10%	NA	47.5	39.6
Residential	U.S. Midwest	-5%	NA	-15%	-6%	NA	-17%	-7%	NA	-19%	5.1	NA	9.3	-5%	NA	-13%	-5%	NA	-14%	-6%	NA	-16%	6.2	NA	11.3	-4%	-8%	-11%	-4%	-9%	-12%	-5%	-10%	-13%	9.5	NA	17.3
Hospital	U.S. Midwest	-11%	-15%	-17%	-12%	-16%	-18%	-13%	-17%	-20%	2.6	2.9	3.4	-7%	-9%	-11%	-8%	-10%	-12%	-8%	-11%	-13%	5.9	6.6	7.5	0%	-2%	-4%	0%	-2%	-4%	0%	-2%	-4%	NA	45.0	34.3
Hotel	U.S. Midwest	-7%	-11%	-15%	-7%	-12%	-16%	-8%	-12%	-17%	9.7	9.1	9.8	-6%	-10%	-14%	-7%	-11%	-15%	-7%	-12%	-17%	11.9	11.1	11.9	0%	-4%	-8%	0%	-4%	-9%	0%	-5%	-10%	NA	37.2	27.0
Office	U.S. Midwest	-10%	-15%	-19%	-11%	-16%	-20%	-11%	-17%	-21%	10.5	10.5	11.4	-8%	-12%	-15%	-9%	-13%	-16%	-9%	-13%	-16%	10.6	10.7	11.7	0%	-4%	-7%	0%	-4%	-7%	0%	-4%	-7%	NA	41.2	33.3
Retail	U.S. Midwest	-12%	-18%	-22%	-13%	-20%	-25%	-14%	-22%	-27%	3.8	3.7	4.2	-11%	-17%	-21%	-11%	-17%	-22%	-11%	-18%	-22%	6.7	6.3	7.1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
School	U.S. Midwest	-8%	-14%	-18%	-9%	-15%	-21%	-10%	-17%	-23%	8.8	7.7	8.6	-6%	-12%	-16%	-7%	-12%	-17%	-7%	-13%	-18%	14.6	12.3	13.3	0%	-5%	-8%	0%	-5%	-9%	0%	-5%	-10%	NA	51.9	42.9
Residential	U.S. Northeast	-6%	NA	-18%	-7%	NA	-19%	-7%	NA	-20%	2.6	NA	4.7	-5%	NA	-16%	-6%	NA	-16%	-6%	NA	-17%	3.3	NA	5.9	-4%	-9%	-13%	-5%	-10%	-14%	-5%	-11%	-14%	5.2	NA	9.3
Hospital	U.S. Northeast	-12%	-15%	-17%	-13%	-17%	-19%	-14%	-18%	-21%	1.5	1.8	2.1	-8%	-10%	-12%	-8%	-11%	-13%	-9%	-12%	-14%	3.6	4.1	4.7	0%	-2%	-4%	0%	-2%	-4%	0%	-2%	-4%	NA	28.7	22.2
Hotel	U.S. Northeast	-7%	-11%	-15%	-8%	-12%	-17%	-8%	-13%	-18%	6.5	6.1	6.6	-6%	-10%	-14%	-7%	-11%	-15%	-7%	-12%	-16%	8.5	7.9	8.5	0%	-4%	-8%	0%	-4%	-9%	0%	-5%	-10%	NA	27.2	19.7
Office	U.S. Northeast	-11%	-17%	-20%	-12%	-18%	-22%	-13%	-19%	-23%	5.9	6.0	6.6	-8%	-12%	-15%	-9%	-13%	-16%	-9%	-14%	-17%	6.9	7.0	7.7	0%	-4%	-6%	0%	-4%	-6%	0%	-4%	-7%	NA	32.7	26.4
Retail	U.S. Northeast	-14%	-21%	-25%	-15%	-23%	-28%	-16%	-25%	-30%	2.1	2.0	2.3	-12%	-19%	-23%	-14%	-21%	-25%	-15%	-22%	-27%	3.5	3.4	3.9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
School	U.S. Northeast	-8%	-14%	-19%	-10%	-16%	-22%	-11%	-18%	-24%	4.9	4.3	4.9	-6%	-11%	-15%	-7%	-12%	-17%	-7%	-13%	-18%	10.5	8.8	9.6	0%	-4%	-8%	0%	-5%	-9%	0%	-5%	-9%	NA	40.6	33.4
Residential	U.S. South	-5%	NA	-13%	-5%	NA	-15%	-6%	NA	-16%	7.0	NA	13.0	-4%	NA	-11%	-4%	NA	-12%	-5%	NA	-14%	8.3	NA	15.1	-3%	-7%	-9%	-4%	-8%	-10%	-4%	-8%	-11%	12.6	NA	23.3
Hospital	U.S. South	-12%	-15%	-18%	-13%	-17%	-19%	-14%	-18%	-21%	2.2	2.6	3.0	-7%	-9%	-10%	-7%	-10%	-12%	-8%	-11%	-12%	6.5	7.3	8.3	0%	-2%	-4%	0%	-2%	-4%	0%	-2%	-4%	NA	47.0	36.3
Hotel	U.S. South	-7%	-10%	-15%	-7%	-11%	-15%	-7%	-11%	-16%	11.5	10.8	11.6	-7%	-10%	-15%	-7%	-11%	-16%	-8%	-12%	-17%	12.0	11.3	12.2	0%	-4%	-8%	0%	-4%	-9%	0%	-5%	-10%	NA	40.3	29.0
Office	U.S. South	-12%	-18%	-22%	-13%	-19%	-22%	-13%	-19%	-23%	9.0	9.1	10.0	-8%	-13%	-15%	-9%	-13%	-16%	-9%	-13%	-16%	11.3	11.4	12.4	0%	-5%	-7%	0%	-5%	-8%	0%	-5%	-8%	NA	38.2	31.2
Retail	U.S. South	-9%	-14%	-18%	-9%	-15%	-18%	-10%	-15%	-19%	6.9	6.5	7.3	-12%	-19%	-23%	-13%	-19%	-24%	-13%	-20%	-24%	6.0	5.7	6.5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
School	U.S. South	-9%	-15%	-20%	-9%	-16%	-21%	-10%	-17%	-22%	8.8	7.8	8.8	-7%	-12%	-17%	-7%	-13%	-17%	-7%	-13%	-18%	15.3	13.0	14.2	0%	-5%	-9%	0%	-5%	-9%	0%	-5%	-10%	NA	50.9	42.5
Residential	U.S. West	-4%	NA	-12%	-5%	NA	-13%	-6%	NA	-15%	9.3	NA	17.7	-4%	NA	-10%	-4%	NA	-11%	-4%	NA	-12%	11.4	NA	21.2	-3%	-6%	-8%	-3%	-6%	-8%	-3%	-7%	-9%	17.7	NA	33.3
Hospital	U.S. West	-12%	-15%	-17%	-13%	-17%	-19%	-14%	-18%	-21%	2.4	2.7	3.2	-7%	-9%	-11%	-8%	-10%	-12%	-8%	-11%	-13%	6.2	7.0	8.0	0%	-2%	-4%	0%	-2%	-4%	0%	-2%	-4%	NA	48.3	37.2
Hotel	U.S. West	-6%	-9%	-13%	-6%	-10%	-14%	-7%	-11%	-15%	13.4	12.4	13.2	-6%	-10%	-14%	-7%	-11%	-15%	-7%	-11%	-16%	13.3	12.4	13.3	0%	-4%	-8%	0%	-4%	-9%	0%	-4%	-9%	NA	43.4	31.5
Office	U.S. West	-9%	-14%	-17%	-10%	-15%	-18%	-10%	-15%	-19%	13.1	12.9	13.9	-7%	-11%	-14%	-8%	-11%	-14%	-8%	-11%	-14%	13.8	13.7	14.8	0%	-4%	-6%	0%	-4%	-6%	0%	-4%	-6%	NA	52.9	42.5
Retail	U.S. West	-9%	-15%	-18%	-10%	-16%	-20%	-11%	-17%	-21%	6.3	5.9	6.7	-10%	-16%	-19%	-10%	-16%	-20%	-10%	-16%	-20%	8.7	8.1	9.1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Figure 23 – North America simulation results

		1980 standard building (fossil fuel heating)												2006 standard building (fossil fuel heating)												2018 standard building (fossil fuel heating)											
		EE %			CO2 %			$ savings			Payback Y			EE %			CO2 %			$ savings			Payback Y			EE %			CO2 %			$ savings			Payback Y		
Segment	Category / Country	C	B	A	C	B	A	C	B	A	C	B	A	C	B	A	C	B	A	C	B	A	C	B	A	C	B	A	C	B	A	C	B	A	C	B	A
Residential	Denmark	-8%	NA	-24%	-8%	NA	-24%	-6%	NA	-18%	1.8	NA	3.3	-7%	NA	-22%	-8%	NA	-22%	-5%	NA	-15%	2.3	NA	4.2	-7%	-14%	-19%	-7%	-14%	-19%	-4%	-9%	-12%	3.8	NA	6.9
Hospital	Denmark	-15%	-20%	-23%	-15%	-20%	-23%	-13%	-17%	-20%	0.8	0.9	1.1	-13%	-17%	-19%	-13%	-17%	-19%	-8%	-11%	-12%	2.2	2.4	2.8	0%	-3%	-6%	0%	-3%	-6%	0%	-2%	-4%	NA	15.9	12.3
Hotel	Denmark	-10%	-15%	-22%	-10%	-16%	-22%	-8%	-12%	-17%	3.5	3.3	3.6	-9%	-14%	-20%	-9%	-14%	-20%	-7%	-11%	-15%	4.7	4.4	4.7	0%	-6%	-13%	0%	-6%	-13%	0%	-4%	-9%	NA	15.6	11.3
Office	Denmark	-16%	-23%	-28%	-16%	-24%	-28%	-12%	-18%	-22%	3.2	3.3	3.6	-12%	-18%	-21%	-13%	-18%	-22%	-9%	-13%	-16%	3.7	3.8	4.1	0%	-5%	-7%	0%	-5%	-8%	0%	-4%	-6%	NA	16.8	13.5
Retail	Denmark	-22%	-33%	-39%	-23%	-34%	-40%	-14%	-22%	-27%	1.2	1.2	1.4	-19%	-29%	-34%	-19%	-29%	-35%	-13%	-20%	-25%	2.0	1.9	2.2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
School	Denmark	-11%	-19%	-24%	-11%	-19%	-24%	-7%	-13%	-18%	5.1	4.3	4.7	-7%	-13%	-18%	-7%	-13%	-18%	-5%	-10%	-14%	8.8	7.0	7.3	0%	-5%	-9%	0%	-5%	-9%	0%	-3%	-6%	NA	35.4	27.6
Residential	France	-8%	NA	-23%	-9%	NA	-26%	-6%	NA	-17%	3.2	NA	5.8	-7%	NA	-21%	-9%	NA	-25%	-5%	NA	-14%	4.1	NA	7.4	-6%	-13%	-18%	-8%	-17%	-24%	-4%	-8%	-11%	7.1	NA	13.0
Hospital	France	-15%	-20%	-23%	-19%	-24%	-28%	-14%	-18%	-21%	1.2	1.3	1.6	-13%	-16%	-19%	-18%	-24%	-27%	-9%	-12%	-13%	3.0	3.4	3.9	0%	-3%	-6%	0%	-5%	-9%	0%	-2%	-4%	NA	23.4	18.2
Hotel	France	-9%	-15%	-21%	-12%	-20%	-28%	-8%	-12%	-17%	5.5	5.2	5.6	-8%	-14%	-19%	-11%	-18%	-26%	-7%	-11%	-16%	7.0	6.5	7.0	0%	-6%	-12%	0%	-8%	-17%	0%	-4%	-9%	NA	23.1	16.7
Office	France	-16%	-23%	-28%	-22%	-31%	-36%	-14%	-20%	-24%	4.3	4.4	4.8	-12%	-17%	-20%	-17%	-25%	-29%	-9%	-14%	-17%	5.5	5.5	6.1	0%	-4%	-7%	0%	-6%	-10%	0%	-4%	-6%	NA	26.7	21.6
Retail	France	-20%	-31%	-36%	-29%	-43%	-50%	-14%	-22%	-26%	2.1	2.0	2.3	-17%	-26%	-31%	-24%	-36%	-43%	-14%	-21%	-26%	3.0	2.9	3.3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
School	France	-10%	-17%	-23%	-14%	-23%	-29%	-7%	-13%	-18%	9.1	7.6	8.2	-6%	-12%	-16%	-10%	-17%	-23%	-5%	-9%	-14%	15.1	11.9	12.2	0%	-4%	-8%	0%	-7%	-13%	0%	-3%	-6%	NA	63.3	48.5
Residential	Germany	-8%	NA	-24%	-7%	NA	-21%	-6%	NA	-16%	2.2	NA	4.0	-7%	NA	-22%	-6%	NA	-18%	-5%	NA	-13%	2.8	NA	5.1	-7%	-14%	-19%	-5%	-11%	-15%	-4%	-8%	-10%	4.4	NA	8.2
Hospital	Germany	-15%	-20%	-23%	-14%	-18%	-21%	-13%	-17%	-19%	0.8	0.9	1.1	-13%	-17%	-19%	-10%	-13%	-15%	-7%	-10%	-11%	2.3	2.6	3.0	0%	-3%	-6%	0%	-3%	-4%	0%	-2%	-4%	NA	16.0	12.4
Hotel	Germany	-10%	-15%	-22%	-8%	-13%	-18%	-7%	-12%	-16%	3.5	3.3	3.6	-9%	-14%	-20%	-7%	-12%	-17%	-6%	-10%	-15%	4.7	4.4	4.7	0%	-6%	-13%	0%	-5%	-10%	0%	-4%	-8%	NA	16.2	11.7
Office	Germany	-16%	-23%	-28%	-13%	-20%	-24%	-12%	-17%	-21%	3.2	3.2	3.5	-12%	-18%	-21%	-10%	-15%	-18%	-8%	-12%	-15%	3.7	3.7	4.1	0%	-5%	-7%	0%	-4%	-7%	0%	-4%	-6%	NA	16.0	12.9
Retail	Germany	-22%	-33%	-39%	-18%	-27%	-32%	-13%	-20%	-25%	1.3	1.3	1.5	-19%	-29%	-34%	-15%	-23%	-28%	-12%	-19%	-23%	2.1	2.0	2.3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
School	Germany	-11%	-19%	-24%	-9%	-15%	-21%	-7%	-12%	-17%	5.6	4.6	5.0	-7%	-13%	-18%	-6%	-11%	-15%	-5%	-9%	-13%	8.9	7.0	7.2	0%	-5%	-9%	0%	-4%	-7%	0%	-3%	-6%	NA	36.2	27.9
Residential	Italy	-7%	NA	-21%	-7%	NA	-21%	-6%	NA	-16%	2.8	NA	5.1	-7%	NA	-19%	-6%	NA	-18%	-5%	NA	-14%	3.4	NA	6.1	-6%	-12%	-16%	-5%	-11%	-15%	-4%	-8%	-11%	5.2	NA	9.5
Hospital	Italy	-15%	-20%	-23%	-15%	-20%	-23%	-14%	-18%	-21%	0.9	1.0	1.2	-12%	-16%	-18%	-11%	-15%	-18%	-9%	-12%	-13%	2.3	2.6	3.0	0%	-3%	-5%	0%	-3%	-5%	0%	-2%	-4%	NA	17.1	13.4
Hotel	Italy	-9%	-14%	-20%	-9%	-14%	-20%	-8%	-13%	-18%	4.0	3.8	4.1	-8%	-14%	-19%	-8%	-13%	-19%	-8%	-12%	-17%	4.8	4.6	4.9	0%	-6%	-12%	0%	-6%	-11%	0%	-5%	-10%	NA	16.7	12.0
Office	Italy	-16%	-23%	-27%	-15%	-22%	-27%	-14%	-21%	-25%	3.1	3.2	3.5	-11%	-16%	-19%	-11%	-16%	-19%	-9%	-14%	-17%	4.1	4.2	4.6	0%	-5%	-8%	0%	-5%	-7%	0%	-4%	-7%	NA	17.5	14.3
Retail	Italy	-18%	-27%	-32%	-17%	-25%	-30%	-13%	-20%	-25%	1.8	1.7	2.0	-15%	-24%	-29%	-15%	-23%	-28%	-14%	-22%	-26%	2.1	2.1	2.4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
School	Italy	-12%	-19%	-25%	-11%	-19%	-25%	-11%	-18%	-23%	2.9	2.6	3.0	-8%	-15%	-20%	-8%	-15%	-20%	-8%	-14%	-19%	5.1	4.4	4.9	0%	-6%	-11%	0%	-6%	-11%	0%	-5%	-10%	NA	20.4	17.2
Residential	Netherlands	-8%	NA	-22%	-6%	NA	-18%	-6%	NA	-15%	3.8	NA	7.1	-7%	NA	-19%	-5%	NA	-15%	-4%	NA	-11%	5.3	NA	9.8	-6%	-12%	-16%	-4%	-9%	-12%	-3%	-7%	-9%	8.1	NA	15.5
Hospital	Netherlands	-15%	-20%	-22%	-14%	-18%	-20%	-13%	-17%	-19%	1.2	1.4	1.6	-12%	-15%	-18%	-9%	-11%	-13%	-7%	-9%	-11%	3.7	4.2	4.7	0%	-3%	-5%	0%	-2%	-4%	0%	-2%	-3%	NA	26.7	20.3
Hotel	Netherlands	-8%	-13%	-18%	-7%	-11%	-15%	-6%	-10%	-14%	6.6	6.1	6.5	-7%	-12%	-17%	-6%	-10%	-15%	-6%	-10%	-14%	7.8	7.2	7.7	0%	-5%	-11%	0%	-4%	-9%	0%	-4%	-8%	NA	25.1	18.3
Office	Netherlands	-14%	-20%	-24%	-11%	-16%	-20%	-10%	-15%	-18%	6.2	6.2	6.6	-9%	-14%	-17%	-8%	-12%	-14%	-7%	-11%	-14%	6.8	6.7	7.3	0%	-4%	-6%	0%	-3%	-6%	0%	-3%	-5%	NA	30.0	23.7
Retail	Netherlands	-19%	-29%	-34%	-14%	-22%	-26%	-12%	-18%	-22%	2.6	2.5	2.8	-13%	-20%	-25%	-11%	-17%	-21%	-10%	-15%	-19%	4.4	4.1	4.6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
School	Netherlands	-11%	-18%	-24%	-9%	-15%	-21%	-8%	-14%	-19%	6.3	5.4	5.9	-7%	-12%	-17%	-6%	-11%	-15%	-6%	-10%	-15%	10.8	8.8	9.3	0%	-6%	-10%	0%	-5%	-9%	0%	-4%	-8%	NA	35.5	28.8
Residential	Spain	-8%	NA	-23%	-8%	NA	-22%	-6%	NA	-17%	2.4	NA	4.2	-7%	NA	-21%	-7%	NA	-20%	-5%	NA	-14%	2.9	NA	5.2	-6%	-13%	-18%	-6%	-12%	-17%	-4%	-9%	-12%	4.6	NA	8.3
Hospital	Spain	-15%	-20%	-23%	-15%	-19%	-22%	-14%	-18%	-21%	0.9	1.0	1.2	-13%	-16%	-19%	-11%	-15%	-17%	-8%	-11%	-13%	2.4	2.7	3.1	0%	-3%	-6%	0%	-3%	-5%	0%	-2%	-4%	NA	17.9	14.0
Hotel	Spain	-9%	-15%	-21%	-9%	-14%	-20%	-8%	-12%	-17%	4.1	3.9	4.2	-8%	-14%	-19%	-8%	-13%	-18%	-7%	-11%	-16%	5.3	5.0	5.3	0%	-6%	-12%	0%	-5%	-11%	0%	-4%	-9%	NA	18.0	13.0
Office	Spain	-16%	-23%	-28%	-15%	-22%	-26%	-13%	-20%	-24%	3.2	3.3	3.6	-12%	-17%	-20%	-11%	-16%	-19%	-9%	-14%	-17%	4.1	4.2	4.6	0%	-4%	-7%	0%	-4%	-7%	0%	-4%	-6%	NA	19.9	16.0
Retail	Spain	-20%	-31%	-36%	-19%	-28%	-33%	-14%	-21%	-25%	1.7	1.6	1.8	-17%	-26%	-31%	-16%	-24%	-29%	-13%	-21%	-25%	2.3	2.2	2.6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
School	Spain	-12%	-20%	-25%	-11%	-19%	-25%	-10%	-17%	-23%	3.1	2.8	3.1	-8%	-15%	-20%	-8%	-14%	-19%	-7%	-13%	-18%	5.8	4.9	5.4	0%	-6%	-10%	0%	-5%	-10%	0%	-5%	-9%	NA	23.6	19.6
Residential	United Kingdom	-8%	NA	-23%	-8%	NA	-22%	-6%	NA	-15%	5.2	NA	9.6	-7%	NA	-21%	-7%	NA	-20%	-4%	NA	-12%	6.7	NA	12.4	-6%	-13%	-18%	-6%	-12%	-16%	-3%	-7%	-9%	11.3	NA	21.3
Hospital	United Kingdom	-15%	-20%	-23%	-15%	-20%	-22%	-14%	-18%	-20%	1.4	1.6	1.9	-13%	-16%	-19%	-12%	-15%	-18%	-8%	-10%	-12%	4.2	4.7	5.4	0%	-3%	-6%	0%	-3%	-5%	0%	-2%	-4%	NA	29.9	23.3
Hotel	United Kingdom	-9%	-15%	-21%	-9%	-14%	-20%	-7%	-12%	-17%	6.8	6.5	7.0	-8%	-14%	-19%	-8%	-13%	-18%	-7%	-11%	-15%	8.7	8.2	8.8	0%	-6%	-12%	0%	-6%	-12%	0%	-4%	-9%	NA	30.5	22.0
Office	United Kingdom	-16%	-23%	-28%	-15%	-22%	-27%	-13%	-19%	-23%	5.3	5.4	5.9	-12%	-17%	-20%	-11%	-16%	-19%	-9%	-13%	-16%	6.7	6.8	7.5	0%	-4%	-7%	0%	-4%	-7%	0%	-4%	-6%	NA	32.0	25.8
Retail	United Kingdom	-20%	-31%	-36%	-19%	-29%	-34%	-13%	-20%	-24%	2.9	2.8	3.2	-17%	-26%	-31%	-16%	-25%	-30%	-13%	-20%	-24%	3.9	3.7	4.2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
School	United Kingdom	-10%	-17%	-23%	-9%	-16%	-22%	-6%	-11%	-16%	13.0	10.6	11.3	-6%	-12%	-16%	-6%	-11%	-16%	-5%	-9%	-13%	19.4	15.0	15.3	0%	-4%	-8%	0%	-4%	-8%	0%	-3%	-6%	NA	81.3	61.9

Figure 24 – Europe simulation results

		1980 building with electric heat pumps												2006 building with electric heat pumps												2018 building with electric heat pumps											
		EE %			CO2 %			$ savings			Payback Y			EE %			CO2 %			$ savings			Payback Y			EE %			CO2 %			$ savings			Payback Y		
Segment	Category / Country	C	B	A	C	B	A	C	B	A	C	B	A	C	B	A	C	B	A	C	B	A	C	B	A	C	B	A	C	B	A	C	B	A	C	B	A
Residential	Denmark	-6%	NA	-18%	-6%	NA	-18%	-7%	NA	-20%	1.4	NA	2.5	-5%	NA	-16%	-5%	NA	-16%	-6%	NA	-17%	1.8	NA	3.2	-4%	-9%	-12%	-4%	-9%	-12%	-5%	-10%	-13%	2.9	NA	5.3
Hospital	Denmark	-12%	-15%	-17%	-11%	-15%	-17%	-14%	-18%	-21%	0.8	0.9	1.0	-8%	-10%	-12%	-8%	-10%	-12%	-9%	-12%	-14%	1.8	2.1	2.3	0%	-2%	-4%	0%	-2%	-4%	0%	-2%	-4%	NA	14.2	11.0
Hotel	Denmark	-7%	-11%	-15%	-7%	-11%	-15%	-8%	-13%	-18%	3.2	3.0	3.3	-6%	-10%	-14%	-6%	-10%	-14%	-7%	-12%	-16%	4.2	3.9	4.2	0%	-4%	-8%	0%	-4%	-8%	0%	-5%	-10%	NA	13.5	9.8
Office	Denmark	-11%	-16%	-20%	-11%	-16%	-20%	-13%	-19%	-23%	2.9	3.0	3.3	-8%	-12%	-15%	-8%	-12%	-15%	-9%	-14%	-17%	3.4	3.4	3.8	0%	-4%	-6%	0%	-4%	-6%	0%	-4%	-7%	NA	16.1	13.0
Retail	Denmark	-14%	-21%	-25%	-14%	-21%	-25%	-16%	-25%	-30%	1.0	1.0	1.1	-12%	-19%	-22%	-12%	-18%	-22%	-14%	-22%	-27%	1.8	1.7	1.9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
School	Denmark	-7%	-12%	-16%	-7%	-12%	-16%	-8%	-15%	-20%	4.2	3.6	3.9	-5%	-9%	-13%	-5%	-9%	-12%	-6%	-10%	-15%	7.9	6.3	6.6	0%	-3%	-6%	0%	-3%	-6%	0%	-4%	-7%	NA	31.4	24.6
Residential	France	-6%	NA	-16%	-5%	NA	-16%	-6%	NA	-18%	3.0	NA	5.5	-5%	NA	-14%	-4%	NA	-13%	-5%	NA	-15%	3.9	NA	7.0	-4%	-8%	-10%	-3%	-7%	-10%	-4%	-8%	-11%	6.7	NA	12.3
Hospital	France	-12%	-16%	-18%	-8%	-10%	-12%	-14%	-18%	-21%	1.1	1.3	1.5	-8%	-10%	-12%	-6%	-7%	-9%	-9%	-12%	-14%	2.9	3.3	3.8	0%	-2%	-4%	0%	-2%	-3%	0%	-2%	-4%	NA	23.0	17.9
Hotel	France	-7%	-11%	-15%	-5%	-7%	-10%	-8%	-12%	-17%	5.4	5.1	5.5	-6%	-10%	-14%	-4%	-7%	-9%	-7%	-12%	-16%	6.8	6.4	6.9	0%	-4%	-8%	0%	-3%	-6%	0%	-5%	-9%	NA	22.6	16.3
Office	France	-12%	-18%	-22%	-9%	-13%	-15%	-14%	-20%	-24%	4.2	4.3	4.8	-9%	-13%	-16%	-7%	-10%	-12%	-9%	-14%	-17%	5.4	5.5	6.0	0%	-4%	-6%	0%	-3%	-5%	0%	-4%	-6%	NA	26.6	21.5
Retail	France	-12%	-19%	-23%	-9%	-14%	-17%	-15%	-22%	-27%	2.0	2.0	2.3	-12%	-18%	-22%	-8%	-12%	-15%	-14%	-21%	-26%	3.0	2.9	3.3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
School	France	-6%	-11%	-15%	-5%	-8%	-11%	-7%	-13%	-18%	8.8	7.3	8.0	-4%	-8%	-12%	-3%	-6%	-8%	-5%	-9%	-14%	14.9	11.7	12.0	0%	-3%	-6%	0%	-2%	-4%	0%	-3%	-6%	NA	62.0	47.6
Residential	Germany	-6%	NA	-18%	-7%	NA	-19%	-7%	NA	-20%	1.3	NA	2.3	-5%	NA	-15%	-6%	NA	-16%	-6%	NA	-17%	1.6	NA	2.9	-4%	-9%	-12%	-5%	-10%	-13%	-5%	-10%	-14%	2.7	NA	4.9
Hospital	Germany	-12%	-15%	-17%	-13%	-17%	-19%	-14%	-18%	-21%	0.7	0.8	0.9	-8%	-10%	-12%	-8%	-11%	-13%	-9%	-12%	-14%	1.7	1.9	2.1	0%	-2%	-4%	0%	-2%	-4%	0%	-2%	-4%	NA	13.1	10.1
Hotel	Germany	-7%	-11%	-15%	-8%	-12%	-17%	-8%	-13%	-18%	2.9	2.8	3.0	-6%	-10%	-14%	-7%	-11%	-15%	-7%	-12%	-17%	3.8	3.6	3.8	0%	-4%	-8%	0%	-4%	-9%	0%	-5%	-10%	NA	12.3	8.9
Office	Germany	-11%	-16%	-20%	-12%	-18%	-22%	-13%	-19%	-24%	2.7	2.7	3.0	-8%	-12%	-15%	-9%	-13%	-16%	-10%	-14%	-17%	3.1	3.2	3.5	0%	-4%	-6%	0%	-4%	-6%	0%	-4%	-7%	NA	14.9	12.0
Retail	Germany	-14%	-21%	-25%	-15%	-23%	-28%	-17%	-25%	-31%	0.9	0.9	1.0	-12%	-18%	-22%	-14%	-21%	-25%	-15%	-23%	-28%	1.6	1.5	1.8	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
School	Germany	-7%	-12%	-16%	-8%	-14%	-18%	-9%	-15%	-21%	3.8	3.2	3.5	-5%	-9%	-13%	-5%	-10%	-14%	-6%	-11%	-15%	7.2	5.8	6.0	0%	-3%	-6%	0%	-4%	-7%	0%	-4%	-7%	NA	28.8	22.5
Residential	Italy	-5%	NA	-14%	-5%	NA	-14%	-6%	NA	-17%	2.7	NA	4.9	-4%	NA	-12%	-4%	NA	-12%	-5%	NA	-14%	3.3	NA	5.9	-3%	-7%	-9%	-3%	-7%	-10%	-4%	-8%	-11%	5.1	NA	9.2
Hospital	Italy	-12%	-16%	-18%	-13%	-16%	-19%	-14%	-18%	-21%	0.9	1.0	1.2	-8%	-10%	-12%	-8%	-10%	-12%	-9%	-12%	-14%	2.2	2.5	2.9	0%	-2%	-4%	0%	-2%	-4%	0%	-2%	-4%	NA	16.9	13.2
Hotel	Italy	-7%	-11%	-16%	-7%	-12%	-16%	-8%	-13%	-18%	4.0	3.8	4.0	-7%	-11%	-15%	-7%	-11%	-15%	-8%	-12%	-17%	4.8	4.5	4.9	0%	-4%	-8%	0%	-4%	-9%	0%	-5%	-10%	NA	16.4	11.8
Office	Italy	-13%	-19%	-23%	-13%	-19%	-23%	-14%	-21%	-25%	3.1	3.2	3.5	-9%	-13%	-16%	-9%	-13%	-16%	-9%	-14%	-17%	4.1	4.2	4.6	0%	-4%	-7%	0%	-4%	-7%	0%	-4%	-7%	NA	17.4	14.2
Retail	Italy	-11%	-18%	-21%	-12%	-18%	-22%	-13%	-20%	-25%	1.8	1.7	2.0	-13%	-20%	-24%	-13%	-21%	-25%	-14%	-22%	-27%	2.1	2.0	2.4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
School	Italy	-9%	-15%	-20%	-9%	-16%	-21%	-11%	-18%	-24%	2.9	2.6	2.9	-8%	-13%	-18%	-8%	-13%	-18%	-8%	-14%	-19%	5.1	4.4	4.8	0%	-5%	-9%	0%	-5%	-9%	0%	-6%	-10%	NA	20.3	17.0
Residential	Netherlands	-5%	NA	-15%	-6%	NA	-16%	-6%	NA	-17%	2.9	NA	5.4	-4%	NA	-12%	-5%	NA	-13%	-5%	NA	-13%	4.0	NA	7.4	-3%	-7%	-9%	-4%	-7%	-10%	-4%	-8%	-10%	6.3	NA	11.9
Hospital	Netherlands	-11%	-15%	-17%	-13%	-17%	-19%	-14%	-18%	-20%	1.1	1.3	1.5	-7%	-9%	-11%	-8%	-10%	-12%	-8%	-11%	-12%	3.1	3.5	3.9	0%	-2%	-3%	0%	-2%	-4%	0%	-2%	-4%	NA	24.1	18.3
Hotel	Netherlands	-6%	-9%	-13%	-6%	-10%	-14%	-7%	-11%	-15%	6.0	5.6	5.9	-5%	-9%	-12%	-6%	-10%	-14%	-6%	-10%	-14%	7.2	6.6	7.0	0%	-3%	-7%	0%	-4%	-8%	0%	-4%	-8%	NA	22.1	16.1
Office	Netherlands	-9%	-14%	-17%	-10%	-15%	-19%	-11%	-16%	-20%	5.7	5.6	6.1	-7%	-11%	-13%	-7%	-11%	-14%	-8%	-11%	-14%	6.4	6.3	6.9	0%	-3%	-5%	0%	-3%	-5%	0%	-3%	-5%	NA	28.7	22.6
Retail	Netherlands	-11%	-17%	-21%	-12%	-19%	-23%	-13%	-20%	-25%	2.1	2.0	2.3	-9%	-14%	-18%	-10%	-16%	-20%	-10%	-16%	-20%	4.0	3.8	4.2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
School	Netherlands	-7%	-12%	-16%	-8%	-14%	-19%	-9%	-15%	-21%	5.4	4.6	5.2	-5%	-10%	-14%	-6%	-10%	-15%	-6%	-11%	-15%	10.2	8.3	8.8	0%	-4%	-7%	0%	-4%	-8%	0%	-5%	-8%	NA	32.0	26.0
Residential	Spain	-5%	NA	-16%	-6%	NA	-16%	-7%	NA	-19%	2.1	NA	3.7	-5%	NA	-13%	-5%	NA	-14%	-6%	NA	-16%	2.6	NA	4.6	-4%	-8%	-11%	-4%	-8%	-11%	-4%	-9%	-12%	4.1	NA	7.4
Hospital	Spain	-12%	-16%	-18%	-13%	-16%	-19%	-14%	-18%	-21%	0.8	1.0	1.1	-7%	-10%	-11%	-8%	-10%	-12%	-9%	-12%	-14%	2.2	2.5	2.9	0%	-2%	-4%	0%	-2%	-4%	0%	-2%	-4%	NA	17.1	13.3
Hotel	Spain	-7%	-11%	-15%	-7%	-11%	-16%	-8%	-12%	-17%	4.0	3.8	4.1	-6%	-10%	-14%	-6%	-10%	-14%	-7%	-12%	-16%	5.1	4.8	5.1	0%	-4%	-8%	0%	-4%	-8%	0%	-4%	-9%	NA	16.9	12.2
Office	Spain	-12%	-18%	-21%	-13%	-19%	-22%	-14%	-20%	-24%	3.1	3.2	3.5	-9%	-13%	-15%	-9%	-13%	-16%	-9%	-14%	-17%	4.0	4.0	4.4	0%	-4%	-6%	0%	-4%	-6%	0%	-4%	-6%	NA	19.6	15.8
Retail	Spain	-12%	-18%	-22%	-13%	-19%	-23%	-14%	-22%	-27%	1.5	1.5	1.7	-12%	-18%	-22%	-12%	-19%	-23%	-14%	-21%	-26%	2.2	2.1	2.4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
School	Spain	-8%	-14%	-18%	-9%	-15%	-20%	-11%	-18%	-23%	2.9	2.6	3.0	-7%	-12%	-16%	-7%	-12%	-17%	-8%	-13%	-18%	5.6	4.8	5.3	0%	-4%	-8%	0%	-5%	-8%	0%	-5%	-9%	NA	23.0	19.0
Residential	United Kingdom	-6%	NA	-17%	-6%	NA	-17%	-7%	NA	-19%	3.3	NA	6.0	-5%	NA	-14%	-5%	NA	-14%	-5%	NA	-15%	4.3	NA	7.7	-4%	-8%	-10%	-4%	-8%	-11%	-4%	-9%	-11%	7.4	NA	13.6
Hospital	United Kingdom	-12%	-16%	-18%	-13%	-17%	-19%	-15%	-19%	-22%	1.3	1.5	1.7	-8%	-10%	-12%	-8%	-11%	-12%	-9%	-12%	-14%	3.2	3.7	4.2	0%	-2%	-4%	0%	-2%	-4%	0%	-2%	-4%	NA	26.1	20.3
Hotel	United Kingdom	-7%	-11%	-15%	-7%	-11%	-16%	-8%	-13%	-18%	6.1	5.7	6.2	-6%	-10%	-14%	-7%	-10%	-15%	-8%	-12%	-17%	7.7	7.2	7.7	0%	-4%	-8%	0%	-4%	-8%	0%	-5%	-10%	NA	25.1	18.2
Office	United Kingdom	-12%	-18%	-22%	-13%	-19%	-23%	-14%	-21%	-25%	4.8	4.9	5.4	-9%	-13%	-16%	-9%	-13%	-16%	-10%	-14%	-17%	6.1	6.2	6.9	0%	-4%	-6%	0%	-4%	-6%	0%	-4%	-6%	NA	30.7	24.8
Retail	United Kingdom	-13%	-19%	-23%	-13%	-20%	-24%	-15%	-23%	-28%	2.3	2.2	2.5	-12%	-18%	-22%	-12%	-19%	-23%	-14%	-22%	-27%	3.3	3.2	3.7	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
School	United Kingdom	-6%	-11%	-15%	-6%	-11%	-15%	-8%	-14%	-19%	9.6	8.0	8.7	-4%	-8%	-12%	-5%	-9%	-13%	-5%	-10%	-14%	16.8	13.2	13.6	0%	-3%	-6%	0%	-3%	-6%	0%	-3%	-6%	NA	70.2	53.9

Figure 25 – Europe simulation results

		1980 standard building (fossil fuel heating)												2006 standard building (fossil fuel heating)											
		EE %			CO2 %			$ savings			Payback Y			EE %			CO2 %			$ savings			Payback Y		
	Category	C	B	A	C	B	A	C	B	A	C	B	A	C	B	A	C	B	A	C	B	A	C	B	A
Segment	Country																								
Residential	China - North Central	-8%	NA	-24%	-7%	NA	-19%	-7%	NA	-21%	4.1	NA	7.1	-8%	NA	-22%	-6%	NA	-16%	-7%	NA	-19%	5.1	NA	8.9
Hospital	China - North Central	-14%	-18%	-21%	-12%	-16%	-18%	-13%	-16%	-19%	3.8	4.4	5.1	-13%	-17%	-19%	-8%	-11%	-13%	-10%	-13%	-15%	6.2	7.1	8.1
Hotel	China - North Central	-9%	-15%	-21%	-7%	-11%	-16%	-8%	-13%	-18%	13.5	12.6	13.5	-9%	-14%	-20%	-7%	-11%	-15%	-7%	-12%	-17%	16.4	15.1	16.2
Office	China - North Central	-15%	-22%	-26%	-10%	-16%	-19%	-12%	-18%	-22%	14.0	14.1	15.5	-12%	-18%	-21%	-9%	-13%	-16%	-10%	-15%	-18%	12.7	13.0	14.4
Retail	China - North Central	-22%	-33%	-39%	-15%	-22%	-27%	-18%	-27%	-32%	3.5	3.4	4.0	-18%	-27%	-32%	-13%	-20%	-24%	-14%	-22%	-27%	6.9	6.6	7.6
School	China - North Central	-12%	-19%	-25%	-9%	-15%	-21%	-10%	-17%	-22%	11.4	10.0	11.4	-9%	-15%	-20%	-7%	-12%	-17%	-8%	-13%	-18%	19.1	16.3	17.9
Residential	China - Eastern	-8%	NA	-23%	-7%	NA	-18%	-7%	NA	-21%	4.1	NA	7.1	-7%	NA	-21%	-5%	NA	-15%	-7%	NA	-19%	5.1	NA	8.8
Hospital	China - Eastern	-15%	-20%	-23%	-14%	-18%	-21%	-15%	-19%	-22%	2.5	2.9	3.3	-13%	-16%	-19%	-9%	-12%	-13%	-11%	-14%	-16%	5.1	5.8	6.7
Hotel	China - Eastern	-9%	-15%	-21%	-8%	-12%	-17%	-9%	-14%	-19%	11.2	10.6	11.4	-8%	-14%	-19%	-7%	-11%	-16%	-8%	-13%	-18%	14.3	13.2	14.1
Office	China - Eastern	-16%	-23%	-28%	-14%	-20%	-24%	-15%	-22%	-26%	9.1	9.3	10.4	-12%	-17%	-20%	-9%	-14%	-17%	-10%	-15%	-18%	11.5	11.7	12.9
Retail	China - Eastern	-20%	-31%	-36%	-14%	-22%	-26%	-18%	-27%	-32%	3.6	3.5	4.0	-17%	-26%	-31%	-14%	-21%	-26%	-15%	-24%	-28%	6.0	5.8	6.7
School	China - Eastern	-12%	-20%	-25%	-10%	-17%	-23%	-11%	-19%	-24%	8.1	7.2	8.3	-8%	-15%	-20%	-7%	-13%	-18%	-8%	-14%	-19%	16.8	14.4	15.9
Residential	China - South Central	-7%	NA	-21%	-6%	NA	-17%	-6%	NA	-18%	6.8	NA	12.2	-7%	NA	-19%	-5%	NA	-14%	-5%	NA	-15%	8.2	NA	14.6
Hospital	China - South Central	-15%	-20%	-23%	-14%	-18%	-21%	-14%	-19%	-21%	2.5	2.9	3.4	-12%	-16%	-18%	-9%	-12%	-14%	-10%	-13%	-15%	5.9	6.8	7.8
Hotel	China - South Central	-9%	-14%	-20%	-8%	-13%	-18%	-8%	-13%	-18%	11.6	11.0	11.8	-8%	-14%	-19%	-8%	-12%	-17%	-8%	-13%	-18%	14.1	13.2	14.2
Office	China - South Central	-16%	-23%	-27%	-14%	-21%	-25%	-14%	-21%	-25%	9.2	9.4	10.4	-11%	-16%	-19%	-9%	-14%	-17%	-10%	-14%	-17%	12.1	12.3	13.6
Retail	China - South Central	-18%	-27%	-32%	-13%	-20%	-25%	-14%	-22%	-27%	4.9	4.7	5.4	-15%	-24%	-29%	-14%	-22%	-27%	-15%	-22%	-27%	6.4	6.1	7.0
School	China - South Central	-12%	-19%	-25%	-11%	-18%	-23%	-11%	-18%	-24%	8.4	7.5	8.6	-8%	-15%	-20%	-8%	-14%	-19%	-8%	-14%	-19%	15.2	13.2	14.6
Residential	China - Northeast	-8%	NA	-24%	-7%	NA	-20%	-8%	NA	-24%	2.7	NA	4.7	-8%	NA	-23%	-6%	NA	-18%	-7%	NA	-22%	3.4	NA	5.9
Hospital	China - Northeast	-15%	-19%	-22%	-12%	-16%	-19%	-14%	-18%	-21%	3.4	3.9	4.6	-14%	-18%	-21%	-9%	-12%	-14%	-12%	-16%	-19%	4.6	5.3	6.1
Hotel	China - Northeast	-11%	-17%	-24%	-8%	-12%	-17%	-10%	-15%	-21%	10.6	10.0	10.8	-10%	-16%	-23%	-7%	-12%	-16%	-9%	-15%	-20%	12.8	11.9	12.8
Office	China - Northeast	-18%	-26%	-30%	-12%	-18%	-22%	-16%	-23%	-27%	9.7	10.0	11.2	-14%	-21%	-25%	-10%	-15%	-18%	-13%	-18%	-22%	10.1	10.4	11.7
Retail	China - Northeast	-25%	-37%	-44%	-17%	-26%	-31%	-22%	-34%	-40%	2.3	2.2	2.6	-22%	-33%	-39%	-15%	-24%	-29%	-20%	-30%	-36%	4.2	4.1	4.8
School	China - Northeast	-13%	-21%	-27%	-10%	-17%	-22%	-12%	-20%	-25%	7.9	7.1	8.2	-10%	-17%	-23%	-8%	-13%	-18%	-9%	-16%	-21%	14.1	12.4	13.9
Residential	China - Northwest	-8%	NA	-24%	-7%	NA	-20%	-8%	NA	-23%	3.7	NA	6.4	-8%	NA	-23%	-6%	NA	-18%	-7%	NA	-21%	4.7	NA	8.1
Hospital	China - Northwest	-15%	-19%	-22%	-12%	-16%	-19%	-13%	-17%	-20%	4.1	4.7	5.5	-14%	-18%	-21%	-9%	-12%	-14%	-11%	-15%	-17%	6.1	7.0	8.1
Hotel	China - Northwest	-11%	-17%	-24%	-8%	-12%	-17%	-9%	-14%	-20%	13.4	12.7	13.6	-10%	-16%	-23%	-7%	-12%	-16%	-8%	-14%	-19%	16.1	15.1	16.2
Office	China - Northwest	-18%	-26%	-30%	-12%	-18%	-22%	-14%	-21%	-25%	12.4	12.7	14.2	-14%	-21%	-25%	-10%	-15%	-18%	-12%	-17%	-20%	12.6	13.0	14.5
Retail	China - Northwest	-25%	-37%	-44%	-17%	-26%	-31%	-20%	-31%	-37%	3.1	3.0	3.5	-22%	-33%	-39%	-15%	-24%	-29%	-18%	-28%	-33%	5.5	5.3	6.3
School	China - Northwest	-13%	-21%	-27%	-10%	-17%	-22%	-11%	-19%	-24%	10.3	9.2	10.6	-10%	-17%	-23%	-8%	-13%	-18%	-9%	-15%	-20%	17.7	15.4	17.2
Residential	China - Southern	-7%	NA	-18%	-6%	NA	-15%	-6%	NA	-18%	8.0	NA	14.5	-6%	NA	-16%	-5%	NA	-13%	-5%	NA	-15%	9.1	NA	16.3
Hospital	China - Southern	-15%	-20%	-23%	-14%	-19%	-21%	-15%	-20%	-23%	2.4	2.8	3.3	-12%	-16%	-18%	-9%	-12%	-14%	-11%	-15%	-17%	4.8	5.5	6.3
Hotel	China - Southern	-10%	-15%	-21%	-9%	-14%	-20%	-9%	-15%	-21%	10.2	9.7	10.5	-9%	-15%	-21%	-9%	-14%	-20%	-9%	-15%	-20%	11.9	11.2	12.0
Office	China - Southern	-16%	-23%	-28%	-15%	-22%	-26%	-16%	-23%	-27%	8.6	8.9	10.0	-11%	-16%	-19%	-11%	-16%	-19%	-11%	-16%	-19%	11.4	11.6	12.8
Retail	China - Southern	-16%	-25%	-30%	-14%	-22%	-26%	-16%	-24%	-29%	4.7	4.5	5.3	-17%	-26%	-31%	-17%	-26%	-31%	-17%	-26%	-31%	5.0	4.9	5.7
School	China - Southern	-12%	-20%	-26%	-12%	-19%	-25%	-12%	-20%	-26%	6.9	6.2	7.2	-10%	-16%	-22%	-9%	-16%	-21%	-10%	-16%	-22%	11.8	10.4	11.7
Residential	Japan	-8%	NA	-23%	-7%	NA	-20%	-7%	NA	-21%	2.0	NA	3.5	-7%	NA	-21%	-6%	NA	-17%	-6%	NA	-19%	2.5	NA	4.3
Hospital	Japan	-15%	-20%	-23%	-14%	-19%	-21%	-15%	-19%	-22%	1.2	1.4	1.6	-13%	-16%	-19%	-10%	-13%	-15%	-11%	-14%	-16%	2.5	2.8	3.2
Hotel	Japan	-9%	-15%	-21%	-8%	-13%	-18%	-8%	-13%	-19%	5.4	5.1	5.4	-8%	-14%	-19%	-8%	-12%	-17%	-8%	-13%	-18%	6.8	6.3	6.8
Office	Japan	-16%	-23%	-28%	-14%	-21%	-25%	-15%	-21%	-26%	4.3	4.4	4.9	-12%	-17%	-20%	-10%	-15%	-18%	-10%	-15%	-18%	5.5	5.6	6.2
Retail	Japan	-20%	-31%	-36%	-16%	-24%	-29%	-17%	-26%	-31%	1.7	1.7	2.0	-17%	-26%	-31%	-15%	-22%	-27%	-15%	-23%	-28%	2.9	2.8	3.2
School	Japan	-12%	-20%	-25%	-11%	-18%	-24%	-11%	-19%	-24%	3.9	3.5	4.0	-8%	-15%	-20%	-8%	-13%	-18%	-8%	-14%	-19%	8.0	6.8	7.6

		2018 standard building (fossil fuel heating)											
		EE %			CO2 %			$ savings			Payback Y		
	Category	C	B	A	C	B	A	C	B	A	C	B	A
Segment	Country												
Residential	China - North Central	-7%	-14%	-19%	-5%	-10%	-13%	-6%	-12%	-16%	8.7	NA	15.2
Hospital	China - North Central	0%	-4%	-7%	0%	-2%	-4%	0%	-3%	-5%	NA	44.7	35.1
Hotel	China - North Central	0%	-6%	-13%	0%	-4%	-9%	0%	-5%	-10%	NA	49.3	35.9
Office	China - North Central	0%	-6%	-9%	0%	-4%	-7%	0%	-5%	-7%	NA	55.7	45.4
Retail	China - North Central	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
School	China - North Central	0%	-6%	-11%	0%	-5%	-8%	0%	-5%	-9%	NA	79.4	65.2
Residential	China - Eastern	-6%	-13%	-18%	-4%	-9%	-12%	-6%	-12%	-16%	8.5	NA	15.0
Hospital	China - Eastern	0%	-3%	-6%	0%	-2%	-4%	0%	-3%	-5%	NA	45.7	35.6
Hotel	China - Eastern	0%	-6%	-12%	0%	-4%	-9%	0%	-5%	-11%	NA	42.6	31.0
Office	China - Eastern	0%	-4%	-7%	0%	-4%	-6%	0%	-4%	-7%	NA	61.1	49.3
Retail	China - Eastern	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
School	China - Eastern	0%	-6%	-10%	0%	-5%	-9%	0%	-5%	-10%	NA	68.1	56.3
Residential	China - South Central	-6%	-12%	-16%	-4%	-8%	-11%	-4%	-9%	-12%	13.1	NA	23.5
Hospital	China - South Central	0%	-3%	-5%	0%	-2%	-4%	0%	-3%	-4%	NA	48.6	38.0
Hotel	China - South Central	0%	-6%	-12%	0%	-5%	-10%	0%	-5%	-10%	NA	46.1	33.3
Office	China - South Central	0%	-5%	-8%	0%	-4%	-7%	0%	-4%	-7%	NA	53.0	43.2
Retail	China - South Central	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
School	China - South Central	0%	-6%	-11%	0%	-6%	-10%	0%	-6%	-10%	NA	60.1	50.4
Residential	China - Northeast	-7%	-15%	-21%	-5%	-11%	-15%	-7%	-14%	-19%	5.7	NA	9.8
Hospital	China - Northeast	0%	-4%	-7%	0%	-3%	-5%	0%	-4%	-6%	NA	34.4	27.5
Hotel	China - Northeast	0%	-7%	-14%	0%	-5%	-10%	0%	-6%	-13%	NA	37.5	27.2
Office	China - Northeast	0%	-5%	-8%	0%	-4%	-6%	0%	-5%	-7%	NA	62.5	50.9
Retail	China - Northeast	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
School	China - Northeast	0%	-7%	-12%	0%	-5%	-9%	0%	-6%	-11%	NA	57.7	48.6
Residential	China - Northwest	-7%	-15%	-21%	-5%	-11%	-15%	-6%	-13%	-18%	7.7	NA	13.4
Hospital	China - Northwest	0%	-4%	-7%	0%	-3%	-5%	0%	-3%	-6%	NA	45.0	35.8
Hotel	China - Northwest	0%	-7%	-14%	0%	-5%	-10%	0%	-6%	-12%	NA	48.7	35.3
Office	China - Northwest	0%	-5%	-8%	0%	-4%	-6%	0%	-4%	-7%	NA	74.0	59.9
Retail	China - Northwest	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
School	China - Northwest	0%	-7%	-12%	0%	-5%	-9%	0%	-6%	-11%	NA	72.3	60.5
Residential	China - Southern	-5%	-11%	-15%	-4%	-9%	-12%	-5%	-10%	-14%	11.6	NA	20.7
Hospital	China - Southern	0%	-3%	-6%	0%	-3%	-5%	0%	-3%	-5%	NA	40.9	32.3
Hotel	China - Southern	0%	-6%	-13%	0%	-5%	-11%	0%	-6%	-12%	NA	37.7	27.3
Office	China - Southern	0%	-5%	-9%	0%	-5%	-8%	0%	-5%	-9%	NA	45.5	37.7
Retail	China - Southern	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
School	China - Southern	0%	-7%	-12%	0%	-6%	-11%	0%	-7%	-12%	NA	48.5	41.2
Residential	Japan	-6%	-13%	-18%	-5%	-11%	-14%	-5%	-11%	-15%	4.2	NA	7.3
Hospital	Japan	0%	-3%	-6%	0%	-3%	-4%	0%	-3%	-5%	NA	21.9	17.1
Hotel	Japan	0%	-6%	-12%	0%	-5%	-10%	0%	-5%	-11%	NA	20.5	14.9
Office	Japan	0%	-4%	-7%	0%	-4%	-7%	0%	-4%	-7%	NA	28.9	23.4
Retail	Japan	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
School	Japan	0%	-6%	-10%	0%	-5%	-9%	0%	-5%	-10%	NA	32.4	26.8

Figure 26 – Asia simulation results

		1980 building with electric heat pumps												2006 building with electric heat pumps												2018 building with electric heat pumps											
		EE %			CO2 %			$ savings			Payback Y			EE %			CO2 %			$ savings			Payback Y			EE %			CO2 %			$ savings			Payback Y		
	Category	C	B	A	C	B	A	C	B	A	C	B	A	C	B	A	C	B	A	C	B	A	C	B	A	C	B	A	C	B	A	C	B	A	C	B	A
Segment	Country																																				
Residential	China - North Central	-6%	NA	-18%	-7%	NA	-20%	-7%	NA	-19%	5.8	NA	10.1	-5%	NA	-16%	-6%	NA	-17%	-6%	NA	-17%	7.2	NA	12.6	-4%	-9%	-13%	-5%	-11%	-14%	-5%	-10%	-13%	11.9	NA	21.2
Hospital	China - North Central	-10%	-14%	-16%	-12%	-16%	-18%	-12%	-15%	-17%	4.4	5.0	5.8	-8%	-10%	-12%	-9%	-12%	-14%	-8%	-11%	-13%	8.2	9.3	10.6	0%	-2%	-4%	0%	-3%	-4%	0%	-2%	-4%	NA	57.1	44.5
Hotel	China - North Central	-6%	-10%	-14%	-7%	-12%	-16%	-7%	-11%	-16%	16.2	15.1	16.2	-6%	-10%	-13%	-7%	-11%	-16%	-7%	-11%	-15%	19.7	18.2	19.5	0%	-4%	-8%	0%	-4%	-9%	0%	-4%	-9%	NA	62.2	45.2
Office	China - North Central	-10%	-14%	-17%	-11%	-16%	-20%	-10%	-16%	-19%	16.9	16.9	18.4	-8%	-12%	-15%	-9%	-14%	-17%	-9%	-13%	-16%	14.8	15.0	16.5	0%	-4%	-6%	0%	-4%	-7%	0%	-4%	-7%	NA	63.4	51.3
Retail	China - North Central	-14%	-20%	-24%	-16%	-24%	-29%	-15%	-22%	-27%	4.7	4.5	5.3	-11%	-17%	-21%	-13%	-20%	-25%	-13%	-19%	-24%	8.5	8.1	9.3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
School	China - North Central	-8%	-13%	-17%	-9%	-16%	-22%	-9%	-15%	-20%	14.8	13.0	14.6	-6%	-11%	-15%	-7%	-13%	-18%	-7%	-12%	-17%	22.7	19.2	20.9	0%	-4%	-7%	0%	-5%	-9%	0%	-4%	-8%	NA	93.9	76.8
Residential	China - Eastern	-6%	NA	-16%	-7%	NA	-19%	-6%	NA	-17%	7.4	NA	13.0	-5%	NA	-14%	-6%	NA	-16%	-5%	NA	-14%	9.1	NA	16.0	-4%	-8%	-11%	-4%	-9%	-13%	-4%	-9%	-12%	14.6	NA	26.1
Hospital	China - Eastern	-12%	-16%	-18%	-14%	-18%	-21%	-13%	-17%	-19%	3.0	3.5	4.1	-8%	-10%	-12%	-9%	-12%	-14%	-8%	-11%	-13%	7.9	8.9	10.3	0%	-2%	-4%	0%	-2%	-4%	0%	-2%	-4%	NA	59.4	46.3
Hotel	China - Eastern	-7%	-11%	-15%	-8%	-12%	-17%	-7%	-12%	-16%	14.2	13.4	14.4	-6%	-10%	-14%	-7%	-12%	-16%	-7%	-11%	-15%	18.3	17.1	18.3	0%	-4%	-8%	0%	-4%	-9%	0%	-4%	-9%	NA	60.5	43.8
Office	China - Eastern	-12%	-18%	-22%	-14%	-20%	-24%	-13%	-19%	-23%	11.0	11.2	12.4	-9%	-13%	-16%	-9%	-14%	-17%	-9%	-13%	-16%	13.8	14.0	15.4	0%	-4%	-6%	0%	-4%	-6%	0%	-4%	-6%	NA	66.4	53.6
Retail	China - Eastern	-12%	-19%	-22%	-14%	-22%	-27%	-13%	-20%	-24%	5.5	5.3	6.2	-12%	-18%	-22%	-14%	-21%	-26%	-13%	-20%	-24%	7.9	7.6	8.7	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
School	China - Eastern	-8%	-14%	-19%	-10%	-18%	-23%	-9%	-16%	-21%	10.9	9.7	11.1	-7%	-12%	-16%	-7%	-13%	-18%	-7%	-12%	-17%	19.9	17.0	18.7	0%	-5%	-8%	0%	-5%	-9%	0%	-5%	-9%	NA	80.5	66.7
Residential	China - South Central	-5%	NA	-14%	-6%	NA	-17%	-6%	NA	-16%	8.6	NA	15.6	-4%	NA	-12%	-5%	NA	-14%	-5%	NA	-14%	10.3	NA	18.4	-3%	-7%	-10%	-4%	-9%	-11%	-4%	-8%	-11%	15.9	NA	28.8
Hospital	China - South Central	-12%	-16%	-18%	-14%	-18%	-21%	-14%	-18%	-20%	2.7	3.1	3.7	-8%	-10%	-12%	-9%	-12%	-14%	-9%	-11%	-13%	7.0	7.9	9.1	0%	-2%	-4%	0%	-3%	-4%	0%	-2%	-4%	NA	52.6	41.2
Hotel	China - South Central	-7%	-11%	-16%	-8%	-13%	-18%	-8%	-13%	-17%	12.4	11.8	12.7	-7%	-11%	-15%	-8%	-12%	-17%	-8%	-12%	-17%	15.1	14.3	15.4	0%	-4%	-8%	0%	-5%	-10%	0%	-5%	-10%	NA	51.7	37.3
Office	China - South Central	-13%	-19%	-23%	-14%	-21%	-25%	-14%	-20%	-24%	9.7	9.9	11.0	-9%	-13%	-16%	-10%	-14%	-17%	-9%	-14%	-17%	12.8	12.9	14.2	0%	-4%	-7%	0%	-4%	-7%	0%	-4%	-7%	NA	54.0	44.1
Retail	China - South Central	-12%	-18%	-22%	-13%	-21%	-25%	-13%	-20%	-24%	5.6	5.3	6.2	-13%	-20%	-25%	-14%	-22%	-27%	-14%	-22%	-26%	6.7	6.4	7.4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
School	China - South Central	-9%	-16%	-20%	-11%	-18%	-24%	-10%	-17%	-23%	9.1	8.1	9.3	-8%	-13%	-18%	-8%	-14%	-19%	-8%	-14%	-19%	15.8	13.6	15.1	0%	-5%	-9%	0%	-6%	-10%	0%	-5%	-10%	NA	63.5	53.3
Residential	China - Northeast	-7%	NA	-21%	-8%	NA	-23%	-7%	NA	-22%	4.1	NA	7.0	-6%	NA	-19%	-7%	NA	-20%	-7%	NA	-19%	5.1	NA	8.8	-6%	-12%	-16%	-6%	-13%	-18%	-6%	-12%	-17%	8.4	NA	14.5
Hospital	China - Northeast	-11%	-15%	-17%	-14%	-18%	-20%	-12%	-16%	-18%	4.2	4.9	5.6	-10%	-13%	-15%	-11%	-14%	-17%	-10%	-13%	-15%	6.5	7.5	8.6	0%	-3%	-5%	0%	-3%	-5%	0%	-3%	-5%	NA	47.4	37.7
Hotel	China - Northeast	-8%	-12%	-17%	-9%	-14%	-20%	-8%	-13%	-18%	14.0	13.3	14.3	-7%	-12%	-16%	-8%	-14%	-19%	-8%	-12%	-17%	17.0	15.9	17.0	0%	-5%	-10%	0%	-5%	-11%	0%	-5%	-10%	NA	51.7	37.5
Office	China - Northeast	-12%	-18%	-22%	-14%	-21%	-25%	-13%	-19%	-23%	13.1	13.4	14.9	-10%	-15%	-18%	-11%	-17%	-20%	-11%	-16%	-19%	13.0	13.4	14.9	0%	-4%	-6%	0%	-4%	-7%	0%	-4%	-7%	NA	72.6	58.7
Retail	China - Northeast	-18%	-27%	-32%	-20%	-30%	-36%	-19%	-28%	-33%	3.3	3.2	3.8	-16%	-24%	-29%	-18%	-28%	-33%	-17%	-25%	-30%	5.9	5.7	6.7	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
School	China - Northeast	-10%	-16%	-21%	-11%	-19%	-25%	-10%	-17%	-22%	11.2	10.0	11.5	-7%	-13%	-17%	-9%	-15%	-21%	-8%	-14%	-18%	18.7	16.2	18.1	0%	-5%	-9%	0%	-6%	-11%	0%	-5%	-10%	NA	75.7	63.4
Residential	China - Northwest	-7%	NA	-20%	-8%	NA	-22%	-7%	NA	-21%	5.1	NA	8.8	-6%	NA	-18%	-7%	NA	-19%	-6%	NA	-19%	6.4	NA	11.1	-5%	-11%	-15%	-6%	-12%	-16%	-6%	-12%	-16%	10.4	NA	18.1
Hospital	China - Northwest	-11%	-14%	-16%	-13%	-17%	-20%	-12%	-16%	-18%	4.8	5.5	6.3	-9%	-12%	-14%	-10%	-13%	-16%	-10%	-13%	-15%	7.9	9.0	10.4	0%	-3%	-4%	0%	-3%	-5%	0%	-3%	-5%	NA	56.8	44.9
Hotel	China - Northwest	-7%	-11%	-16%	-8%	-13%	-19%	-8%	-13%	-17%	16.4	15.4	16.6	-7%	-11%	-15%	-8%	-13%	-18%	-7%	-12%	-17%	19.7	18.5	19.8	0%	-4%	-9%	0%	-5%	-11%	0%	-5%	-10%	NA	61.5	44.6
Office	China - Northwest	-11%	-17%	-20%	-13%	-20%	-24%	-13%	-18%	-22%	15.4	15.7	17.3	-9%	-14%	-17%	-11%	-16%	-19%	-10%	-15%	-18%	15.1	15.4	17.2	0%	-4%	-6%	0%	-4%	-7%	0%	-4%	-7%	NA	81.7	65.9
Retail	China - Northwest	-17%	-25%	-29%	-19%	-28%	-34%	-18%	-27%	-32%	4.1	3.9	4.6	-15%	-22%	-26%	-17%	-26%	-31%	-16%	-24%	-29%	7.0	6.8	7.9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
School	China - Northwest	-9%	-15%	-19%	-11%	-18%	-24%	-10%	-17%	-22%	13.4	12.0	13.7	-7%	-12%	-16%	-8%	-14%	-20%	-8%	-13%	-18%	21.6	18.7	20.7	0%	-5%	-8%	0%	-6%	-10%	0%	-5%	-9%	NA	87.5	72.9
Residential	China - Southern	-5%	NA	-13%	-6%	NA	-15%	-5%	NA	-13%	12.9	NA	23.8	-4%	NA	-11%	-5%	NA	-13%	-4%	NA	-12%	14.1	NA	25.7	-4%	-8%	-10%	-4%	-9%	-12%	-4%	-8%	-10%	17.9	NA	32.4
Hospital	China - Southern	-12%	-16%	-19%	-14%	-19%	-21%	-13%	-17%	-19%	3.1	3.6	4.2	-8%	-10%	-12%	-9%	-12%	-14%	-8%	-11%	-13%	7.8	8.9	10.2	0%	-3%	-5%	0%	-3%	-5%	0%	-3%	-5%	NA	49.6	39.5
Hotel	China - Southern	-8%	-13%	-18%	-9%	-14%	-20%	-9%	-13%	-19%	11.9	11.4	12.3	-8%	-13%	-18%	-9%	-14%	-20%	-8%	-13%	-18%	14.1	13.6	14.7	0%	-5%	-10%	0%	-5%	-11%	0%	-5%	-10%	NA	50.7	36.4
Office	China - Southern	-14%	-21%	-25%	-15%	-22%	-26%	-15%	-21%	-25%	9.7	10.0	11.2	-10%	-15%	-18%	-11%	-16%	-19%	-11%	-15%	-19%	11.9	12.2	13.5	0%	-5%	-8%	0%	-5%	-8%	0%	-5%	-8%	NA	47.0	39.1
Retail	China - Southern	-13%	-20%	-24%	-14%	-22%	-26%	-13%	-20%	-25%	6.0	5.7	6.6	-17%	-25%	-30%	-17%	-26%	-31%	-17%	-26%	-31%	5.2	5.0	5.9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
School	China - Southern	-11%	-18%	-23%	-12%	-19%	-25%	-11%	-18%	-24%	7.8	7.1	8.2	-9%	-16%	-21%	-9%	-16%	-21%	-9%	-16%	-21%	12.4	10.9	12.4	0%	-6%	-11%	0%	-6%	-11%	0%	-6%	-11%	NA	53.3	45.5
Residential	Japan	-6%	NA	-16%	-6%	NA	-18%	-6%	NA	-17%	3.4	NA	6.0	-5%	NA	-14%	-5%	NA	-15%	-5%	NA	-15%	4.2	NA	7.4	-4%	-8%	-11%	-4%	-9%	-12%	-4%	-9%	-12%	6.8	NA	12.1
Hospital	Japan	-12%	-16%	-18%	-14%	-18%	-20%	-13%	-17%	-20%	1.4	1.6	1.9	-8%	-10%	-12%	-9%	-11%	-13%	-8%	-11%	-13%	3.7	4.1	4.8	0%	-2%	-4%	0%	-2%	-4%	0%	-2%	-4%	NA	27.7	21.6
Hotel	Japan	-7%	-11%	-15%	-8%	-12%	-17%	-7%	-12%	-16%	6.6	6.3	6.7	-6%	-10%	-14%	-7%	-11%	-16%	-7%	-11%	-15%	8.5	8.0	8.5	0%	-4%	-8%	0%	-4%	-9%	0%	-4%	-9%	NA	28.1	20.4
Office	Japan	-12%	-18%	-22%	-13%	-20%	-24%	-13%	-19%	-23%	5.1	5.2	5.8	-9%	-13%	-16%	-9%	-14%	-17%	-9%	-14%	-16%	6.5	6.5	7.2	0%	-4%	-6%	0%	-4%	-6%	0%	-4%	-6%	NA	31.2	25.2
Retail	Japan	-12%	-19%	-23%	-14%	-21%	-26%	-13%	-21%	-25%	2.6	2.5	2.9	-12%	-18%	-22%	-13%	-20%	-25%	-13%	-20%	-24%	3.7	3.5	4.1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
School	Japan	-9%	-14%	-19%	-10%	-17%	-22%	-10%	-16%	-21%	5.1	4.5	5.2	-7%	-12%	-16%	-7%	-13%	-18%	-7%	-13%	-17%	9.3	7.9	8.7	0%	-5%	-8%	0%	-5%	-9%	0%	-5%	-9%	NA	37.6	31.2

Figure 27 – Asia simulation results

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