ADOPTING DECARBONIZATION POLICIES IN THE BUILDINGS & CONSTRUCTION SECTOR

COSTS AND BENEFITS

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Global Alliance for Buildings and Construction

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» PREFACE

The building sector is not on track to lower total greenhouse gas emissions. Given that emissions from the sector represent nearly 40% of global energy-and process-related emissions, this represents a serious challenge to keeping global warming to 1.5ºC. The Buildings sector must therefore decarbonize.

To support this goal, this report focuses on policy drivers for decarbonisation, and the costs and benefits associated with their implementation. In this report these policies are referred to as building climate actions, and include policies that tackle reducing (1) direct emissions from building energy use which includes (2) indirect emissions from the power sector, (3) and emissions from energy used in the building materials and construction supply chain (embodied emissions). All three aspects of the carbon footprint of buildings need to be addressed by policy-makers and practitioners in cost effective ways. Although gaps in the evidence base make generalisation unreliable, the body of experience over many years indicates that the social and economic co-benefits of taking these actions outweigh the costs of development and implementation. Inaction also increases the cost of climate adaptation, and exacerbates risks to health, security and property that create an imperative for taking urgent actions to decarbonize the buildings sector.

Limitations

These findings are based on an extensive literature review, based mainly on English language refereed publications. Rigorous and focused rapid reviews were undertaken to look for causal links between specific polices and observed policy impacts such as, reductions in energy demand and/or emissions, behaviour change, and health impacts. A sample of more than 4000 journal articles were surveyed, with a short list of 120 journal papers and peer-reviewed grey literature included in a final analytical set. For the most part the articles included for content analysis were systematic reviews of building climate action policies.

Rather than reinforcing the evidence on the impact of building energy policies, the rapid review demonstrated that there are major gaps in the evidence base. Furthermore, it indicated that is difficult to generalise findings of policy studies in the built environment because there is little consistency of methodologies, scope of studies, analysis or data-quality standards being applied. This is also influenced by the larger number of EU-based studies, and a lack of systematic research on policy impacts in developing countries.

It is possible to identify costs, benefits and impacts of building energy policies in specific locations, at specific times within the limitations of the methodologies applied. A number of scenario-based studies where ex-post (measured) baselines or other methodological rigour was evident have also been reviewed. However, because every study is unique, the insights and experience upon which this report is based should not be considered generalisable guidance. Rather, it is hoped that policy makers can draw on the lessons learned from specific cases to better evaluate the potential costs and benefits of building sector climate actions in their jurisdictions.

Report Structure

This report is designed for national, state and local governments and relevant ministries in charge of developing and implementing buildings and construction policies. It provides a review of the evidence on cost-effective public policies for reducing building energy consumption and associated greenhouse gas emissions that also deliver societal benefits and provide insight into best-practices. It further shines a first light on multiple impacts and cost implications of the selected policies. It is organised into four sections.

The first section establishes the problem context and policy priorities for decarbonising the buildings sector to support achieving the Paris Agreement goals of limiting global warming to 1.5°C. It also introduces the GlobalABC Global Roadmap and Regional Roadmaps, which provide a strategic framework for packaging cost-effective building climate actions.

Section 2 focusses on cost-effective building climate policies and on the financial and energy impacts of key policy measures including building codes, renovation targets, building energy performance certificates, rating and disclosure schemes. Section 2 also reviews the costs and benefits of market-based approaches including grants, carbon pricing and emissions trading, and energy efficiency obligations.

Section 3 then looks at the broader monetary and co-benefits of policy packages including stimulating economic development, employment, health & wellbeing, productivity, climate change resilience, integrated planning and nature-based solutions.

Section 4 draws from the preceding sections to provide insights into developing cost-effective and high impact policy packages for designing and implementing sustainable buildings roadmaps. The report concludes with recommendations for policy makers on how to implement policy packages for decarbonising the buildings sector.

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» KEY INSIGHTS: SUMMARY FOR POLICY MAKERS

Enabling actions & conditions for effective building climate policies:

- Early action and long-term commitment to ambitious building climate policies is fundamental to contributing to keeping global warming to 1.5°C.
- Speed is of the essence. Advanced jurisdictions have more than three decades of experience in designing, implementing and improving policy-packages that are effective in reducing energy demand and associated emissions. Yet, the greatest growth in new floor area and building energy demand are in jurisdictions that have only recently implemented, or are yet to implement building energy codes and policies. They need support to leapfrog to significant policy achievements in just one decade.
- Ambitious building energy policies pay off. Implementing policies targeting holistic absolute goals for near or net zero energy performance provide long-term positive returns on investments after 2030. Long-term political commitment to such ambition is therefore also necessary.
- Evidence from multiple studies demonstrates that higher energy performance buildings including near and net-zero energy and net zero carbon homes provide lower operational energy costs compared to standard practices.
- While the evidence demonstrates that building energy performance targets including near and net-zero energy standards can be economically viable, more research of very low energy buildings is required in order to quantify, monetise and determine the net present value of many known co-benefits.
- The monetary benefits of energy efficiency measures to economies is often underestimated because impact analyses predominantly concentrate on direct energy and cost savings (cost-effectiveness), but seldom include quantitative analysis of the costs and benefits of co-benefits (policy value).
- When implemented as a package of aligned strategies, ambitious policies reduce total final energy demand and associated greenhouse gas (GHG) emissions (policy impact). Policy strategies are more often associated with these positive climate and economic impacts when they are designed to address local market conditions, respond to the priorities of key stakeholders, and are monitored transparently for impact and value (policy effectiveness).
- Evidence for which policy actions bring what cost and benefits is poor, especially in developing country contexts. It is essential that governments and other entities properly fund monitoring and evaluation as well as case studies to enable evidence-based policies.
- The cost-effectiveness of building codes can be undermined if intended energy and emissions savings are not met. Even where building energy codes are in place they are not necessarily being complied with. One of the biggest impacts and 'short term wins' governments can have to invest in ensuring compliance mechanisms are put in place and enforced.
- Without an enabling framework, policy impact will remain limited: Putting a price on carbon and putting in place ambitious commitments are essential for such an enabling framework.

The most cost-effective policy strategies: Mandatory building energy codes, rating & disclosure and energy efficiency obligations.

- The most cost-efficient and highest positive impact policies remain a combination of building energy provisions in mandatory building codes coupled with energy rating and disclosure programs such as mandatory energy rating and labelling for buildings in operation, and appliances. Energy performance requirements in mandatory codes improve energy efficiency of new buildings and major renovation works, while energy rating and disclosure programs support achieving required performance in building operations and market awareness of better performing buildings.
- Despite the diversity of approaches well-designed energy efficiency obligations schemes (EEOs) can deliver significant energy savings from low-cost measures over many years by encouraging energy efficiency renovations. However, as energy efficiency targets become more ambitious the scope of EEOs will need to increase, and be designed to incorporate less cost-effective, but higher energy savings measures. Experience from countries with long-established EEOs show that their success should not be taken for granted, as the variables of policy design, governance, implementation, and market conditions all influence EEOS performance, and on-bill costs increase their political vulnerability.

Most value is created by: Policy packages including mandatory, incentive, and voluntary awareness-raising and capacity building programs

- Supporting the success of these policy instruments are a range of incentive, and voluntary awareness-raising and capacity building programs. Where these are most needed are in markets with high lock-in risk due to rapid urbanisation, and where markets for energy efficiency renovations, integrated renewables, and demand-side management need to be created and or boosted. It is in renovation markets that the largest impact on co-benefits, especially job creation and indoor health & well-being have been observed.

Most impact created by: Implementing and enforcing policy best-practices with clear and ambitious absolute performance targets.

- The largest economic gains are to be made by implementing policy best-practices with clear and ambitious absolute performance targets, that require holistic performance, are strategic and mandatory, are enforced and integrated, are transparent and evidence-based.
- Building energy policies need to be considered as part of a suite of policy strategies aimed at decarbonising the buildings sector, and the built-environment more generally. The most important in terms of achieving Paris agreement decarbonisation are integrated urban design and planning policies, which incorporate near-zero energy or emissions buildings, distributed renewable energy generation, appropriate bioclimatic design, mobility planning, and circular-economy supply chains. Carbon pricing, fiscal and investment policies are also important drivers for market transformation and decarbonization.

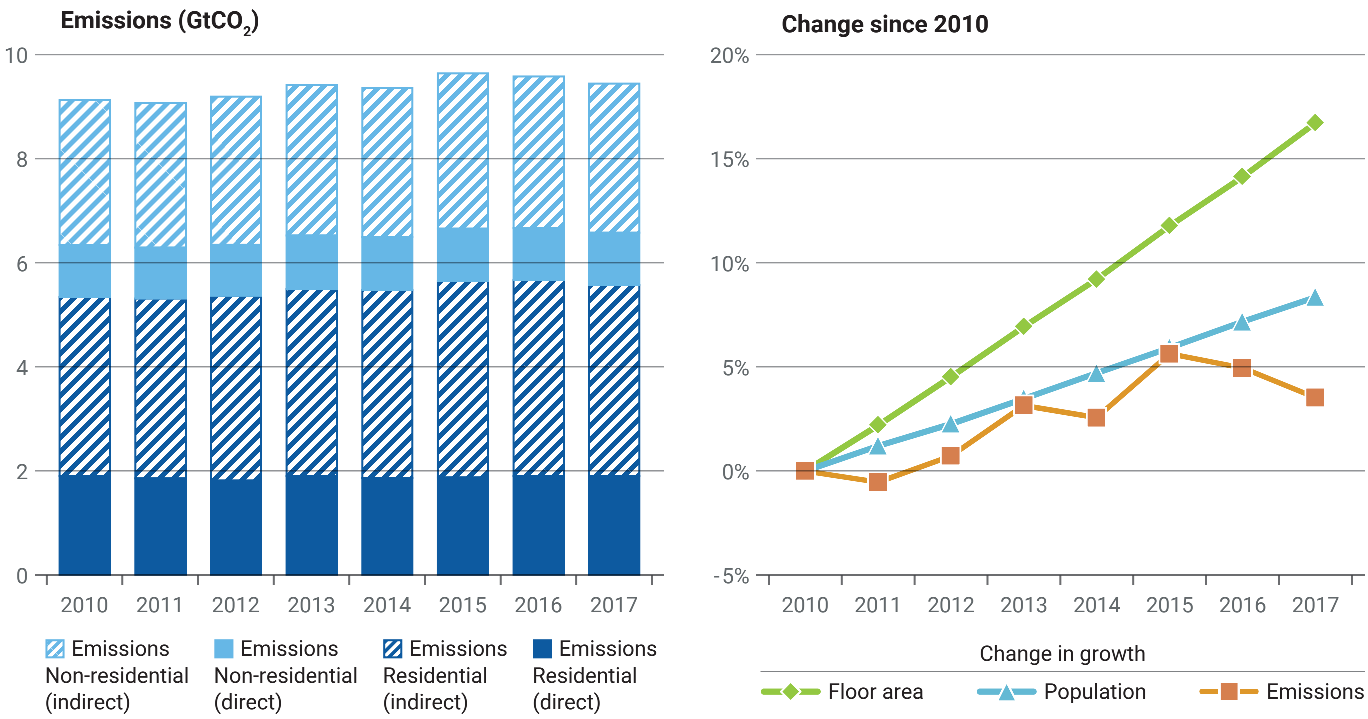
Most effective when: Tailored to local non-energy priorities, climate and socio-economics, tackle up-front costs, are monitored, reported and verified. Building energy policies are more effective when they:

- Are tailored to the priorities of primary decision-makers. Variables other than cost and economic performance such as health, comfort, and having control over comfort often play a larger role in decision making than energy efficiency considerations.
- Tackle up-front costs by providing finance, subsidies or support for policy adoption and compliance.
- Are designed to address local conditions such as the location, climatic conditions, energy prices and socio-economic and cultural variables.
- Are monitored for impact and results, and progress toward performance targets are verified and reported openly.

1. THE CHALLENGE: PARIS TARGETS & ROADMAP TRANSITIONS

Improvements in energy efficiency over the past decade have helped keep building-energy related GHG emissions level off despite rapid expansion of built floor area and increasing economic prosperity***, though recent evidence suggests emissions may be rising again. A combination of new building energy efficiency polices, power sector decarbonization and more efficient technologies have been the main contributor to this result. However, the rate of energy efficiency improvements has not outpaced the increased overall demand for energy and associated greenhouse gas emissions (GHG) being driven by rapid urbanisation and increasing affluence. The net effect is rising total energy demand and a 0% rate of decarbonization in the buildings sector[1]. It is therefore important to look at where building energy and climate policy is effective and identify priorities and opportunities for reducing total energy demand from the buildings sector in addition to improving energy efficiency.

Figure 1 **Global buildings energy-related emissions by building type and change in indicators, 2010-17[2]**



Source: *Derived from IEA (2018a), World Energy Statistics and Balances 2018, www.iea.org/statistics and IEA Energy Technology Perspectives buildings model, www.iea.org/buildings*

Policy priorities

The first step taken in any cost-effective climate policy strategy for buildings is to target the priority issues that are driving energy demand and associated emissions.

Target direct GHG emissions from buildings

Direct GHG emissions from buildings are those which are generated predominantly by the use of fossil fuels for meeting on-site energy services demand. These are predominantly natural gas, oil or biomass for cooking, space and water heating, and diesel fuel used for power generation. Direct emissions tend to be more predominant in smaller buildings, particularly detached housing and informal settlements.

The most effective actions for reducing these emissions include:

- Optimising the design of buildings to provide thermal comfort and natural light.
- Increasing the energy efficiency of building envelopes to reduce demand for space heating and cooling.
- Increasing the efficiency of appliances and lighting.
- Electrification of cooking.
- Supporting building occupants to reduce energy consumption.
- Roof-top photovoltaic and solar thermal installations.

There is general consensus that a combination of building energy codes and appliance efficiency standards are the most cost-effective policy measures for encouraging these actions in most markets globally[3].

Target indirect and embodied GHG emissions from buildings

Indirect GHG emissions are predominantly emissions associated with generating electricity to meet the energy demands of building operations. These include provision of space-heating and cooling, lighting, building automation, vertical mobility, information and communications technologies, and appliances. Indirect energy-related emissions are associated with any building type connected to an energy grid, however, the main contributor of current indirect emissions is the existing building stock, while drivers of increased demand and associated emissions are multi-family residential buildings in non-OECD Asia. Non-residential buildings and office buildings are also prominent drivers.

The most effective actions for reducing these emissions include:

- Decarbonising electricity supply.
- Demand-side management.
- Optimising the design of buildings to provide thermal comfort and natural light.
- Increasing the energy efficiency of building envelopes to reduce demand for space heating and cooling.
- Increasing the efficiency of appliances and lighting.
- Supporting building occupants to reduce energy consumption.

Embodied GHG emissions are associated with deforestation, land-use changes and transport dependencies related to the site, the energy required to manufacture and transport building material and products, and the energy required to maintain, demolish and replace building elements over the building life-span. Embodied emissions from consumer goods and food can also be attributed to building design and occupant behaviours and social practices. Embodied emissions are associated with all building types and represent approximately nine-years of operating emissions over a buildings' life in industrialised countries. As emissions from building operations are reduced, the significance of embodied emissions in the life-cycle carbon footprint of a building increases.

The most effective actions for reducing embodied emissions include:

- Refurbishing existing buildings rather than demolishing and building new.
- Applying principles of life-cycle design to buildings to ensure short life-span components can be repaired or replaced without damaging longer life-span components.
- Specifying timber products from certified sustainably managed forests.
- Transitioning to a circular economy supply chain.
- Increasing prefabrication of buildings structures and envelopes to reduce waste, construction defects, and emissions from transport.
- Integrated building design with life-cycle analysis.
- Integrated urban design and planning to reduce urban sprawl and offer non-vehicular mobility choices.
- Providing space for urban food production and composting.

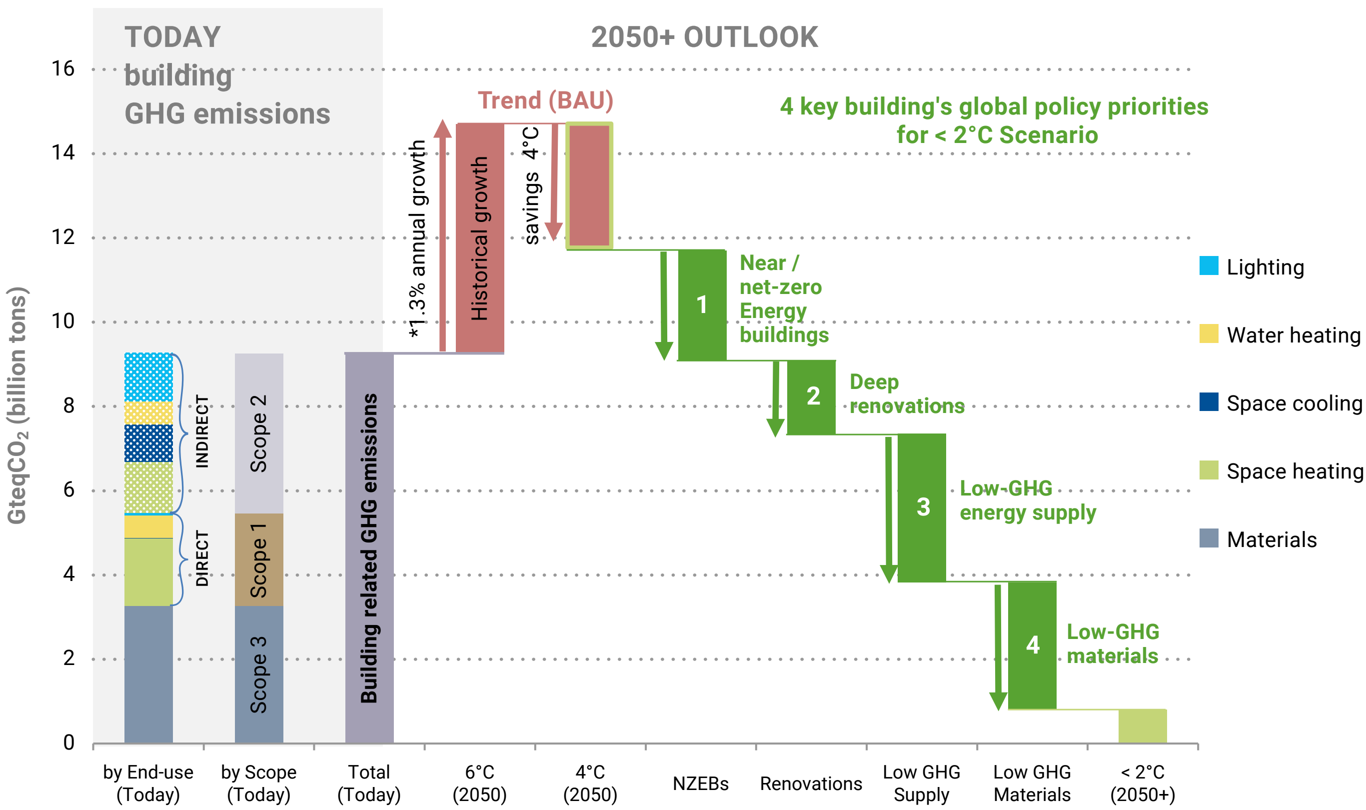
A number of these policy priorities overlap or reinforce each other. The Global Alliance for Buildings and Construction (GlobalABC) has therefore crystallised these priorities for policy action into a Global Roadmap towards zero-emission, efficient, and resilient buildings and construction (which is being regionalized for four major regions) that provides eight overarching policy goals[4] (Box 1). The Roadmap guides members and the larger professional community towards a more sustainable, robust building and construction sector that delivers its part to fulfil international commitments to limit global temperature rise to 1.5°C.

Box 1 **GlobalABC | Global Roadmap Towards low-GHG and resilient buildings**

1. Implement urban planning policies for energy efficiency
2. Accelerate the improvement of existing buildings' performance
3. All new buildings achieve nearly net zero operating emission performances
4. Improve the management of all buildings
5. Decarbonised energy
6. Reduced embodied energy and GHG emissions
7. Reduce energy demand from appliances
8. Reduced climate change-related risks for buildings

The Global Roadmap includes actions ranging in scope from energy supply and the urban scale to the building and construction value chain. At the buildings scale, the Global Roadmap recommends mainstreaming deep renovations or residential and commercial buildings, requiring near or net-zero energy new buildings, and using low-GHG materials. These actions have the potential to reduce GHG emissions to a level that is aligned with 1.5°C goal as set out by the Paris Agreement if combined with decarbonising energy supply (Figure 2).

Figure 2 **Split of global building-related emissions and emissions reduction potential**



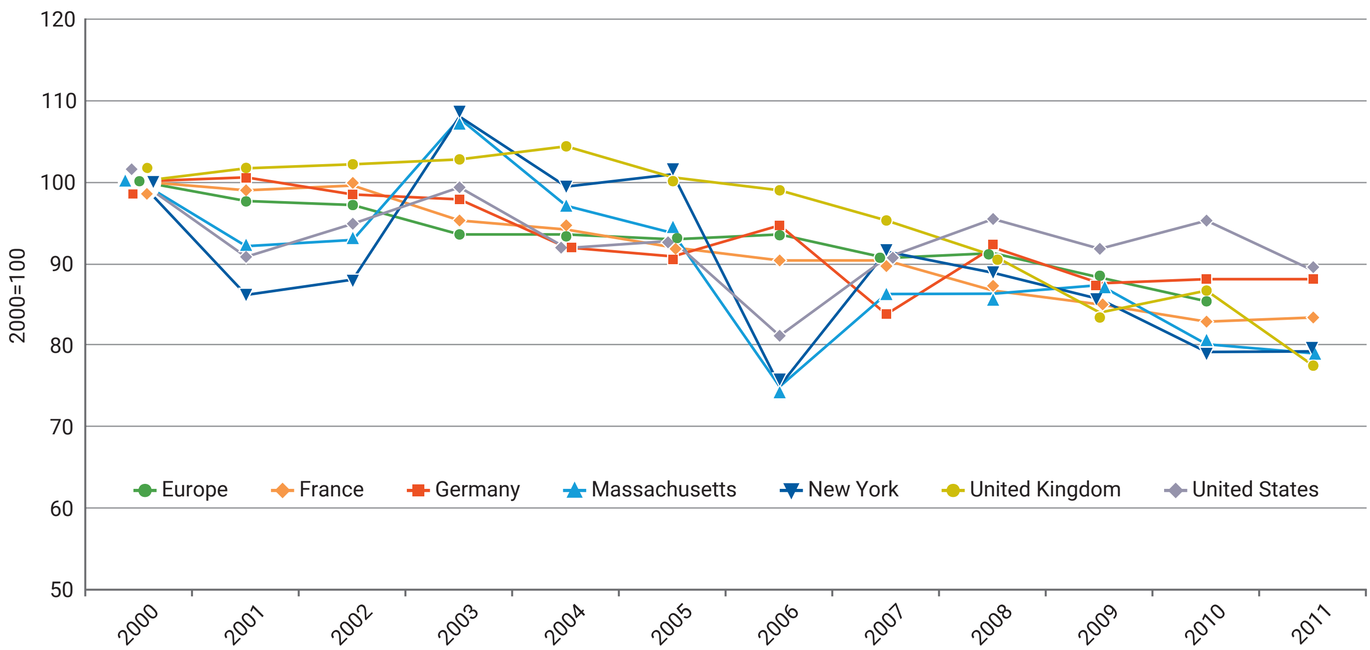
Source: *IEA Energy Technology Perspectives 2016*

Mainstreaming these actions in the buildings sector requires policy strategies that drive local market transformations. Policy interventions are often needed to correct market failures and to encourage new business and investment models in low-carbon buildings[6 7].

In most cases policy instruments deliver better results when designed to contribute to overarching policy frameworks such as the Energy Performance in Buildings Directive in the EU or China's State Council Green Building Action Plan, with clear long-term energy savings and emission reduction goals combined in a package, taking note of local circumstances and priorities[8] [9]. Effective policy packages combine strategies to regulate minimum required energy performance, provide incentives to encourage demand and reduce upfront costs, and raise awareness and build capacity to highlight, reward and encourage high-performance performance, taking note of local circumstances and priorities[10].

Some jurisdictions have been able to reduce total building energy demand in some sectors of their buildings and construction industry by implementing such packages. For example, total residential energy demand per dwelling in some EU countries, and some U.S. states* has been reducing over the past decades. Research into the policy drivers of this trend showed that jurisdictions were commonly adopting packages of policies which include mandatory codes that set minimum energy performance requirements, incentive programs for going beyond minimum standards, and energy rating and reward programs that recognize best-practices. Effective implementation of such policy packages in these EU countries and U.S. jurisdictions has reduced energy demand in residential buildings by between 10% and 20% since 20011 (Figure 3).

Figure 3 **Change in Total Residential Building Energy Consumption relative to year 2000**



Source: *GBPN Renovation Policy Tool - available at: www.gbpn.org*

But have these policy successes also reduced GHG emissions? Have they come at a net cost or benefit? And were the policies adopted the most cost-effective approaches for reducing building energy consumption and related greenhouse gas emissions? To answer these questions, it is necessary to define what is meant by costs and benefits, and to determine what societal, individual and monetary returns on investment have been created.

* *Denmark, France, Germany, Netherlands, Sweden and U.K. - Based on analysis of consumption data for the EU countries sourced from ODYSSEE, energy efficiency database. The data for population and floor area were sourced from Eurostat.*

California, Massachusetts, New Jersey, New York, Oregon and Vermont - The total consumption data for each state was sourced from the U.S. Energy Information Administration (EIA). The number of dwellings and population estimates were sourced from the U.S. Census Bureau; the floor space was sourced from Pacific Northwest National Laboratory (PNNL).

2. COST–EFFECTIVE POLICIES

It is difficult to compare the efficacy and cost-efficiency of policy strategies between jurisdictions due to the large variation in market complexity, building type, construction activity, socio-economic and cultural impacts of energy use, as well as the variety of policy impact methodologies employed[12]. However, it is important to establish a definition of cost-efficiency in building energy and climate policies.

Designing and implementing any policy generates costs and benefits. The most cost-effective policies deliver high-impact with the least monetary costs over a given period. However, there are multiple costs and benefits that need to be considered and factored in to a calculation of cost-effectiveness.

According to the International Energy Agency (IEA) the costs can be determined as the additional incremental spending required to meet new energy performance requirements compared with the cost of achieving previous energy performance levels[13]. Costs and benefits of building energy policies also need to be evaluated against a base case, which may be either continuing with no policy, or continuing with no changes to current policy.

The overall direct cost of a policy intervention is normally calculated as a function of the additional costs incurred by all affected stakeholders, including public authorities, policy implementers, and end-users compared to business as usual. These can either be one-time costs, or a sum of repeated investments, discounted over the lifetime of a policy intervention. Costs to industry of responding to changes in codes are generally assumed to be passed on to consumers. The monetary benefits of a policy are normally calculated as a function of the monetary value of energy saved by the policy over its lifetime. The magnitude of the net benefit is strongly influenced by new construction activity and renovation rates[14].

However, costs and benefits of promoting low-carbon and energy efficient buildings accrue to different stakeholders at different times during the building life-cycle (Table 1). For example, a major concern for policy makers is to raise performance requirements of codes for new construction and renovation without substantially increasing upfront design or construction costs. This is often complicated by sensitivity in the market about perceived high up-front costs, and a lack of trust in the realisation of projected benefits[15 16].

Determining the cost-effectiveness of a policy is therefore both a technical and political calculation. This is because benefits accrue over periods that are often longer than election cycles, and because the construction and real-estate industries often over-estimate the costs of increasing the energy performance and reducing the carbon footprint of buildings, and under-estimate the financial benefits[17]. Many of the financial benefits do not accrue directly to building developers and constructors, but rather to building occupants, creating a split incentive.

Table 1 Summary of major benefits, costs and risks to building-sector stakeholders of building energy and climate policies identified in systematic reviews

STAKEHOLDER	GOVERNMENT	INVESTORS & DEVELOPERS	DESIGNERS & BUILDERS	OWNER	OCCUPANTS	UTILITIES
Benefits	Economic modernisation & stimulus Reduced energy poverty Equitable energy access Environmental quality Public health Resilience & adaptive capacity Achieving climate goals & commitments Job-creation	Higher value & lower risk assets New financing opportunities Lower default risks	Higher design fees Value-added services Improved occupational health & safety Reduced construction waste	Higher asset value Lower running & maintenance costs Reputation value Lower risk of climate obsolesce-ence	Lower energy costs High indoor environment quality Improved productivity Improved health	Deferred capital investment Lower maintenance and distribution costs
Costs	Vertical & horizontal integration New policy design & implement-ation Monitoring & reporting Compliance & enforcement	Higher up-front design costs related to higher environmental performance	Learning/ training costs Higher material/ product costs Compliance costs	Potentially higher construction costs	Higher rents Inefficient behaviours and social practices (rebound effects)	Demand-side management
Risks	Political pressure by stakeholders with vested interests in maintaining the status quo Sub-optimal policy impacts due to lack of coordination of implement-ation between local, state and national governments, and between government agencies Lack of information and awareness among stakeholders	Lack of demand or willingness to pay for higher performance Poor evidence base	Lack of enforcement of codes and standards creates an uneven playing field Lack of technical capability in the labour market Lack of availability of appropriate technologies, materials and building systems	Lack of availability of tailored finance Building occupants do not operate buildings to achieve potential energy cost-savings	Increasing inequity of housing choices due to increasing property values catalysed by better building and urban planning and design	Power grid instability due to increased distributed supply from renewables

Governments also incur administrative and transaction costs which differ depending on the role of a jurisdiction in the governance of building codes. In many countries, codes are developed by national government agencies, then adapted and adopted by state or regional governments, and implemented and enforced by municipal governments[18]. Collaboration on policy goals across government agencies and between different levels of government, with various priorities for societal and economic benefits of building energy polices, is therefore often challenging. For example, national and state governments can use tax revenue generated by increased direct and in-direct employment, or value-added tax from new green construction activity to cover the cost of policy development, where as local governments are limited in their options to raise revenue for meeting the costs of policy implementation[19].

At a macro-economic level, cost-effectiveness has been defined as the cost of developing and implementing building climate policies weighed against potential benefits to the general economy including, avoiding or reducing infrastructure costs such as energy supply, job-creation and direct and indirect consumer spending, opportunities for trade, and improved economic efficiency. At a micro-economic level cost-effectiveness has been defined as the cost of implementing energy saving strategies in buildings compared with the reduced energy costs of building operations, and increased property values associated with higher energy performance[20 21 22]. From the perspective of property investors or building owners this is sometimes referred to as a positive risk to return ratio[23].

The realisation of net benefits or costs is also influenced by a number of common barriers to implementation that create real or perceived risks to achieving policy objectives. The likelihood and severity of risks to cost-effective policies is very context dependent and it is important to tailor policy responses to specific barriers affecting particular markets[24]. However, a range of recent studies have identified common typologies of barriers that influence policy impact. These are:

- ***Economic barriers:*** Perceived or actual increases in up-front costs of higher energy performance buildings and equipment[25]. Lack of availability of finance and/or grants to address upfront costs. Poor understanding of life-cycle of 'hidden' costs of maintaining high-performance in operations.
- ***Political and institutional barriers:*** Implementing building energy and climate policies requires a long-term commitment to continual improvement over many election cycles. Design and implementation often require coordination between government departments within jurisdictions (horizontal integration) and between local, state and national governments (vertical integration). These complexities often promote conservative incremental improvements in policy stringency rather than ambitious step-changes toward net-zero or positive energy requirements[26 27].
- ***Social barriers:*** The behaviour and social-practices of building occupants have a significant influence on the gap between predicted and realised performance. These factors are complex to address and are influenced strongly by emotional rather than rational decision-making.
- ***Knowledge & information barriers:*** These barriers range from a lack of professional capability to design and construct high-performance buildings, to a lack of capacity or training in policy design and implementation. Performance data is not always sought-after by building professionals[28]. Data on energy cost savings and returns on investment is inconsistent and poorly trusted by investors[29 30]. This contributes to the building sector having no consistent evidence base[31].

From a market transitions perspective, these barriers have been influential in maintaining low-carbon and low energy buildings, including green buildings as a well-defined and contained niche market, that has not yet disrupted mainstream construction activity[32 33 34]. This is despite many studies of such projects, collectively indicating that significant improvements in building design and operational performance can, under the right circumstances, be achieved with no increase, or even decreases in total costs[35].

Global reviews of the cost-effectiveness of a diversity of policy strategies for decarbonizing the buildings sector have identified policy measures that can all be packaged and implemented cost-effectively to reduce building energy demand and related emissions and contribute to achieving energy-savings and climate action goals[36 37 38]. These include:

Table 2 Cost-effective building energy policy measures

Regulatory measures	Market Intervention Measures
• Building energy codes. • Renovation obligations.	• Public procurement. • Emissions trading, carbon taxes & grants • Voluntary agreements.
Information measures	**Advice & leadership Measures**
• Building energy certificates and labelling.	• Information campaigns. • Knowledge services. • Public leadership & capacity building.

In advanced markets these measures are organised as policy packages designed to significantly improve the performance of new buildings toward zero net energy and emissions, and increase the rate and depth of existing building renovations. Policy packages in turn need to be implemented through a clear governance framework that includes sectoral energy conservation and GHG mitigation targets, and policy implementation roadmaps, and clear mandates and accountability for monitoring, reporting and verifying progress[39].

The cost-effectiveness and impact value of any of these measures are highly dependent on local market conditions. Contextual factors that influence the energy cost-efficiency of building sector actions include the difference between the current baseline efficiency of new and existing buildings, and the assumed life-time of the measure. For carbon emissions factors include energy prices, fuel subsidies, background emissions factors and discount-rates. Differences in building type, climate, and geographic region influence the profitability of both energy conservation and emissions mitigation actions[40]. As such it is not possible to be definitive about how costly or how impactful any one, or a combination of these measures is likely to be in any context. However, research into specific cases can provide insights into the effectiveness of key policy measures at specific times in specific contexts.

Regulation: Building energy codes

Regulating minimum energy performance requirements for buildings by incorporating efficiency targets, or energy use thresholds in buildings codes are among the most applied and cost-effective long-term policy strategies for reducing energy demand and associated emissions from buildings[41 42]. Recent mapping of the adoption of building energy codes identified 69 countries that have either mandatory or voluntary energy codes. However, many developing economies with rapid construction rates are yet to implement mandatory building energy codes[43]. The most effective building energy codes share common best-practice features (Box 2).

Box 2 Best practice in building energy code design & implementation

High ambition: Stringent performance benchmarks such as 'nearly' or 'net' zero energy are set to achieve ambitious overarching policy goals such as zero-emissions buildings or carbon neutrality in a market or jurisdiction. Over achievement is further rewarded.

Holistic performance: Covers all building types, renovations, renewable energy and energy end-uses by mandating performance rather than prescribing technologies.

Strategic: Codes are included as an enabling measure in a policy pathway that has clearly communicated future stringency increases to provide certainty for planning and investment, and to encourage innovation.

Mandatory: Codes must mandate minimum energy performance – voluntary schemes do not transform markets, but can be used to prepare markets for planned increases in stringency.

Enforced: At design, construction/refurbishment, and in operation.

Integrated: Codes perform best when integrated with complimentary policies into policy packages – typically including regulatory measures (codes), incentives (fiscal or financial), and voluntary measures (green rating, education & awareness, rewards/awards).

Transparent: Achieved performance is made public through aligned mandatory rating and disclosure programs.

Evidence-Based: Building performance data and compliance rates are systematically and independently collected and verified, and shared openly to encourage research and development, and build trust in investors.

Source: [44]

The extent to which governments implement these best-practices in building energy codes, depends on local factors such as income levels, building types, availability of data and climate zones. Global reviews have however, identified a number of jurisdictions and regions that are pursuing a best-practice approach relevant to their specific contexts[45 46]. Appendix 1 provides an overview of policy design in selected best-practice jurisdictions.

Countries where building energy codes have been implemented have achieved reductions in operating energy consumption over time. For example, building energy codes have reduced building energy demand in the European Union by between 6% in southern European countries to 22% in the Netherlands and Germany dependent on the stringency of the performance required[47]. Minimum energy performance requirements for buildings in the EU region reduced annual energy-related emissions by between 35 – 45MtCO_2 between 2010 and 2011 (equivalent to the emissions from 11 coal fired power stations)[48] at a cost of >US$36.5/t$CO_2$[49]. In the USA energy codes delivered 106 million tonnes of oil-equivalent energy savings cumulatively between 1992 and 2012[50]. Implementation of building energy efficiency standards in Beijing during the 12th five-year plan (2011-2015) saved 230.8Mtce in energy consumption and reduced CO_2 emissions by 1585Mtce[51]. However, the mitigation potential of building energy codes is often undermined by poor implementation and enforcement[52].

The extent to which each of these features is enacted in a building energy code programme depends on local market conditions. Markets with the most advanced integrated code regimes have taken between ten and twenty years to incorporate such features, as it takes time for the market to be effectively engaged in, and respond to, transformations in regulations. Given that the building sector globally must reduce its energy intensity by 85% by 2030 in order to contribute to keeping global warming below 2˚C[53], the challenge for countries who are just beginning to develop building energy codes, is to achieve the kind of market transformations being observed in countries like Denmark and Germany, but in a decade or less.

Time has a bearing on the costs and benefits as well. Experience from advanced markets shows that costs associated with meeting more stringent code requirements reduces rapidly when there is uptake in the market. This has been evident for European and U.S.

passive houses. With time the construction and compliance costs approach the costs of traditional new construction and then get less costly as markets mature and experience grows. Over time investment costs for energy efficiency upgrading also go down as higher-performance buildings replace inefficient building stock, with positive return on investment to public accounts based on energy savings achieved after 25-30 years[54].

To be effective, building codes need to be regularly strengthened. It is important to establish a plan for implementing best-practice codes that begin with policy strategies that the market is ready for. Failure to do so may have unintended consequences on the cost of design, compliance and construction[55]. However, given the time it takes to achieve returns, it is also more cost-effective to be ambitious with policy targets. The cost-effectiveness of building codes can be undermined if intended energy and emissions savings are not met. This is a common issue globally, and is most often affected by the following issues[56]:

- Not aligning codes with supporting policies such as energy performance certificates, incentives and voluntary rating schemes.
- Poor code implementation, enforcement, revision planning and compliance.
- Lack of local industry capability to design and/or construct compliant buildings.
- Lack of monitoring and data gathering to verify building energy performance during operation.

Improving compliance can be one of the most cost-effective measures for delivering policy impact in a relatively short time-frame.

Renovation targets

Despite currently accounting for the majority of building energy demand and associated emissions, only about thirty jurisdictions globally, apply the energy performance requirements of their building codes to the renovation of existing buildings. According to the International Energy Agency** (Appendix 2) eleven jurisdictions at either national or state level require energy performance improvements for existing residential and non-residential buildings in their mandatory building codes. Another seven jurisdictions include renovation of non-residential buildings in building energy codes, while two countries include measures in voluntary codes – Pakistan (existing residential and non-residential) and South Africa (existing residential). Canada also includes requirements for existing residential and non-residential buildings in the model energy code under the National Building Code of Canada.

Increasing the scope of building codes to include mandatory energy improvement of existing buildings should be encouraged. However, experience from jurisdictions that have been able to reduce the energy demand of existing building stock over time, shows that a range of policy measures, including – but not limited to codes is required. Policy measures must reduce building energy demand to comply with minimum code requirements, and also provide incentives to encourage 'deep' energy renovations and increase the rate of energy-renovations. This is essential to avoid locking in sub-optimal building energy performance for decades[57].

Research by the Global Buildings Performance Network into policies for encouraging energy renovation of residential buildings consisted of combinations of regulatory measures including renovation targets, codes and performance certificates, financial and fiscal incentives, market-based incentives, awareness and capacity building, and measurement and reporting of energy performance[58] (Table 3).

One of the fundamental strategies for encouraging renovation is establishing clear national or regional targets, and binding obligations for increasing both the level of energy performance improvement and the rate of renovation. Establishing emission reduction and renovation targets also provides an opportunity to incorporate flexible policy measures, which by allowing different approaches to achieving targets, enable stake-holders to choose the most cost-effective options for reducing emissions. Systematic reviews of low-carbon policies support the view that flexible policies have the capability to maximise their effectiveness of achieving targets while minimising costs[59]. Experience from the European Union (EU) and China illustrate this point, and also reveal a number of barriers that influence the potential impact of policy measures.

*** https://www.iea.org/beep/ accessed 11 November 2019*

Table 3 **Policy Instruments used by best-practice jurisdictions to encourage energy renovation of residential buildings**

REGULATORY MEASURES	BUILDING ASSESSMENT	FINANCIAL INSTRUMENTS
Overall National Targets	Code Requirements	Incentive Schemes
Residential Buildings	Labelling Schemes	Taxation Mechanisms
Public Buildings		
ECONOMIC INSTRUMENTS	**CAPACITY BUILDING**	**OVERALL PERFORMANCE**
Utility-Funded Programmes	Training and Education	Consumption/Capita
Market Instruments	One stop Shop	Consumption/Unit
		Total Consumption

Source: *www.gbpn.org*

In the EU, the Energy Efficiency Directive (EED) and Energy Performance of Buildings Directive (EPBD) create a policy framework for improving the energy performance of Europe's existing building stock. The EED requires Member States to establish an update every 3 years, National Energy Efficiency Action Plans, including a commitment to increase the rate of renovating in public buildings to 3 per year, and a long-term strategy for mobilizing investment in renovating existing residential and commercial building stock beyond 2020[60]. Achieving the targeted 20% improvement in Energy Efficiency by 2020 was estimated to increase the EU's GDP by 2.7% (€33.8bn) by 2020 compared to 2012. In 2018 this target was revised to 32.5% improvement by 2030 compared to 2007[61]. The EPBD requires defining near-zero energy (NZEB) performance requirements for new buildings and existing buildings undergoing major renovations for implementation in 2021[62].

Two key factors influencing cost-effectiveness of renovation policies in Europe are the 'cost-optimality' of energy performance measures, and the level of ambition, or 'depth' of the renovation work. The EPBD introduced a common methodology for calculating the 'cost-optimal' package of energy efficiency and renewable energy supply measures that could be applied to a building during renovation to reduce its life-cycle energy consumption while minimising life-cycle costs[63].

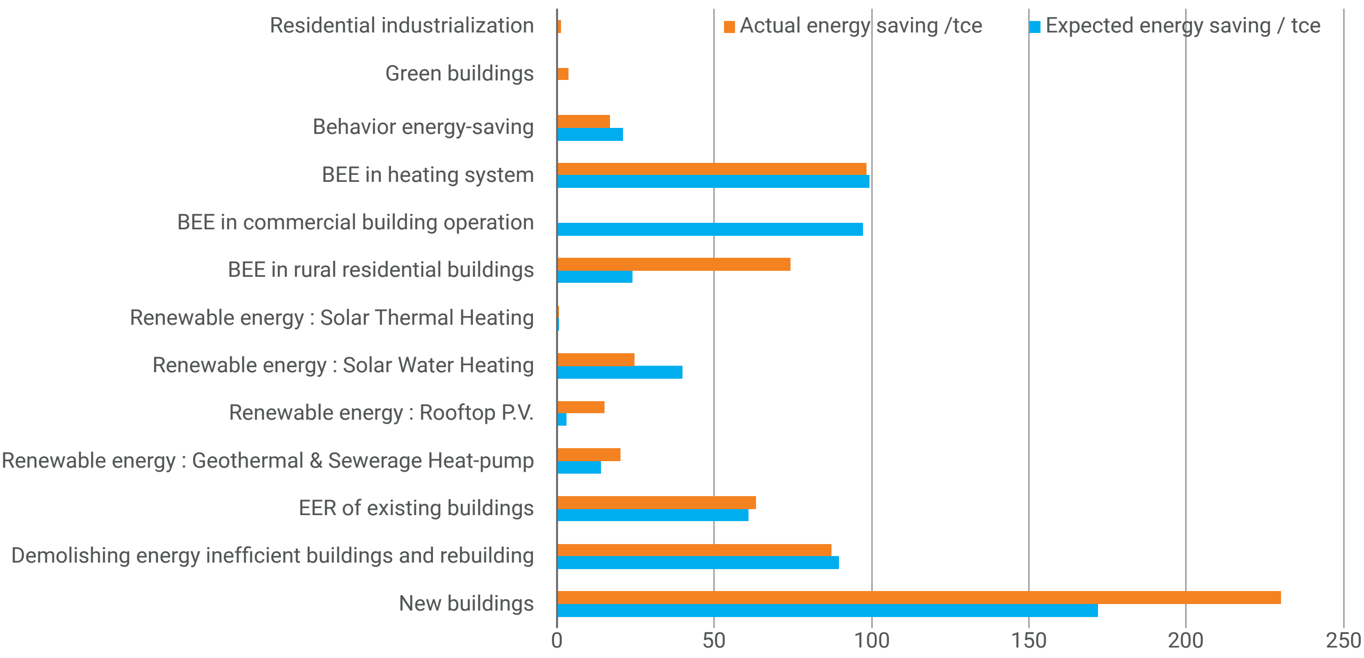
Because input data on issues such as construction costs, climate zones, building design and building age vary from country to country, so too does the range of cost-optimal NZEB performance levels being adopted by Member States. Primary energy requirements defining NZEB levels also range between 20 - 25kWh/m2/yr for existing residential and non-residential buildings respectively in Denmark, to 200 – 250kWh/m2/yr in Austria[64].

The level of ambition for energy efficiency improvement, can range from 'minor' or 'moderate' improvements which reduce final energy demand by up to 30%, and from 30%-60% respectively compared to pre-renovation levels. However, the benefits to cost ratio of building renovation programs tend to improve as the level of ambition increases toward 'deep' renovation. EU definitions of 'deep' renovation vary. A definition that incorporates most aspirations of EU stakeholders offered by BPIE is a renovation that "…adopts a holistic approach, viewing the renovation as a package of measures working together, resulting in energy reductions in the range 60%–90%, with an average total project cost of 330 €/m^2"[65] An analysis of deep renovation scenarios covering EU27, Switzerland and Norway indicated that for an investment of €940bn(2013) net energy savings of up to €1300bn(2013) could accrue to end-users, and create 1.1 million new jobs by 2050.

Building Energy Efficiency improvement programs have been incorporated into China's long-term planning since 1996. More recently the Ministry of Housing and Urban and Rural Development (MOHURD) introduced the *Development planning for Building Energy Efficiency and Green Buildings* under the 13th five year Plan (2016-2020). In-line with this framework China's State Council Green Building Action Plan, launched in 2014, mandates that public buildings and any single building area over 20,000 square meters, must meet the green building standards of China's 3-Star Rating System GBEL (The Green Building Evaluation Label). The Green Building Action Plan also provides for the refurbishment of 400 million m^2 of existing urban housing in northern China. In addition, 400,000 rural dwellings are subject to major thermal rehabilitation works. Responsibility for designing and implementing policies to achieve China's national targets in the buildings sector is mainly devolved to provincial and local governments who adapt the national action plan targets into provincial green building development regulations and renovation targets implemented by provincial governments including Jiangsu, Guizhou and Guangxi provinces, and municipal green building regulations in place in Beijing, Shanghai, Fujian, Hebei, and Shenzhen.

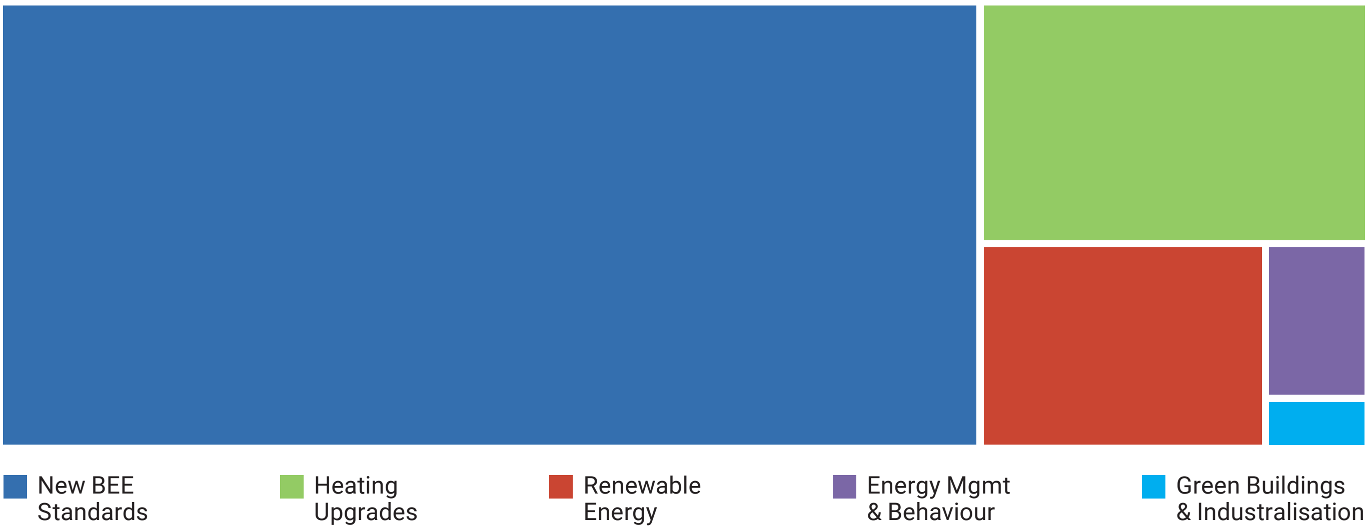
A comprehensive measured impact analysis of the performance of building energy efficiency and green building policies in Beijing under the 12th five-year plan has demonstrated that a diversity of strategies has enabled Beijing to marginally exceed its energy savings goals and reduce greenhouse gas emissions. This was achieved by a range of measures, the most influential of which were energy efficiency renovation of urban and rural buildings, demolishing energy inefficient buildings and constructing new buildings to more stringent building energy codes. Other policy measures included behavior and awareness raising programs, retrofitting and metering heating systems, introduction of solar water heating, and roof-top P.V. installation (Figure 4). Over the 12 five-year plan period (2000-2015) Beijing reduced building energy use by 634Mtce, exceeding its goal of 620Mtce[66].

Figure 4 Predicted and actual energy savings from policy measures implemented to achieve Beijing's building energy efficiency and green building targets under the 12th 5-year plan[67]



The results of this study show the positive impact of applying building energy code requirements to building renovations as well as to new construction (Figure 5). Other reviews of progress of the 13^{th} five-year plan building energy efficiency retrofit program (EER) goals showed that by the end of 2015 about 1.35 billion m^2 of buildings in norther China had been retrofitted, which exceeded the initial goal by 0.36 billion m^2 [68]. However, the average cost of the EERs being undertaken was estimated to be more than US$29.14/$m^2$, meaning that the total program cost will be over US$14.57 billion. The level of energy efficiency improvements achieved from measurement of case-study buildings was around 25.7%, putting the renovations in the 'minor-moderate' range in comparison with the EU approach. Low financial returns from energy savings being realized in retrofitted buildings has made it difficult to attract market-based investors. This in turn has led to suggestions that the Chinese government develop further economic incentives that encourage market investment[69]. Reviews are now underway of the performance of jurisdictions in meeting their 13the five-year plan targets in order to inform the development of the 14^{th} five-year plan.

Figure 5 **The impact of different policy measures on achieving Beijing's building energy efficiency and green building targets under the 12^{th} 5-year plan**[70]



Information: Building performance certificates, rating, and labelling

Building performance rating schemes have been defined as *"…the overall program put in place to rate the efficiency of buildings, including the rating tool and associated programmatic elements, such as enforcement, communication or quality control"71. Their aim is to provide reliable and comparable information about the energy and/or environmental performance, and in some cases the CO_2 emissions, from building operations. They are most effective when designed as a package of measures including* [72]:

- A rating tool that provides a user interface and analytical platform for rating a building
- A certification process that organises the official rating process, recognises the results of rating and provides a certificate – which is the document that officially recognizes the energy performance of a building
- A label that presents the information on building energy use such as the rating score, and potentially indicates energy performance or consumption.
- A compliance process that ensures rating and certification meet regulatory requirements.

Most rating schemes are designed to provide an 'asset rating' – that is a predicted energy performance level compared to that of similar building types based on the analysis of a building's design. This is keeps costs down and enables the scheme to apply more broadly across the building stock. Examples include Australia's National Home Energy Rating Scheme (NatHERS), the U.S. Home Energy Rating Scheme, and the Canadian 'EnerGuide' Rating System. These asset ratings can also be designed to demonstrate compliance with energy provisions of building codes. It should be noted that these schemes are different to 'green building rating' schemes, which include energy performance as one of a number of environmental performance attributes being assessed. Green rating schemes are also predominantly voluntary and designed for more bespoke application.

Extending beyond predicted energy performance are 'operational' ratings, which rate the measured energy performance of buildings. These schemes require better access to energy use data, and more coordination with building owners, occupiers and energy utilities to operate successfully, but enable policy-makers and the private sector to identify the actual energy performance of existing buildings. This information can be used to support design and implementation of energy renovation strategies. A mix of asset and operational rating schemes are often deployed across residential and non-residential buildings. There are also a range of approaches to implementing schemes as either voluntary or mandatory[73].

In jurisdictions such in the European Union, New York State, China and Australia for example, mandatory asset and operational ratings are applied for new buildings, and existing buildings respectively. In most jurisdictions however, rating schemes are applied voluntarily. Whether voluntary or mandatory, energy certified buildings tend to deliver measurable energy savings, while labels and certificates are influencing price premiums for rental and real-estate purchases[74, 75]. However, mandatory and voluntary schemes play different roles in encouraging energy and emissions savings from the building sector.

Mandating certification and labelling is beneficial because it signals regulatory stability and supports standardisation of performance assessment and reporting. This in turn stimulates investment in energy efficiency improvements. Mandatory reporting and disclosure of energy performance, particularly in commercial and public buildings also provides real-estate markets with information that supports 'green premium' rents and 'brown discounting' of poor performing buildings[76]. Mandatory regulations also support a 'level playing field' where stakeholders are clear about the minimum performance requirements that apply to the entire market[77].

It is also beneficial to establish voluntary certification and labelling programs when introducing new performance requirements to a market. Encouraging uptake of voluntary certification in the residential market requires government support to keep the cost of certification to home owners as low as possible, or even free[78]. In the commercial market, green building rating and certification, which typically include performance issues beyond just energy efficiency, have been effective in leveraging mandatory energy performance requirements and encouraging building projects to achieve performance that exceeds the regulatory minimum requirements. The cost of certification is often reflected in higher rental prices.

Rating scheme policies aim to remove information barriers and raise the profile of energy efficient buildings in the marketplace. To be effective, certification schemes should have clearly defined objectives, that are translated into ambitious (but achievable), measurable, reportable, verifiable and time-bound targets. They must also be quality assured and appropriately enforced. Best-practices link the certification of energy performance to the minimum performance requirements in building codes, and provide a scale and recognition for achieving better than minimum performance. Certification programs also create employment opportunities through training and accreditation processes. Best-practices link these training and accreditation processes to existing education institutions and qualification opportunities.

Important factors influencing the cost-benefits of certification schemes include the level of access to the required data, access to funding and how it is distributed, and keeping the cost to home owners under US$200 for assessment and labelling[79]. Quantification of the impact of building certification schemes are not well documented in the academic literature, and the majority of studies of impacts are based on modelling that assumes the ready take-up of efficiency measures by market actors[80].

Some studies of the measured impact of appliance labelling do exist. Recent research on the impact of appliance energy labelling in the EU for example, shows that applying labels to the appliances that represent 10% of household electricity use leads to a reduction in annual per-capita energy use of 0.24% in subsequent years. The investment also pays off. For example, an energy efficiency label on home refrigerators, which accounts for about 20% of residential energy demand saved about 5% in electricity demand within 10 years[81]. A mandatory building certification program in the Slovak-Republic provided building energy related emission savings of 0.05MtCO_2 between 2008 – 2010 at a cost of about $US27(2010)/t$CO_2$, while the promotion of voluntary schemes and audits delivered savings of 0.001 MtCO_2[82].

In the U.S., buildings with the ENERGY STAR label can signify large energy savings compared with typical buildings. Ten percent of all ENERGY STAR certified buildings use 50% less energy than typical buildings. The U.S. EPA estimated that between 1999 and 2009 the program prevented emissions of nearly 120 million metric tons of carbon dioxide equivalent, equal to the emissions from the electricity used by more than 60 million American homes per year[83].

The Chinese city of Shanghai has been implementing a building energy efficiency labelling scheme (BEEL) since 2008. The program is applicable to both new and existing buildings. It is voluntary for residential and small public buildings, and mandatory for government owned office buildings and large public buildings. A review of a sample labelled office buildings showed a nearly 40% improvement in energy efficiency with mean annual energy use intensity (EUI) of 79.14kWh/m^2, compared to a sample of unlabelled buildings with a mean EUI of 129.79kWh/m^2 [84]. Such gains are also long-lived. Energy certificates introduced in the UK were found to have only reduced CO_2 emissions by 0.3% but delivered savings of 44% of the 200 million pounds spent by the government. This will provide a monetary benefit for the next 40 years[85].

The proponents of different certification schemes also tend to account for the potential energy and emissions savings based on the assumption that performance levels are achieved. The International Finance Corporations' Excellence in Design for Greater Efficiencies (EDGE) certification scheme estimates that all EDGE certified buildings to date are delivering more than 300,000 MWh/yr in operational energy savings, saving more than 136,000 tCO_2/yr in emissions, and have cumulatively saved more than 18 million GJ of embodied energy through material efficiencies[86].

However, there is a well-documented performance gap between predicted energy and emissions impacts and observed building performance[87]. One contributing factor is that the design of some rating and certification schemes are focussed on cumulative scoring that allows trade-offs between energy and non-energy performance criteria. Rating schemes that provide clear numeric energy targets that are not able to be compensated for by other performance measures are more effective for achieving high-performance[88]. Notwithstanding these limitations, reviews of the influence of energy labelling based on measured data have shown that a combination of energy efficiency labelling for appliances and stricter building performance standards has led to long-lasting reductions in energy consumption[89].

Market interventions

The IEA estimates an annual investment gap in low carbon buildings of about US$200bn/yr needs to be bridged in order to move the buildings sector onto a decarbonization trajectory that will contribute to limiting global warming to 1.5˚C – 2˚C. This requires stimulating both public and private sector investment[90]. Market interventions are therefore important and cover a wide range of initiatives which aim to reduce the up-front cost of adopting low-energy and carbon technologies and/or respond to increased performance standards, support energy retrofitting, and incentivise investment. Interventions include subsidies and grants, energy or emissions trading, tax breaks, loans and green/climate bonds. Recent research and case-studies indicate that a number of market interventions have been effective in delivering cost-effective energy and emissions savings however, the conditions for success are normally specific to local market conditions.

Grants

These policies generally offer one-off payments to cover a percentage of up-front costs in the form of capital subsidies, consumer-grants or rebates[91]. These have been used widely in the buildings sector to encourage investment in energy efficient buildings and retrofitting, adoption of high-performance technologies and renewable energy, and to encourage more energy conserving consumer behaviours. A limited international overview of the impact of a range of grant and subsidy programs indicates that they can be effective in reducing building-related emissions, with results ranging from 0.05MtCO_2/yr to 1.7MtCO_2/yr[92] . The relative percentage impact of such reductions varies depending on the baseline level of emissions in any market.

One of the most robustly reviewed schemes is the grant and preferential loan scheme for energy efficient new and retrofitted building projects operated by the German Kreditanstalt für Wiederaufbau (KfW) development bank. Evaluation of KfW based on a sample of nearly 1,000 applicants from the period 2007–2010 with a combined investment in energy savings of €625 million, of which €364 million (or 58%) was provided in the form of loans, delivered annual energy-savings of 329,000 MWh (1,184 TJ/pa) and reduced carbon emissions of 116,000t/CO_2e per year. The present value of the energy cost savings, over a 30-year lifetime, amounts to €661millions, giving a benefit -cost ratio of 1.06. Note that the building owner will experience a higher benefit cost ratio than this, as between 5-20% of the total investment cost is borne by KfW[93].

The investment of €625 million generated was also estimated to have created 8,450 jobs, of which 6,100 were directly related to the implementation of building energy-saving investments. In other words, ten direct jobs are generated for every €1million of investment in energy efficiency in buildings, along with nearly four additional indirect jobs, which translates into a total of 13.5 jobs per €1 million. The estimated total cost of this program in 2012 was estimated as negative, with an accrued benefit of up to €10 billion to various government agencies[94].

Carbon pricing and emissions trading

Carbon pricing is designed to internalise the cost of GHG emissions pollution to large polluting sectors of economies. According to the World Bank more than 70 jurisdictions, accounting for 20% of global GHG emissions have or are in the process of implementing carbon pricing systems. The number of carbon-pricing systems being planned or implemented has increased four-fold in the past decade[95].

A key application of carbon pricing are emissions trading schemes, or ‘cap-and-trade’ schemes aim to facilitate through 1 – placing a ‘cap’ or ‘limit’ to the amount of emissions permitted by an energy end-user; 2 – creating tradeable emissions allowances; and 3 – a formula for distributing emissions allowances in a market. A regulator controls or limits the number of permits issued each year, and sets up a market-place where permits can be traded[96][97].

In April 2010 Tokyo was the first government in the world to introduce a mandatory emissions cap-and-trade system for urban buildings. The scheme initially set clear CO_2 emission reduction targets for 1300 high-CO_2 emissions buildings in the Tokyo Metropolitan Government jurisdiction as a contribution to the city-wide emission reduction goal of 25% below 2000 levels by 2020. The base-unit for emissions trading is a whole building (including leased and common space). It is implemented with other aligned programmes such as the Tokyo Metropolitan Government green building program for new construction and a renewable energy subsidy scheme[98]. Self-reported results indicate that the scheme influenced a reduction in building energy-related CO_2 emissions in the participating building stock by 25% compared to base-line during its first compliance period between 2010-2014. This equalled a total reduction of 14MtCO_2[99]. Lessons learned from Tokyo's program identified the following key factors as contributors to the effectiveness of the scheme:

- Mandatory reporting of emissions savings results.
- Fair and simple program design, especially emphasising fairness in cap-setting.
- Stakeholder involvement & motivation, including providing public forum for debating the design and implementation of the program, addressing the value proposition to stakeholders, and raising awareness of supporting programs.

An adapted version of the Tokyo cap and trade scheme was soon after adopted by neighbouring Saitama prefecture. The city of Shenzhen in China was the first jurisdiction in Mainland China to implement a cap and trade emissions trading program in 2013. The Shenzhen ETS covers all industrial sectors in the metropolitan region, including 167 large public buildings with floor areas exceeding 20,000m^2 [100].

Energy efficiency obligations

One effective policy strategy for achieving cost-effective energy savings from energy efficiency is through the use of Energy Efficiency Obligation Schemes (EEOS), also known as Energy Efficiency Resource Standards (EERS) in the U.S.A. These schemes require energy companies (energy distributors and/or retailers) to achieve long-term energy savings targets by delivering energy savings from their customers, which are often paid for through extra charges on energy bills, or paid by the company as a business expense[101].

There are estimated to be about 50 EEOSs/EERSs being implemented globally including in 15 EU Member States[102], 27 U.S. states[103], as well as schemes running in Australia, Brazil, Canada, China, Korea, South Africa and Uruguay[104]. They vary widely in their geographical scale, targeted energy types, levels of ambition and metrics applied, and the sectors of the economy to which they apply. Examples of EERS and EEOS measures include resourcing home energy efficiency upgrading, loans and subsidies for purchasing and installing energy efficient heating and cooling equipment, incentives to participate in voluntary energy rating programs, and support for changing energy consumption behaviours through awareness campaigns or engagement with new digital energy management technologies.

Despite this diversity, there is robust experience that as a general policy initiative, well-designed schemes can deliver significant energy savings from low-cost measures over many years[105]. For example, in 2017 in the U.S., States operating EERS achieved an average 1.2% annual incremental saving in electricity consumption compared to an average of 0.3% in States that did not run an EERS[106]. Incremental annual final energy savings among selected EU Member states implementing EEOSs was estimated at around 1.28%, saving an average of 308 ktoe per year[107]. According to the Regulatory Assistance Project's 'rule of thumb', in the EU every €1 invested will leverage €2 to €3 of private investment. These schemes typically cost end-users between 1%-5% of an average energy bill. The total cost of EEOSs schemes in the EU (combining the programme, start-up, societal and administrative costs), are estimated at around 0.4 euro cents per kWh of energy saved[108]. Over time however, they tend to lower energy bills due to the energy cost savings achieved by lowering overall energy consumption, thus delivering a net benefit to consumers. To reduce impact on bill charges, some countries blend EEOS and other rebate schemes. France for example, enables EEOS measures for financing energy efficiency improvements to residential buildings to be part-funded by tax rebates from their Crédit d'impot Transition Energétique scheme[109].

As energy efficiency targets become more ambitious the scope of EEOS will need to increase, and be designed to incorporate less cost-effective, but higher energy savings measures[110]. Experience from countries with long-established EEOS such as the UK and Denmark also show that their success should not be taken for granted, as the variables of policy design, governance, implementation, and market conditions all influence EEOS performance[111]. EEOS can also be politically vulnerable because measures are normally paid for through power bills, raising equity issues for low income households.

3. POLICY BENEFITS

Systematic reviews of published research into the costs and benefits of energy efficiency policies and programs has found that most of the time the economic gains of energy efficiency are under-estimated[112]. This is due to most research focussing on monetary benefits of development in energy efficiency technologies and direct energy savings through policy measures. The wider economic benefits of energy efficiency such as job creation, public image, energy security, pollution reduction, energy access, health and impacts on public budgets are not considered in most current studies[113].

In recent years the term energy productivity has been used to describe the combined impacts of reduced energy consumption through energy efficiency, and the added value of achieving multiple non-energy benefits. It is being applied as a measure of the benefit of energy efficiency programs to broader public policy priorities such as stimulating economic growth, employment and competitiveness[114].

Defined as the economic output per unit of energy consumed, energy productivity is being applied as an overarching policy goal for countries such as the USA and Australia, which have set targets to improve the energy productivity of their economies[115]. The Australian National Energy Productivity Plan (NEPP) for example is a joint commitment by the Federal and State Governments the through the Council of Australian Governments (COAG) to improve the energy productivity of the Australian economy by 40% between 2015 and 2030[116]. The NEPP includes specific energy productivity measures for building sector including investigating stetting a trajectory toward zero energy and carbon ready buildings, increasing the stringency of the National Construction Code in 2022, extending the national commercial building mandatory rating and disclosure scheme (NABERS) to other non-residential buildings, implementing mandatory energy rating and labelling for residential buildings, and adopting or extending government green lease and building energy efficiency programs[117].

Energy productivity goals and strategies are often expressed as relative improvements in the energy efficiency of economies, but should be designed to enable the achievement of absolute emission reductions, leading to decoupling of economic development from increased emissions. In the Australian context for example, the building sector measures being considered under the NEPP, would be adopted by State Governments such as Victoria, New South Wales, Queensland and South Australia who have set goals to achieve net zero emissions by 2050[118].

Aside from delivering energy savings, building energy policies have been shown to have a positive impact on other non-energy and macro-economic benefits through indirect cost savings such as improving energy security and resilience, generating employment, improving the health, productivity, and comfort of building occupants, and improving asset values[119] [120]. Overall, effective policy measures are those which deliver value, while delivering measured reductions in building energy demand, and achieving savings targets. The value of individual co-benefits has been estimated as high as 43% of direct energy savings[121].

Monetary benefits

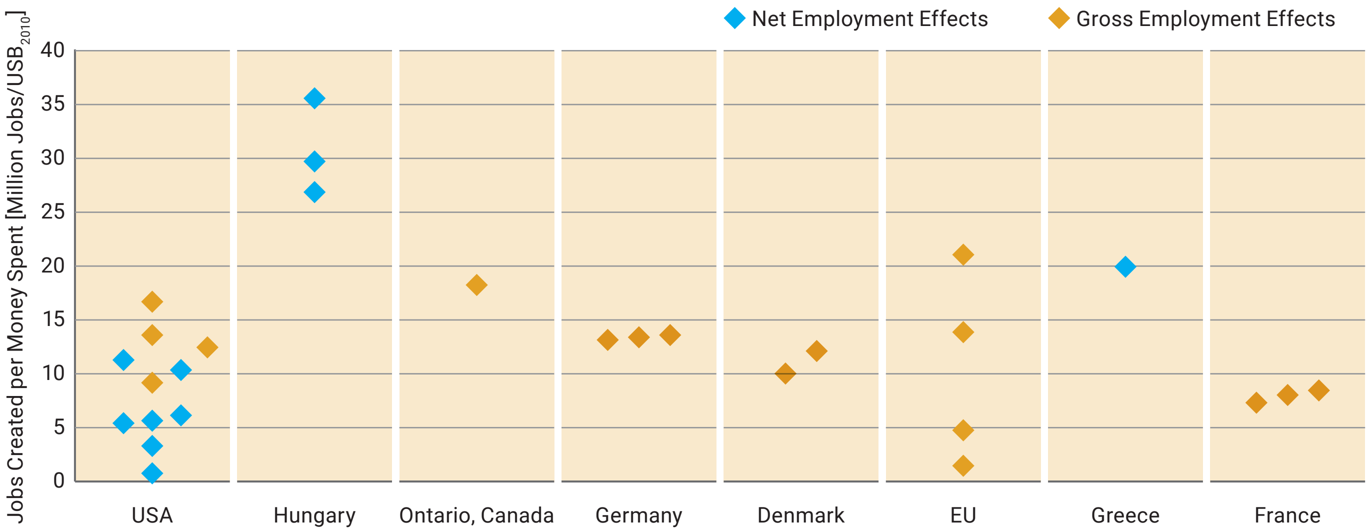
Macro-economic modelling of the monetary cost-benefits of different levels of policy ambition out to 2050 has found that only ambitious building energy policies that set energy performance goals on a below 2˚C pathway provide a positive financial return on investment, while moderate policy measures rarely yield a long-term positive return on investment[122]. For example, focused modelling of the costs and benefits of energy efficiency renovation of buildings in the EU showed that an investment of 39.8billion euro in cost-effective renovation measures could return 56 billion euro in savings; a ROI of +1.4[123]. The present value of the energy cost savings from improving building energy efficiency in Germany over a 30-year lifetime, amounted to €661million, giving a benefit -cost ratio of 1.06 in 2010[124]. The combined influence of the direct and co-benefits of energy efficiency measures have the potential to add 1% growth in GDP[125].

Evidence from multiple studies demonstrates that higher energy performance buildings including near and net-zero energy and net zero carbon homes provide lower operational energy costs compared to standard practices[126]. While the evidence demonstrates that building energy performance targets including near and net-zero energy standards can be economically viable, more research of very low energy buildings is required in order to quantify, monetise and determine the net present value of many known co-benefits.

Employment

Direct and indirect jobs are created as a result of implementing building energy policies. Each US$1Million invested in energy efficient buildings creates and average of 14 job-years of net employment[127]. A summary of the research on the impact of building sector GHG mitigation measures on job creation was tabulated in the IPCC 5th Assessment Report Working Group 3 Chapter 9 (Figure 6).

Figure 6 **Jobs created per $US 1 million invested in building GHG mitigation actions**



Source[128]

The direct employment effect of building energy policies particularly related to the European Energy Performance in Buildings and Energy Efficiency Directives range from 10 to 19 direct jobs per 1 million euros invested. Estimates from Germany indicate that in addition to direct jobs, up to four indirect jobs are created per 1 million euro invested in building energy efficiency policies[129 130 131]. In the USA the implementation of mandatory building energy rating and disclosure policies has the potential to create 59,000 jobs by 2020[132].

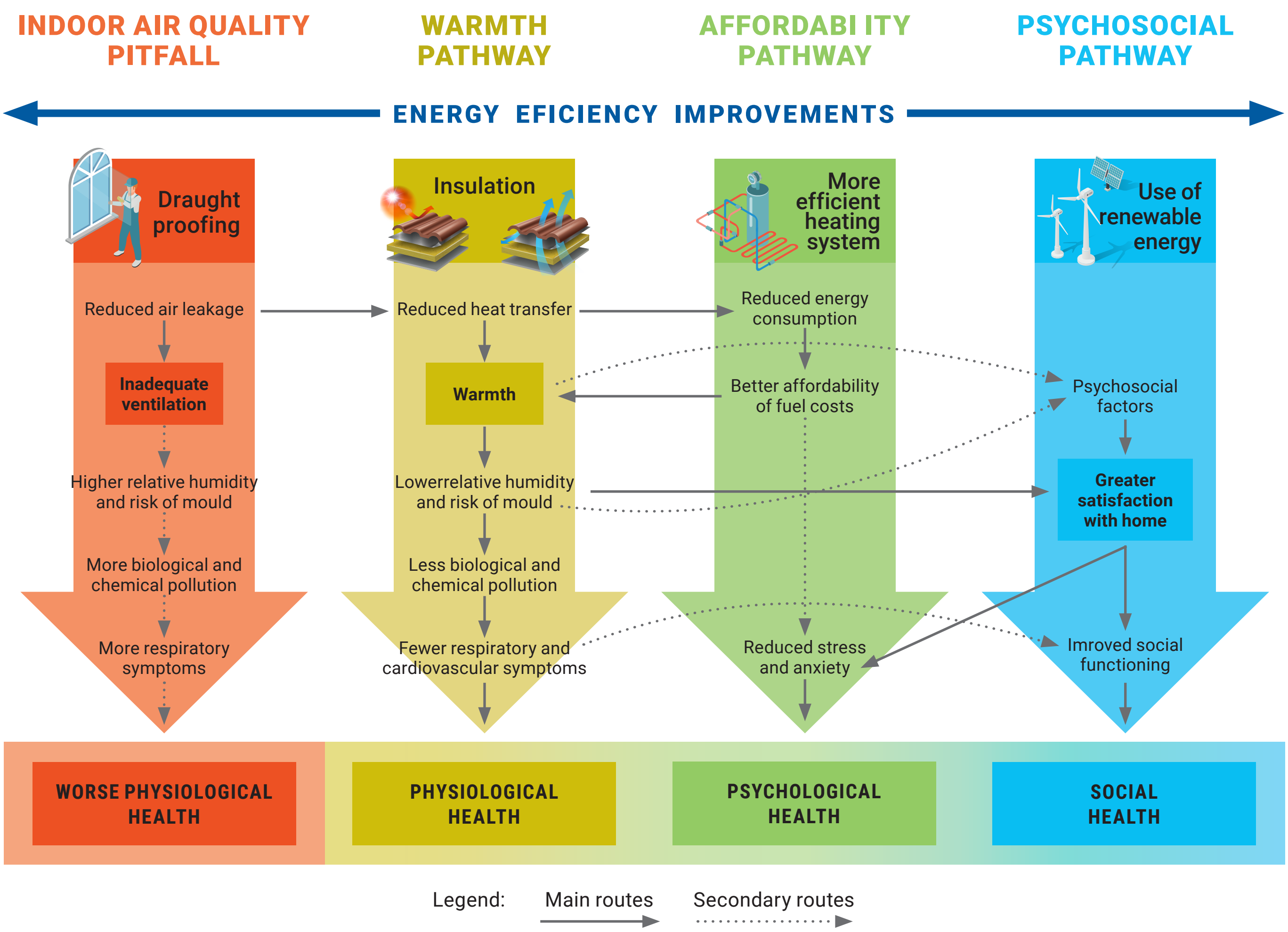
Health, wellbeing, and energy poverty reduction

Around 40% of building energy demand is associated with providing thermal comfort (heating and cooling) for occupants. Good passive-climatic design can significantly reduce, and in some climate zones, eliminate energy consumption required to maintain comfort levels. Achieving this requires attention to the design of buildings, including orientation for optimum day-light and shading, ventilation, choice of materials and more adaptable space planning. Better design in turn leads to more healthy, resilient and productive buildings to live and work in.

Health benefits of efficient buildings in developed countries account for between 8-22% of the value of energy savings. In the EU for example, EUR 1.9 - 2.86 billion in health savings are estimated to accrue by 2020 from reduced electricity production due to more efficient buildings[133]. In the U.K. an investment of £4.6bn in the application of energy efficiency measures to 2.5 million (all fuel poor) households, can eliminate fuel poverty in 71% of households and alleviate it significantly in the remaining 29%. The net economic benefit of this activity to the UK was £1.2bn in 2008[134]. In developing countries this is likely to be higher[135].

Improving thermal comfort in homes has also been shown to benefit cardiovascular and respiratory health. Positive impacts on mental and social health have also been demonstrated. A global review of health impacts of residential energy efficiency improvements found that providing a warm home in winter is a key determinant of physiological, psychological, and social health[136]. The study identified key pathways and pitfalls from residential energy efficiency improvements to health outcomes (Figure 7).

Figure 7 **Pathways from improving residential energy efficiency to health outcomes for heating**

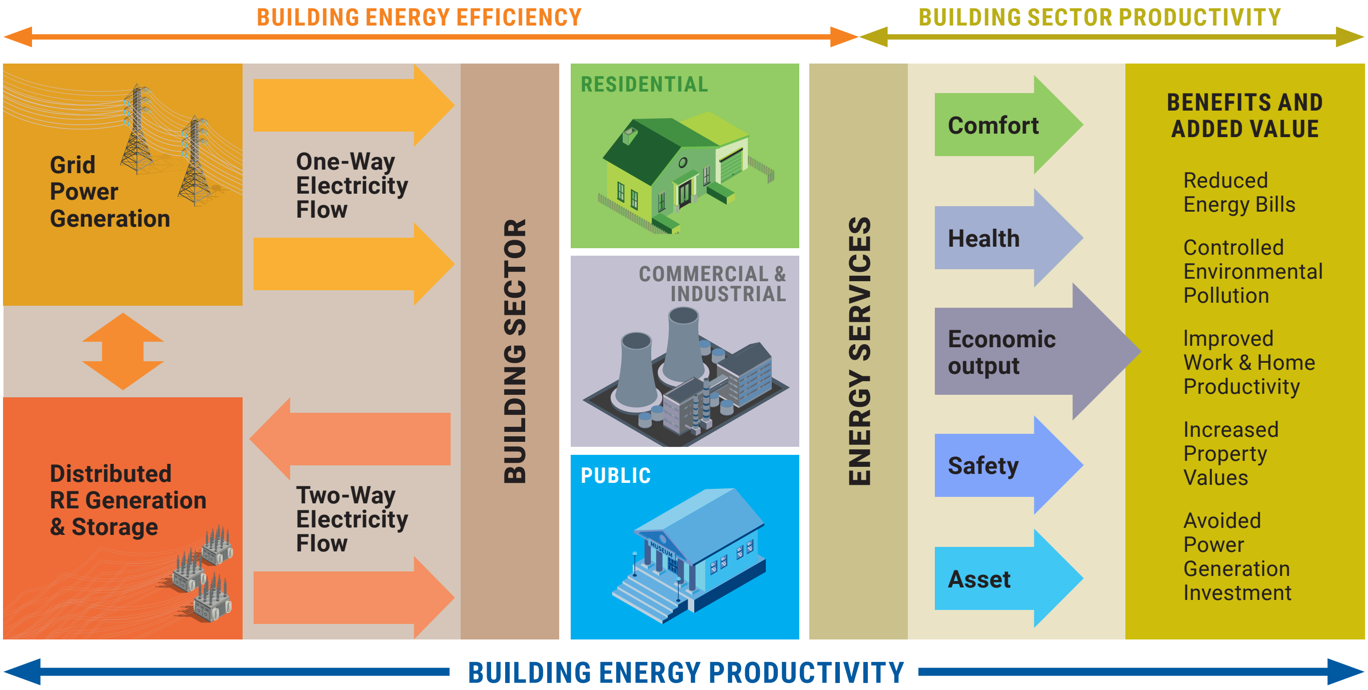


Source[137]

Productivity benefits

Building energy efficiency policies have a positive impact on the productivity of the construction value chain. Many of these non-energy benefits have been described earlier in this report. However, as illustrated in Figure 8, it is important to note that the evidence base also describes these benefits as interdependent, and that building energy efficiency can be seen as an energy service that provides a range of energy and non-energy productivity gains[138].

Figure 8 **Building energy efficiency influences on energy productivity**



Source[139]

There have also been many individual case studies that have identified well-established links between improved thermal comfort in buildings and improved productivity. A study of 1350 households in New Zealand for example, found that occupants who lived in more thermally comfortable homes took less days off work and days off school than people who lived in less thermally comfortable homes[140 141]. Studies of office workers in certified green buildings in the USA showed that worker productivity in 'green' offices was 2-3% higher than standard offices, and that these gains are equivalent to annual energy costs. Tenant satisfaction has also been found to be higher in green office space[142 143].

Life-cycle cost analysis has shown that productivity benefits from better thermal comfort and indoor environmental quality can deliver productivity cost benefits that are 60 times greater than increased costs of implementing higher performance[144 145]. Improving indoor environmental quality in existing U.S. office buildings has been estimated to be able to increase productivity by 0.5-5% and deliver annual economic value of between US$12Bn and US$125 billion(2004)[146]. However, the productivity benefits of living and working in more efficient and comfortable buildings are still yet to be fully researched or quantified in ways which provide reliable and universally applicable outcomes[147].

Construction productivity and profitability has also been positively influenced by building energy regulations. Introducing new technologies or more stringent regulatory requirements is often perceived as risking increasing up-front capital or construction costs. However, increasing the ambition of building energy efficiency regulation can lead to large cost savings and skill development. In Australia for example, builders have been able to halve the original cost premiums they were charging for moving to more stringent National Home Energy Rating Scheme (NATHERS) requirements. These savings were achieved because of greater economies of scale in construction and improvements in the construction supply chain[148].

Studies of cost-optimal definitions of near-zero energy building (nZEB) performance in the EU reinforce this. Data from Germany for instance, showed that additional total costs for meeting cost-effective nZEB standards ranged between 2 - 8%, which is similar to the range of typical fluctuations of construction costs in 'standard' construction[149]. Improved productivity and effectiveness of policy implementation has also been observed in jurisdictions that have made a long-term commitment to building energy policies due to policymaker learning[150].

Energy security and infrastructure savings

Given that the buildings sector accounts for a major proportion of final energy consumption in most countries, decreasing the required demand for building operations, coupled with improved industrial energy efficiency can reduce the need for investment in power generation infrastructure. For example, energy efficiency programs across 20 U.S. States delivered energy savings of between $29/MWh - $79/MWh with the average saving being $46/MWh. In this case, investing in energy savings cost less than half as much as supplying the same amount of retail power, and was lower than the cost of providing new supply[151]. Other U.S. studies have concluded that energy efficiency is the lowest-cost energy resource available to energy utilities[152 153].

Energy efficiency programs improve energy access and reduce the cost of on-grid and off-grid energy supply. Energy efficiency savings can also reduce overall peak energy demand and therefore help to provide more electricity to consumers without the need to building new power plants. For this reason, energy efficiency is considered as a key pillar for ending energy poverty by securing access to affordable and sustainable energy[154]. In Uganda, for example improving energy efficiency through a combination of policy measures including building energy codes, energy benchmarking and disclosure, government leadership programs, and energy-efficiency action plans for cities could effectively provide electricity grid access to an additional 2.1 million urban customers, or 6 million rural customers by 2030 without adding new generation capacity. The incremental cost of the buildings-sector related energy savings is approximately US$0.42/kWh[155].

Resilience & adaptive capacity

Another threat to energy security is the increasing severity of climate change impacts (Box 3). Given that most people are now living in cities, it is not surprising that resilience and adaptive capacity of the built environments are key priorities in National Adaptation Plans.

Box 3 **Potential Impacts of Climate Change on Cities by 2050**[156]

- 1.6 billion people living in more than 970 cities will be regularly exposed to extreme high temperatures.
- Over 800 million living in 570 cities will be vulnerable to sea-level rise and coastal flooding.
- 650 million, in over 500 cities, will be at risk of water shortages.
- 2.5 billion people will be living in over 1,600 cities where national food supplies will be threatened.
- The power supply to 470 million people, in over 230 cities, will be vulnerable to sea-level rise.
- 215 million poor urban residents living in slum areas in over 490 cities will face disproportionate climate risks.

The cost of adapting to a global warming scenario of 2˚C by 2050 varies greatly by region, climate impact scenario assumptions, and by sector. As such there is no real consensus on specific figures. However, there is alignment between key studies that the costs of climate change adaptation are far greater than the current and projected amount of international public finance and private investment[157 158 159]. The most recent estimate of global adaptation cost is in the range of US$140 – US$300 billion per year by 2030 and US$280 – US$500 billion per year by 2050[160].

What these analyses show clearly is that the cost of adaptation rises significantly the longer action is delayed. Costs in 2030 are expected to be 2-3 times higher than projected public finance in 2030 and between 6-13 times higher in 2050. Ambitious mitigation action will help keep costs down, but significant scaling up of public and private sector adaptation financing will be necessary[161].

A 2018 content analysis of National Adaptation Plans[162] showed that developing countries are more concerned about flooding, especially in coastal areas, the lack of integrated planning controls and the growth of informal settlements in areas that are vulnerable to flooding, and exposed to the impacts of extreme weather. Developed countries are concerned about the impacts of flooding and extreme weather on cities, but are also concerned with the ability of existing buildings to cope with increased temperatures. Countries with traditionally cool climates are particularly concerned about the capacity for poorly insulated existing building stock to provide thermal comfort during more extreme heatwaves, and the amplifying risks to health and heat stress of urban heat-island effects (Figure 9).

Figure 9 **Variation in common issues of concern between developed and developing countries based on a content analysis of National Adaptation Plans submitted to the UNFCCC**

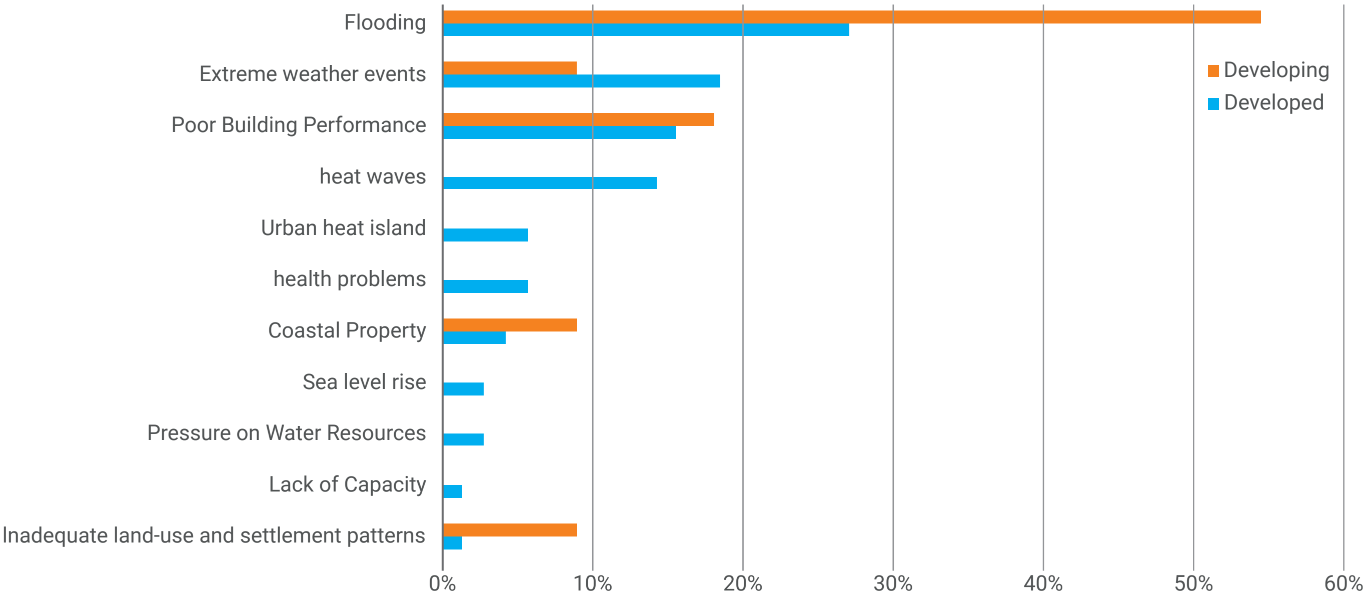
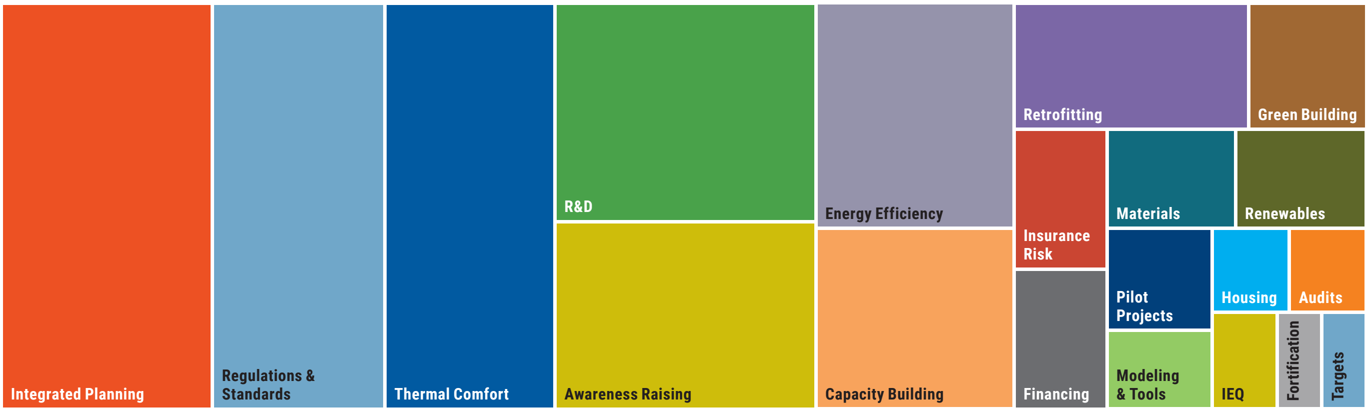


Figure 10 below summarises the global priority buildings sector actions being described in NAPs in response to these issues. It shows that the need for integrated planning is a shared priority globally, but that countries are also planning actions to develop or review building regulations and standards to improve energy efficiency, integrate renewable energy and improve thermal comfort of building stock, investing in research & development in climate adaptation, and raise awareness of climate risks and adaptation actions in the buildings sector. Costs and benefits associated with improving building energy performance and thermal comforts have been discussed in the previous section. However, the costs and benefits of integrated planning should also be addressed, considering it is considered an enabling context for more cost-effective building sector energy efficiency and climate actions in the GlobalABC Roadmap.

Figure 10 **Priority building sector adaptation actions included in National Adaptation Plans**



Integrated planning & nature-based solutions

In total 17 countries have considered integrated urban planning in their National Adaptation Plans. Measures include re-zoning of land to avoid building in areas prone to future flooding or exposure to extreme weather, improving land-tenure regulations and housing standards for informal settlements, encouraging mixed-use and transit-oriented development (TOD), and nature-based solutions.

Policy impact studies indicate that integrated approaches to urban climate policy can deliver greater impacts on emissions and co-benefits such as health than individual measures and that comprehensive strategies targeting multiple economic sectors have the potential to multiply health and climate co-benefits[163]. For example, in the U.K. integrating strategies for low-carbon food and agriculture, household energy efficiency and urban transport were found to reduce GHG emissions in each sector by 50-60% while delivering health co-benefits[164].

Packaging urban spatial planning strategies, with technology and market-based strategies can also be very effective[165]. General equilibrium modelling of OECD economies for example, has found that integrating policies for increasing urban density with congestion pricing, is a more cost-effective strategy for meeting GHG emission reduction targets than using stand-alone economy-wide policies such as carbon taxes[166]. Policies for more compact urban development packaged with technological strategies such as more fuel-efficient vehicles running in low-carbon fuels, has also been estimated to reduce related GHG emissions by 15%-20% more than such policies on their own[167]. Achieving these synergies and results requires a high degree of political leadership and institutional co-ordination.

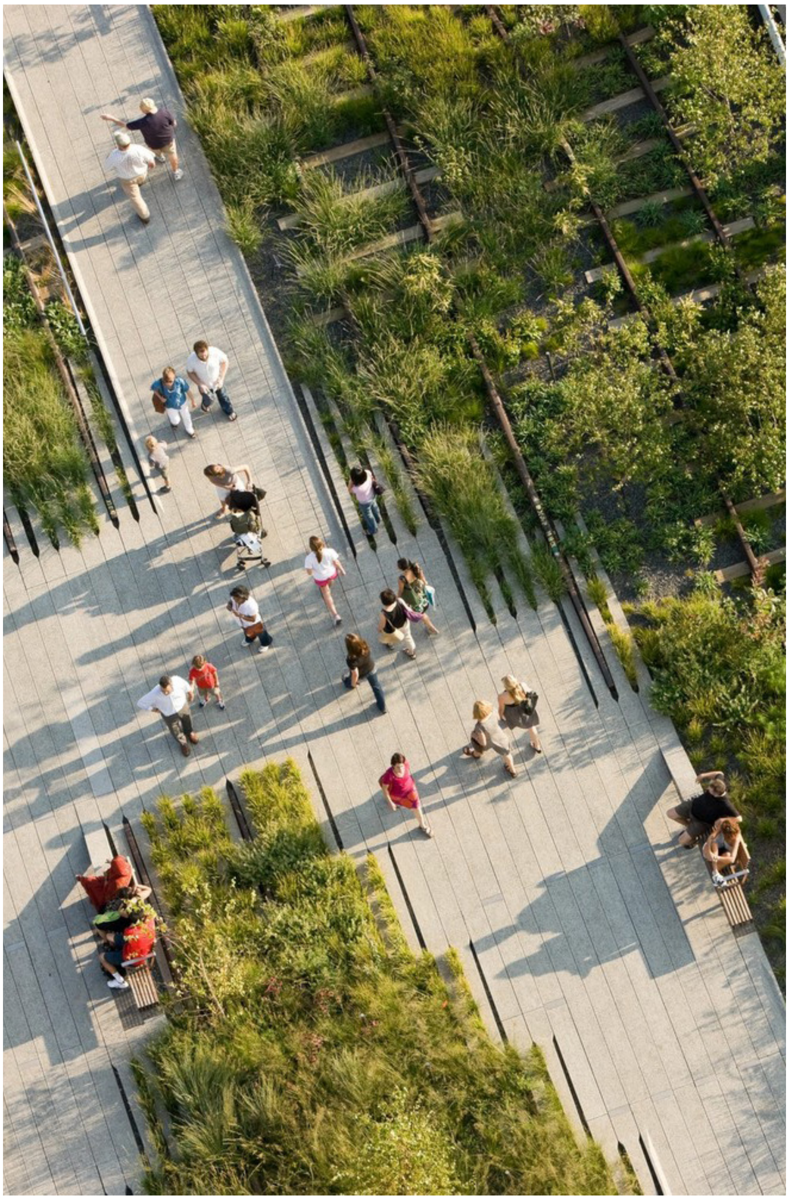
Nature-based solutions (NBS) are also increasingly being implemented in cities to more cost-effectively provide environmental, social and economic benefits, and build resilience[168]. Nature-based solutions generally apply ecosystem-based approaches rather than traditional engineering approaches to provide cities with services such as clean water, clean air, agricultural production, biodiversity and green-space. This approach is considered as potentially more efficient and cost-effective that traditional approaches[169].

NBS are also considered an important economic innovator because policy-makers need to specifically value ecosystem services and societal benefits in cost-benefit analyses, and evaluate system-wide trade-offs rather than focus on direct impacts of specific measures. For example, street trees can promote urban cooling, sequester CO_2 and improve air-quality, but certain species produce allergens that have negative impacts on citizen's health and well-being. Similarly, restoring coastal dunes and wetlands to reduce flooding impacts can provide benefits to residents by improving environmental quality, and increasing property values. However, this might also increase inequality and erode social cohesion by promoting gentrification[170].

Specific NBS measures in cities have been evaluated as performing better than traditional measures. Case-studies of green-roofs and rain-gardens for example indicate that by reducing volume and improving the quality of run-off, they are a more sustainable alternative to traditional piping infrastructure for rain-water collection and storm-water management. Urban agriculture has been shown to improve food security and provide direct cost-savings by reducing transport, energy and waste costs. Net-present value studies have also shown that the majority of ecological restoration projects in EU cities provide net economic benefits through job creation, and are more profitable and create higher-yield investments than traditional approaches[171]. The necessity for system-wide policy analysis, design and implementation has also sparked innovation in planning, governance, and business models[172]. Notwithstanding these positive perspectives, it has been noted that more cost-benefit analysis of NBS, especially outside the EU are required to establish comparable and generalisable insights[173].

4. KEY INSIGHTS: INFORMING ROADMAPS FOR SUSTAINABLE BUILDINGS

The Global Alliance on Buildings and Construction is supporting countries to collaborate to develop regional roadmaps for transitioning to zero-emission, efficient, and resilient buildings and construction, and reduce GHG emission levels that support keeping global warming below 1.5oC. Having reviewed comprehensive studies and systematic reviews, the impact and cost-effectiveness of key policies for designing and implementing these roadmaps can be presented. While noting again that the current evidence base on building energy and climate cost-benefits and impacts is too varied to generalise, the following insights, drawn from the studies reviewed can be arranged by policy priorities for decarbonizing the buildings sector and linked with GlobalABC Regional Roadmap actions.



POLICY PRIORITY

Reduce Direct GHG Emissions from Buildings

ROADMAP IMPERATIVES

- Increase uptake of net-zero operating emissions for buildings.
- Increase the rate of building energy renovation and increase the level of energy efficiency in existing buildings.
- Reduce the operating energy and emissions through improved energy management tools and operational capacity building.
- Reduce the energy and emissions needed for equipment, appliances, lighting and cooking.

POLICY PRIORITY

Reduce indirect and embodied GHG emissions from buildings

ROADMAP IMPERATIVES

- Use urban planning policies to enable reduced energy demand, increased renewable energy capacity and improved infrastructure resilience.
- Increase secure, affordable and sustainable energy and reduce the carbon footprint of energy demand in buildings.
- Reduce building risks related to climate change through building design, selection of materials and improving resilience to structural, water and heat risks.
- Reduce the environmental impact of materials and equipment in the buildings and construction value chain by taking a life-cycle approach.

KEY INSIGHTS ON POLICY COSTS & BENEFITS

1 Modelling indicates that ambitious policy targets such as zero emissions, zero-net energy provide the greatest long-term financial returns on investment in energy efficient buildings in all global regions after 2030. But this requires equally long-term political commitment to policy design and implementation.

2 Evidence from multiple studies demonstrates that higher energy performance buildings including near and net-zero energy and net zero carbon homes provide lower operational energy costs compared to standard practices. More research of very low energy buildings is required in order to quantify, monetise and determine the net present value of many known co-benefits.

3 Ambitious building energy policies pay off. However, the monetary benefits of energy efficiency measures to economies is underestimated because impact analyses predominantly concentrate on direct energy and cost savings (cost-effectiveness), but seldom include quantitative analysis of the costs and benefits of co-benefits (policy value).

4 Mandatory building energy codes + rating & disclosure with appliance standards are the most cost-efficient and highest positive impact policies. Energy performance requirements in mandatory codes improve energy efficiency of new buildings and major renovation works, while energy rating and disclosure programs support achieving required performance in building operations and market awareness of better performing buildings. The influence of energy labelling based on measured data have shown that a combination of energy efficiency labelling for appliances and stricter building performance standards has led to long-lasting reductions in energy consumption.

5 The cost-effectiveness of building codes can be undermined if intended energy and emissions savings are not met. Even where building energy codes are in place they are not necessarily being complied with. One of the biggest impacts and 'short term wins' governments can have to invest in ensuring compliance mechanisms are put in place and enforced.

6 Ambitious energy codes and standards reduce total final energy demand and associated greenhouse gas (GHG) emissions (policy impact) most effectively when implemented as a package of aligned strategies. Policy strategies are more often associated with positive climate and economic impacts when they are designed to address local market conditions, respond to the priorities of key stakeholders, and are monitored transparently for impact and value (policy effectiveness).

7 Well-designed energy efficiency obligations schemes (EEOs) can deliver significant energy savings from low-cost measures over many years by encouraging energy efficiency renovations. However, as energy efficiency targets become more ambitious the scope of EEOs will need to increase, and be designed to incorporate less cost-effective, but higher energy savings measures.

8 Learning effects among policy makers and construction professionals tend to normalise initial increases in up-front costs for achieving higher environmental performance to within the range of cost and price fluctuations associated with standard construction.

KEY INSIGHTS ON POLICY COSTS & BENEFITS

1 Integrated urban planning and land-use policies such as transit oriented development, increasing urban density and diversity of use (mixed use development), and congestion pricing offer potential for more emission reductions and co-benefits, and have been more profitable in some contexts than stand-alone measures.

2 Nature-based solutions show promise as more cost-effective than traditional engineering solutions when integrated with urban and building design strategies such as green-roofs, rain-gardens, ecosystem restoration and urban agriculture. This systems-approach is also considered a catalyst for innovation in governance, planning administration, design standards and business models.

3 Achieving zero-emissions buildings requires decarbonisation of energy supply, and electricity generation in particular. This in turn requires buildings to be highly energy efficient, designed for climate and integrated with renewable energy generation. Investing in building energy efficiency policies has been shown to be a lower-cost option than investing in new power generation, improves the cost-efficiency of grid management by providing demand-side management flexibility, and improves energy access and security of supply.

4 The cost of adaptation rises significantly the longer action is delayed. Costs in 2030 are expected to be 2-3 times higher than projected public finance in 2030 and between 6-13 times higher in 2050. Ambitious mitigation action will help keep costs down, but significant scaling up of public and private sector adaptation financing will be necessary.

5 Without an enabling framework, policy impact will remain limited: Putting a price on carbon and putting in place ambitious commitments are essential for such an enabling framework.

6 Life-cycle cost analysis has shown that productivity benefits from better thermal comfort and indoor environmental quality can deliver productivity cost benefits that are significantly greater than increased costs of implementing higher performance. Construction productivity and profitability has also been positively influenced by building energy regulations. Increasing the ambition of building energy efficiency regulation can lead to large cost savings and skill development.

Recommendations: Implementation for impact

The examples presented in previous sections demonstrate that policy actions in the buildings sector can cost-effectively reduce the climate impact of buildings and construction in specific contexts. Due to the heterogeneity of the many studies that make up our current evidence base, it is not possible to draw general conclusions about policy measures that will always be cost effective and achieve their goals, nor directly compare or rank policy effectiveness. However, the analysis has identified some key influencing factors that should be taken into consideration when designing and implementing buildings sector climate policies and policy packages[174]. Policy strategies that have demonstrated cost-effectiveness, and impact have:

- Tailored policy to decision-makers priorities.
- Targeted up-front costs with incentives and information.
- Designed policies for local contextual factors.
- Implemented earlier rather than later – taking a life-cycle approach.
- Taken a comprehensive systems approach to policy design and implementation.
- Been monitored and improved by robust research.

Tailor policy to decision-makers priorities

Decision-makers in the construction supply chain including building owners, households, trades people and construction industry most often prioritise Issues of health, comfort, finances and having control over energy use higher than consideration of energy efficiency. Policy makers therefore need to be able to communicate the non-energy benefits of policy actions that resonate most with local decision-makers priorities. Studies also indicate that in many markets there is a willingness to pay more for intrinsic value provided by higher performing buildings, but no generalisable findings on how much extra people are willing to pay. This depends on local contextual factors (see point 3 below).

Target up-front costs with incentives and information

A number of exemplary building projects have demonstrated that it is possible to deliver high environmental performance buildings at low marginal cost or even at less cost than conventional buildings. These results are not generic, and there remains a dominant perception that high-performance buildings cost more to design and build. The split incentive issue is also a factor that property investors, and building owners contend with. Policies are more effective when they recognise and address these kinds of financial uncertainties. Incentives such as subsidies and grants that target up-front costs can help reduce uncertainty, as can providing clear and verifiable cost and/or return on investment comparisons between performance levels, building designs or energy savings and renewable energy technologies.

Design policies for the local context

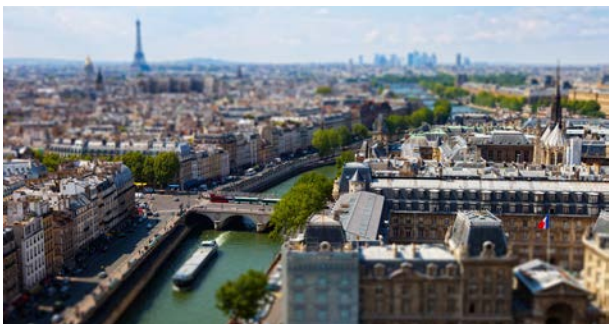
The current body of knowledge reinforces the perspective that energy conservation policies are effective when they are designed to specifically address local geographic, climatic, ecological, economic and socio-cultural conditions. Of these factors, tailoring to the socio-cultural aspects is particularly critical to policy effectiveness. These issues include, but are not limited to key variables such as demographics, consideration of community and industry education levels, attitudes toward impacts of policies on households, attitudes toward impacts of policies beyond households, social influence, social practices and behaviours around energy conservation, household income and expenditures, and preferred channels of communication.

Implement earlier rather than later – taking a life-cycle approach

The perfect is often the enemy of the good. Early implementation of policies that are achievable within existing market conditions is important to get the ball rolling. But a policy framework that sets an ambitious long-term energy performance and decarbonization goals must also be in place with a clearly communicated, and supported timetable for increasing stringency of performance requirements. The cost-optimality of measures included in such frameworks should be calculated over a building's economic life-cycle. There is an appreciable learning effect among building and construction stakeholders that leads to reduction in marginal costs of higher performance over time. The rate of the learning effect, and therefore the speed with which costs normalise is associated with setting clear and ambitious long-term performance goals that are met in progressive stages.

A comprehensive systems approach to policy design and implementation

Incremental costs of investing in increasing building energy performance need to be met by increased savings in energy costs and societal benefits (see section 2). However positive the social benefits are, market failures and market barriers still persistently hinder mainstream diffusion of more sustainable buildings. For instance, incremental increases in performance requirements for more sustainable buildings, have been found to increase the cost of design fees and construction costs (market failures), and lengthen project construction times and hence pay-back periods (market barriers). While additional marginal costs are often only a fraction of the total construction cost, and may not influence the final price of the development, they increase financial risks to developers in particular because much of the increased costs relate to project design[175]. Effective policy packages need to address these market failures, barriers and risks through a combination of ambitious regulations to create a level playing field (sticks); incentives and financing that reduce development costs and risks (carrots) and; awareness-raising and rewards for promoting leadership in sustainable buildings (tambourines).



Monitored and improved by robust research

Policy strategies need to be measurable, reportable and verifiable in order to monitor progress, evaluate performance and analyse for improvement. The brief for this report was to evaluate the overall cost of adopting public policies in the buildings and construction sector. The research was conducted through two rapid systematic reviews of journals and grey literature on these topics filtering 4000 resources down to 120 core papers and reports. These reviews identified a large diversity of research into the costs and benefits of building energy and climate policies. It is also evident that more recent ambitious policy goals such as net-zero energy or emissions building codes and nature-based solutions have not been in operation long-enough for their impacts to be fully studied. Because of the large range of approaches to research design, methodologies, scope and contextual factors, there is not enough consistency of approach to provide robust comparison of policy costs and benefits achieved in different jurisdictions. The evidence-base for which policy actions bring what cost and benefits needs to be improved, especially in developing country contexts. It is essential that governments and other entities properly fund monitoring and evaluation as well as case studies to enable evidence-based policies.

APPENDIX 1: FURTHER POLICY RESOURCES

Policy coverage – global

The International Energy Agency
Building Energy Efficiency Policies Data-base: *www.iea.org/beep/*

The BEEP database was launched in 2012 as part of the work of the IEA's Sustainable Buildings Centre (SBC). It provides a detailed breakdown of policies for energy efficiency in buildings around the world, including those supporting buildings codes, labels, incentive schemes and zero-energy buildings.

Policy design & packaging for new & existing buildings

BigEE Policy Guide
How to combine policies and measures for energy efficiency in buildings: *http://www.bigee.net/en/policy/guide/buildings/recommended/*

This guide is designed to help you find an appropriate combination of policies and measures to gradually make Ultra-Low-Energy buildings the standard in new buildings and to achieve high energy savings in building retrofit and operation.

GlobalABC Regional Roadmaps towards zero-emission, efficient, and resilient buildings and construction: Africa, Asia, Latin America

https://globalabc.org/news%C3%9F/regional-roadmaps

https://www.iea.org/topics/energyefficiency/gabc/regionalroadmap/

The regional Roadmaps identify short-term, mid-term and long-term targets for 8 strategic areas to create goals for the buildings and construction sector that support achieving the Paris Agreement and nationally determined contributions in locally appropriate ways.

Policy implementation – OECD

IPEEC Building Energy Efficiency Task Group
Building Energy Codes Portal @ GBPN: *www.gbpn.org/laboratory/building-energy-codes-portal*

This web portal supports efficient international knowledge exchange on building energy code implementation by providing information, access to local experts, and resources from around the world.

Policy status and implementation – APEC

APEC Building Energy Codes Forum:
www.apec.org/Publications/2017/10/Opportunities-for-Collaboration-to-Improve-Building-Energy-Codes-in-APEC-Economies

Reports detailing the status of building energy code design, governance and implementation in APEC economies. Includes case-studies of Australia, China, Indonesia, Malaysia, Philippines, Singapore, Thailand and Viet Nam.

GlobalABC's guide for incorporating buildings actions in NDCs

https://globalabc.org/uploads/media/default/0001/02/67fea075bbb7a9dc8dd08f2ddb3ebc0f41df8a97.pdf

A guide on incorporating fundable buildings sector Green House Gas (GHG) emission mitigation actions in Nationally Determined Contributions (NDCs)

Best-practice policies – new construction:

The Global Buildings Performance Network
Policy Tool for New Buildings: *www.gbpn.org/databases-tools/purpose-policy-tool-new-buildings*

Compare dynamic energy efficiency policies for new buildings. What are the main components needed to develop ambitious and dynamic building codes and supporting packages? Experiment with this tool to find the combination of elements that help move the building stock in your region towards zero energy.

Best-practice policies – renovation policies:

The Global Buildings Performance Network

Policy Tool for Renovation: *www.gbpn.org/databases-tools/purpose-renovation-policy-tool*

Compare Renovation Policy Packages. Compare and analyze the elements of best practice policy packages for renovation of residential buildings, that have led to measurable reductions in residential building energy use over time.

Best policy practices for promoting energy efficiency

A structured framework of best practices in policies to promote energy efficiency for climate change mitigation and sustainable development
https://www.unece.org/fileadmin/DAM/energy/se/pdfs/geee/pub/ECE_Best_Practices_in_EE_publication.pdf

Calculating policy impacts – multiple benefits:

C40 Urban Climate Impacts Framework:

https://c40-production-images.s3.amazonaws.com/other_uploads/images/1605_C40_UCAIF_report_V3.original.pdf?1518203136

By using the Framework, cities, experts and other stakeholders will be able to explore and provide evidence on how urban climate action translates into wider impacts for society, health, the economy and the environment.

COMBI

Project – EU: *https://combi-project.eu*

The COMBI project aimed at quantifying the multiple non-energy benefits of energy efficiency in the EU-28 area. All data is available from an open-source online database and analysable via a graphic online-visualisation tool (launched at the final conference 17 May 2018)

U.S. EPA

Quantifying the Multiple Benefits of Energy Efficiency and Renewable Energy: A Guide for State and Local Governments: *www.epa.gov/statelocalenergy/quantifying-multiple-benefits-energy-efficiency-and-renewable-energy-guide-state*

EPA's 2018 edition of Quantifying the Multiple Benefits of Energy Efficiency and Renewable Energy: A Guide for State and Local Governments describes methods, tools, and steps analysts can use to quantify these benefits so that they can compare costs and benefits and comprehensively assess the value of energy policy and program choices.

APPENDIX 2: COUNTRIES WITH BUILDING ENERGY CODES WHICH INCLUDE MANDATORY COVERAGE OF BUILDING RENOVATION

POLICY	COUNTRY	JURISDICTION	BUILDING TYPES	REQUIREMENT
Building Code of Australia (Tasmania) 2009	Australia	Tasmania	Existing non-residential, Existing residential, New non-residential, New residential	Mandatory
Ontario Supplementary Standard SB-10 2011	Canada	Ontario	Existing non-residential, Existing residential, New non-residential, New residential	Mandatory
Ontario Supplementary Standard SB-12 2011	Canada	Ontario	Existing residential, New residential	Mandatory
Energy performance of buildings undergoing renovation or alteration	Finland	National	Existing residential, Existing non-residential	Mandatory
Réglementation Thermique (RT) 2005	France	National	Existing non-residential, New non-residential	Mandatory
Réglementation Thermique (RT) 2012	France	National	New non-residential, Existing non-residential	Mandatory
Regulation for Energy Performance of Buildings (KENAK Residential) 2010	Greece	National	New residential, Existing residential	Mandatory
Regulation for Energy Performance of Buildings (KENAK Non-residential) 2010	Greece	National	Existing non-residential, New non-residential	Mandatory
Jakarta Regulation No. 38/2012 on Green Buildings	Indonesia	Jakarta	New residential, New non-residential, Existing residential, Existing non-residential	Mandatory
Conservation of Fuel and Energy: Buildings other than Dwellings (2008)	Ireland	National	Existing non-residential, New non-residential	Mandatory
Italy National Building Energy Code (2011)	Italy	National	Existing residential, New residential	Mandatory
Decree for energy efficiency requirements in buildings (2015)	Italy	National	Existing non-residential, Existing residential, New non-residential, New residential	Mandatory
Energy Efficiency Standard and Notification System	Japan	Japan	New residential, New non-residential, Existing residential, Existing non-residential	Mandatory
Building Energy Efficiency Act (2015)	Japan	National	Existing non-residential, Existing residential, New non-residential, New residential	Mandatory
Building Design Code for Energy Saving (2010)	Korea	National	New residential, Existing residential	Mandatory

POLICY	COUNTRY	JURISDICTION	BUILDING TYPES	REQUIREMENT
Energy Performance of Functional Buildings (2010)	Luxembourg	Luxembourg	New non-residential, Existing non-residential	Mandatory
Règlement grand-ducal modifié la performance nergétique des bâtiments (2008)	Luxembourg		New residential, Existing residential	Mandatory
H1 Energy Efficiency 3rd edition (2011)	New Zealand	National	New residential, Existing residential	Mandatory
The Planning and Building Act (2010-2015)	Norway	National	Existing residential, New residential, New non-residential, Existing non-residential	Mandatory
The Planning and Buildings Act (2016-)	Norway	National	Existing non-residential, Existing residential, New non-residential, New residential	Mandatory
The Construction Law (1994)	Poland	Poland (national)	Existing non-residential, Existing residential, New non-residential, New residential	Mandatory
The Energy Performance of Buildings Law (2014)	Poland	Poland (national)	Existing non-residential, Existing residential, New non-residential, New residential	Mandatory
Regulation Characteristics Of Thermal Performance Of Building (RCCTE) 2010	Portugal	Portugal	New residential, Existing residential	Mandatory
Energy Certification System of Buildings (2013)	Portugal	National	Existing non-residential, Existing residential, New non-residential, New residential	Mandatory
(IEBC 2006) State Building Code (Hawaii)	United States	Hawaii	Existing non-residential	Mandatory
(IECC 2006) Residential (Hawaii)	United States	Hawaii	Existing residential	Mandatory
(IECC 2009) Residential Code (Indiana)	United States	Indiana	Existing residential	Mandatory
(IEBC 2006) State Building Code (Kansas)	United States	Kansas	Existing non-residential	Mandatory
(IECC 2009) Uniform Energy Code (Michigan)	United States	Michigan	Existing residential	Mandatory
ASHRAE 90.1-2004 Commercial Energy Code (Minnesota)	United States	Minnesota	Existing non-residential	Mandatory
(IEBC 2006) State Building Code (Nevada)	United States	Nevada	Existing non-residential	Mandatory

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