GBPN
Global Buildings Performance Network

Building Policies for a Better World

Policy Paper

DESIGNING AND IMPLEMENTING BEST PRACTICE BUILDING CODES: INSIGHTS FROM POLICY MAKERS

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INTRODUCTION

About This Paper

There is a general consensus that if we are to achieve significant green house gas (GHG) mitigation in the building sector, new buildings must be developed to zero energy standards (LBNL, 2012). Mandatory, ambitious[1] building codes play a critical role in ensuring that GHG reduction targets are achieved. Building codes must form part of a clearly defined strategy that sets out the planned code revisions required to realistically achieve the targets set. Such a strategy is essential for preparing the market. Despite increasing awareness of the need for such standards, the practical knowledge about "how to" develop and implement these standards is often missing.

In 2013 the Global Buildings Performance Network (GBPN) developed an on-line policy tool to facilitate the interactive analysis and comparison of twenty-five best-practice building codes for new buildings using specially developed criteria. To support a deeper understanding of how the codes have been developed (i.e. key drivers for change and the lessons learnt as part of the process), the GBPN hosted a series of webinars featuring a number of policy makers from the best practice regions.

The three webinars focused on the themes of "Long-Term Energy Targets and Frequent Revision Cycles", "Performance Based Approach to Code Development" and "Good Enforcement"[2] as the analysis from the tool highlighted the need for further improvement in these areas. Speakers provided insight into how those themes have been addressed in their respective jurisdictions, outlining the barriers and opportunities as well as the key lessons learnt. By sharing critical insights into practical code development, the webinars also aimed to support other jurisdictions to move more quickly towards zero energy.

This paper aims to support the development of ambitious building energy codes and supporting policy packages by providing insights in to current best practices. The paper draws on the main findings of the dialogue initiated by the GBPN with practitioners and code experts on the design and implementation of best practice building codes. The dialogue (facilitated through the webinar series) provided a deeper insight into the practical aspects of developing best practice building codes. This paper captures those insights along with a number of recommendations on how code developers can strengthen progressive buildings codes in future.

The GBPN Policy Tool for New Buildings

GBPN with the support of sixty-four international experts developed fifteen criteria to define the key elements of a state of the art building code for new buildings. These criteria were then used to analyse current examples of best practice. The methodology used to select those elements and to score codes against the criteria developed has been discussed in the GBPN publication *"A Comparative Analysis of Building Energy Efficiency Policies for New Buildings"*. This report can be accessed on the GBPN website at www.gbpn.org/reports.

The five key themes and fifteen elements used to define best practice and to score the codes are outlined in the table below:

Table 1. The key elements of a best practice building code.

Holistic Approach	Dynamic Process	Implementa-tion	Technical Requirements	Overall Performance
Performance approach	Zero energy target	Enforcement standards	Building shell	On-site energy
Includes all energy	Revision cycle	Certification	Technical systems	Primary energy
Energy efficiency & renewable energy	Levels beyond minimum	Policy packages	Renewable energy systems	GHG emissions

Each code was selected based on its demonstration of elements of best practice. They were also selected in order to highlight regional differences in best practices relative to climate, energy prices, construction traditions, maturity, etc. The tool clearly illustrates the priority areas that

[1] Ambitious in this context refers to a building energy code that has set stringent energy requirements.

[2] Links to the webinars can be found in the references section at the end of this document.

codes must address if they are to move new buildings towards zero energy. For example, codes with a long history have in general adopted a fully performance based approach. Those with a shorter track record tend to have a strong focus on technical requirements (prescriptive approach) including stringent requirements for U-values and technical systems. Renewable energy systems are often encouraged. Codes in the earlier stages of development also score well when it comes to technical systems, but there is still need for the establishment of energy targets and roadmaps that clearly outline how these targets should be met.

A number of key findings have emerged from the tool including the fact that there is no such thing as an overall "best" code and that all codes can be improved. Based on the results it is clear that there are certain aspects of code development that still require particular attention if significant GHG mitigation is to be achieved in the building sector. Those aspects include the need to move towards a performance based approach to code design, the establishment of a dynamic process that sets long term targets for achieving zero energy and requires frequent revisions towards the target, and stronger enforcement of existing codes. A number of codes have scored well under these criteria and have a significant amount of practical knowledge that can be gained from the approach taken. Despite the fact that codes must be developed relative to the local context there are a number of core elements of best practice that are essential and remain useful and replicable across regions. All of the selected codes are among the best in their respective regions. The tool showcases codes that are at different stages of development. The tool is interactive and all interested parties can conduct their own analyses and reach their own conclusions by comparing codes in detail using individual elements or multiple elements.

"How To" of Building Code Development Webinar Series

To deepen the analysis from the tool, the GBPN hosted a series of webinars to invite those involved in code development from best practice regions to share their practical experiences with practitioners and international experts. Speakers were asked to provide insight into the main drivers for the development of progressive building codes in their jurisdictions and to outline the barriers and opportunities as well as the key lessons learnt. The speakers presented codes at different stages of development, with some in the early stages of moving towards a performance based approach, while others have a long history of code development and performance based building codes. An important aspect of the webinar series was that it provided practical insight into how codes have been developed rather than focusing solely on the theoretical elements included in the tool. Given the challenges associated with running a webinar over multiple time zones, U.S and European building codes were the focus of this series.

The webinar series facilitated the sharing of best practices in a dynamic environment and showed that there was plenty to learn from all of the codes no matter what their level of development. The aim of the webinar series was to learn from the good experiences and to understand how barriers can be overcome so that other countries/regions could leapfrog those experiences to develop progressive building energy codes in future. By sharing critical insights we hope to support countries to develop policies that help them to make a structured and impactful transition towards zero energy buildings and positive buildings. Recordings of the presentations are available to download on the GBPN website.

PERFORMANCE APPROACH

What is a Performance Approach?

In terms of significantly improving the energy performance of buildings, policies that consider the overall performance of the building are seen as critical (Urge-Vorsatz, 2012). This is particularly relevant when the energy requirements move closer to zero or positive energy. Such a performance approach sets an energy performance target for the whole building based on the supply of energy or the resulting environmental impact, for instance in the form of CO_2 emissions, and a calculation methodology is provided for assessing whether the proposed building complies with the regulations.

Most countries start by developing prescriptive building codes. As ambition increases and expertise are developed, the basic requirements of building codes generally evolve to incorporate more complex calculations such as model building, energy frame and finally, energy performance calculations. The type of building energy code therefore often depends on the maturity of the regulatory system.

Once building component requirements are demanding enough and have been properly implemented, they can be complemented by requirements for overall energy performance. It is not unusual for a number of different compliance options to exist side by side within a country (IEA, 2008).

Analysis from the Tool

Under the theme of "Holistic Approach", the first criterion, "Performance Approach", assesses whether codes included into the GBPN Policy Tool for New Buildings have adopted a holistic understanding of buildings, ensuring that the main requests of the building code are based on total energy performance. These requests can either be based on a performance calculation or a figure based on metered consumption. The energy performance should be based on the balance and integration of difference elements of the building including the technical system. The criterion also

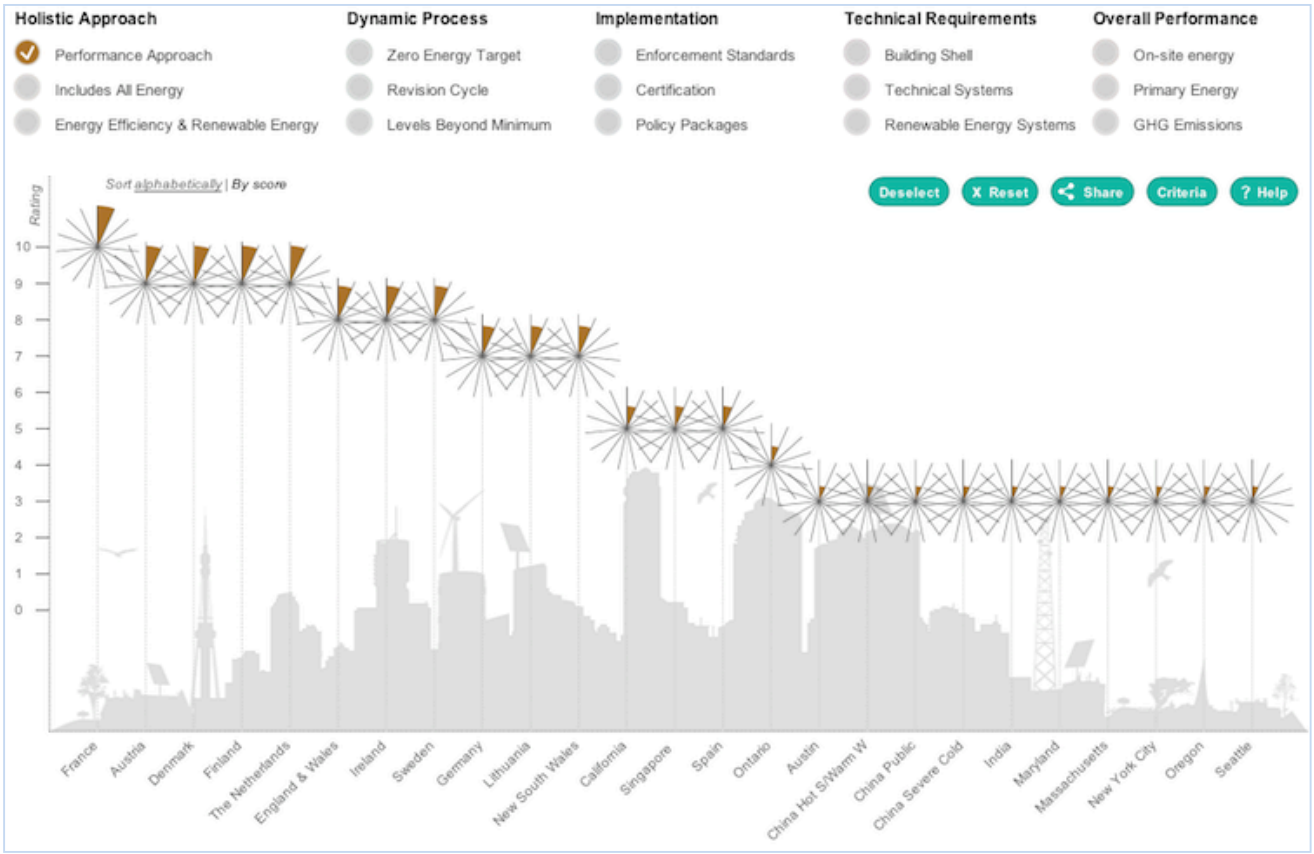

Figure 1. Results of jurisdictions relative to the performance approach criteria.

assesses whether the performance allows and stimulates integrated design or bioclimatic design principles adapted to the actual climate and whether it gives priority to passive design of buildings.

The codes from the GBPN Policy Tool for New Buildings that scored best under this criterion were those that have shifted from an elemental approach to code design, to a mandatory performance-based approach or energy frame calculation. While the energy requirements under the performance approach are based on a building's overall consumption of energy or the building's implied emissions of GHG, the energy frame approach uses an overall framework to establish a building's maximum energy consumption. The procedure for calculating these losses is based on values such as the envelope U-values, temperature, surface area and heat gains from sunlight, etc. Values for the individual parts are not set in this approach but only for total loss or use of energy and efficiency of technical systems overall.

As illustrated in figure 1, France scored full marks under this criterion due to their extremely progressive performance based code that has been adapted to the different regions of the country. The code requires buildings to demonstrate compliance with the maximum allowed primary energy consumption, the 'Cepmax' coefficient. This coefficient represents the maximum consumption of primary energy that considers thermal envelope components and most energy consuming systems including; HVAC, hot water, lighting, heat recovery and auxiliary systems. The code was also awarded full marks due to the requirements for mandatory renewable energy requirements, computer simulations, air-tightness testing for residential buildings and bio-climatic design considerations, all of which are integral to a holistic approach.

The Danish building code is fully performance based and sets a total value in absolute energy use based on size and function of the building. The code addresses all thermal envelope requirements and energy-using efficiency standards in the calculation, including heating, cooling, ventilation, hot water, lighting (only non-residential) heat recovery and conversion and distribution losses. A number of studies of the Danish building regulations have found that they have been effective in reducing energy consumption (Leth-Peterson & Togeby, 2001; Statens Byggeforskningsinstitut (SBI), 2012).

Austria, Finland and the Netherlands also scored very well due to similarly progressive performance based approaches where mandatory energy frame calculations are relied on to calculate the overall performance of buildings in those countries. This approach provides a great deal of flexibility in designing low energy buildings as it focuses on the overall energy losses of the building rather than on the individual elements. In Finland the mandatory energy frame calculation is used to establish the expected monthly final energy consumption (E-luku energy weighted factor) of residential and non-residential buildings. The allowable final energy frame is set to kWh/m2/pa and depends on the type of building. The code addresses thermal envelope requirements and energy uses in the calculation, including, HVAC, hot water, lighting, heat recovery and bio-climatic design.

Other European codes scored slightly lower than these due to the overall performance calculation being based on equivalent/model building calculation i.e. Germany, England/Wales and Ireland. This was also the case for some of the US codes while others are still quite strongly based on direct use of prescriptive values. Under the model building approach, compliance with the building regulations is determined by calculating the annual energy use of a building and comparing it with the energy use of a comparable 'model' or 'reference' building fulfilling a set of prescriptive values. The calculation must demonstrate that the proposed building will perform at least as well as the model building. The German building code requires a mandatory equivalent model building calculation to establish the expected primary energy consumption of residential and non-residential buildings.

California and New South Wales were the codes outside Europe that scored well. Despite not having mandatory overall performance or energy frame calculations, these codes take GHG emissions or peak loads into account and generally encourage bio-climatic design strategies. In California compliance can be demonstrated using a prescriptive approach or an alternative 'energy budget' approach. The energy budget (model building) for a proposed building is the sum of the space conditioning, lighting, and service water-heating budgets expressed in Btu/f2 per annum. This model building approach can be applied to residential and non-residential buildings and

alterations or additions. In Seattle a Target Performance Path sets an energy target (EUI) for a number of building types leaving it up to the design team to decide how to reach the target. The design team submits an energy model in order to receive a permit and then after construction the energy consumption is monitored for a whole year within their energy frame.

Although only a limited number of codes have moved to a fully performance based approach, a large number of codes have adopted sophisticated energy frame and model building calculations. These approaches, in particular the energy frame calculation, are a large step beyond the basic prescriptive requirements. The results from the tool show that almost all the selected codes have included the majority of energy end uses when assessing the performance of the building. Extra points were awarded to those who have assessed the performance in light of primary energy and have included energy demand from heating, cooling, ventilation, dehumidification, hot water, lighting and elevators as well as conversion and transportation losses.

Insights from Policy Makers

In order to provide further insight into how jurisdictions have structured their transition towards a performance based approach, two speakers involved in policy development from Massachusetts and Upper Austria were invited to participate in the webinar series. Upper Austria was selected as a jurisdiction of interest given its long track record of a holistic approach to the development of energy efficiency policy and its implementation of progressive measures. Massachusetts has a shorter history of developing performance based building codes but was selected given the progressive actions the state has taken since 2008 to move in a structured way towards a performance approach. The choice of speakers also provided U.S. and European perspectives.

Massachusetts

Massachusetts is often identified as one of the leading U.S. states in terms of energy efficiency, and some practical insight into the key factors that have supported the introduction of performance based elements in to the energy code were shared during the webinar series. In 2008 landmark energy legislation was passed in Massachusetts that significantly increased investment in energy efficiency and renewable energy across the state. In parallel to the legislative changes, an energy and building industry task force was established by the State Governor to determine how buildings could reach zero net energy as quickly as possible. The main recommendation of the commercial and residential task force report[3] was to establish energy performance standards for buildings.

As a starting point, additions were made to the base energy codes, (then IECC 2009/ASHRAE 90.1-2007, currently IECC 2012/ASHRAE 90.1-2010), which was primarily prescriptive in approach with few design trade-offs. Two new options for code compliance through meeting demonstrated performance requirements were added for new residential construction providing both a HERS rating option and also a Passive House option. These additional energy code compliance pathways streamline energy code requirements for developers who decide to take a whole building approach to energy performance, while maintaining all mandatory prescriptive requirements.

Although these additions to the base code were first steps on the road to up scaling net zero energy buildings, it was acknowledged that something more than the base code was necessary to support a significant upscale in the number of very efficient buildings. A number of cities and towns in Massachusetts had expressed interest in more stringent building codes at the appeals process and as a result, a performance-based 'Stretch' energy code was developed for both residential and commercial new construction. When adopted by cities and towns, it makes performance-based energy code mandatory for new residential units and larger commercial buildings (over 100,000 square feet in size). The code standard is currently set at between 65 and 70 on the HERS index (net zero energy is calibrated at 0 on the scale, whilst a standard new home in 2005 was 100). The stretch code also requires the introduction of a third party specialist who works with the builder to model energy use both in the design phase, and through air leakage testing to project completion. It allows more design trade offs, which allow flexibility to the builder to reach targets while managing costs. On the commercial side the performance modelling option under ASHRAE 90.1 was selected as a base mainly due to its use in the USGBC LEED ratings, and is required for large new commercial buildings. The state energy and building code offices worked with Mathis

[3] http://www.mass.gov/eea/docs/eea/press/publications/zneb-taskforce-report.pdf

Consulting, NEEP, and the New Buildings Institute to develop a prescriptive option that allows some flexibility to encourage builders to save more energy at lower costs.

As outlined during the webinar series, one of the key drivers of change in the state is the "Green Communities" programme, established under the Green Communities Act. Any jurisdiction seeking to be a "Green Community" must adopt the 'stretch code', with 143 jurisdictions, approximately half the state of Massachusetts, doing so as of July 1st 2014. A number of incentive schemes are available to encourage the state's developers to go beyond minimum requirements primarily through utility rebate and loan programmes, and state incentives for renewable energy. To date, training has been found to be invaluable in facilitating a shift towards energy efficiency construction. Outreach to as many stakeholders as possible in order to explain the benefits of energy efficiency and performance based compliance, and how they can take advantage of it was also highlighted.

Some of the key lessons that have been learnt in Massachusetts are that introducing performance elements wherever possible and supporting them with mandatory prescriptive requirements, as an option for smaller buildings, is necessary to ensure that standards are improved and cannot be compromised. Massachusetts also built on existing above-code programmes that have been historically supported through the federal government and the electric and gas utilities, as well as initiatives such as the Green Building Council's LEED rating programme. Demand from local communities and state legislation were also found to be instrumental in changing people's expectations of what should happen in the building sector.

Upper Austria (Austria)

In Austria the responsibility for the development of building regulations is split between the national and regional level. Upper Austria has a long tradition of energy efficiency and renewable energy and in 2007 a regional target was set requiring all space heating and electricity to be supplied by renewable energy by 2030. Energy efficiency of the building sector was highlighted as critical in achieving this target and performance-based building codes are a key element. In 1993 an energy performance indicator was introduced as a requirement for funding. By 1999 a new building code based on energy performance indicators for heating was introduced but minimum u-values were also included. In 2002, the European Energy Performance in Buildings Directive (EPBD) came into force requiring Member States to introduce energy performance certificates. In 2007 they were required for the first time for non-domestic buildings. The 'energy performance indicator/certificate' is calculated based on the orientation of the building, solar gains, insulation quality, ventilation losses, heating system, renewables, and the geometry of the building. In 1994 the performance requirement was set at 110 kWh/m2/pa whilst today's target has been tightened to 54 kWh/m2/pa and this is will be reduced to 34 kWh/m2/pa by 2020 (equivalent to an EUI of 11.4). Long-term targets are viewed as essential in supporting a move towards performance based building codes as they allow the market to prepare for changes. In Upper Austria, low-interest loans for efficient construction and renovation are based on energy performance indicators, and investment plans for renewable heating and specific energy efficiency measures are also provided. Energy advice is also considered to be a very important element.

The energy advice service is a key element in the regional energy policy and is something that has been critical to the success of energy efficiency measures in Upper Austria. It supports private households, public bodies and companies in energy and building related investment decisions by providing situation-specific information, both on technical, financial and practical issues, independent of any economic interest. The importance of ensuring that the right information reaches the appropriate stakeholders at the right time was stressed. Fast and sustainable market growth is dependent on the availability of skilled personnel along the value chain.

Some of the key lessons learnt whilst implementing a performance-based approach in Upper Austria are that the right balance between very ambitious energy efficiency measures and high-level market activation must be struck in order for the measures to be successful. Continuous tightening of the requirements for financial incentives has been shown to ensure a balance across the technologies that are applied, avoiding a market rush to one particular product. Information, training, and quality assurance were also highlighted as critical and it is clear that significant effort has been placed on developing a progressive marketing campaign around energy efficiency. It was highlighted during the webinar series that there is no "one size fits all" solution for mobilizing the market. In the experience of Upper Austria, a combination of "sticks, carrots and tambourines" are essential in ensuring the activation of all market segments.

Conclusions

It is clear from the tool that a limited number of building codes are fully performance based but many of the codes have introduced performance elements and continue to evolve towards a performance-based approach. A strong message that has emerged from the tool and from the webinar is the importance of a holistic approach if performance requirements are to be successfully implemented.

A holistic approach to code development is critical if performance requirements are to be successfully implemented.

The analysis shows that jurisdictions that have successfully implemented progressive performance requirements have ensured a structured and well-planned transition that gradually moves the market towards zero energy. Those jurisdictions noted that the strengthening of performance requirements must be supported by targeted and timely outreach to key stakeholders to ensure market demand. Ongoing training, awareness raising and incentive schemes are all significant in activating the market and ensuring that the performance targets are indeed achieved. A delicate balance between all elements is required. Despite the different political, economic and geographic differences, both Upper Austria and Massachusetts have pursued a staged approach to the introduction of performance-based requirements, ensuring that as many stakeholders as possible are involved in the process.

DYNAMIC PROCESS

What is a Dynamic Process?

Dynamic process can be defined as a continuous closed-loop process of policy design, implementation and evaluation (Morvaj & Bukarica, 2010). The theme of "Dynamic Process" assesses whether ambitious energy savings targets have been set within a realistic time frame and are accompanied by a roadmap that is appropriate for achieving those targets, as well as supporting policy packages that facilitate proper implementation. Such targets, roadmaps and supporting packages are essential for establishing a strong framework within which the market can establish long-term investment strategies. The roadmaps should be built on experience gathered from the evaluation of previous code cycles. The theme also analyses whether there is a well-documented process for regularly updating the energy requirements of the code and whether stakeholders are involved in that process. The "Dynamic Process" theme also considers whether the building code encourages developers to go beyond the minimum requirements for energy performance set in the code. Such encouragement can include certification systems that clearly define classes that exceed the minimum standards for energy efficiency. Incentives should be put in place to encourage developers to go beyond these minimum standards.

Analysis from the Tool

As illustrated by figure 2 a number of codes have scored well under this theme. Others, while on the way towards lower energy consumption, do require stronger commitments about how they aim to realistically meet the zero energy targets. Issues also exist around the definition of zero energy and the setting of aspirational targets for revisions towards zero energy. This was found to be a common issue amongst the countries that have adopted building codes more recently.

The best performing jurisdictions under this theme were those that have set a nZEB target, complete with roadmap and frequent revision cycles in order to reach those targets. They included Denmark, the Netherlands, Sweden, France and Germany, all of whom are required under E.U. legislation to ensure that by 2020 all new buildings are built to nearly zero or zero energy standard. Many of these countries have a long tradition of developing building codes that predated the introduction of the European Energy Performance in Buildings Directive (EPBD) and all countries have now chosen to set targets that go beyond those set in the EPBD.

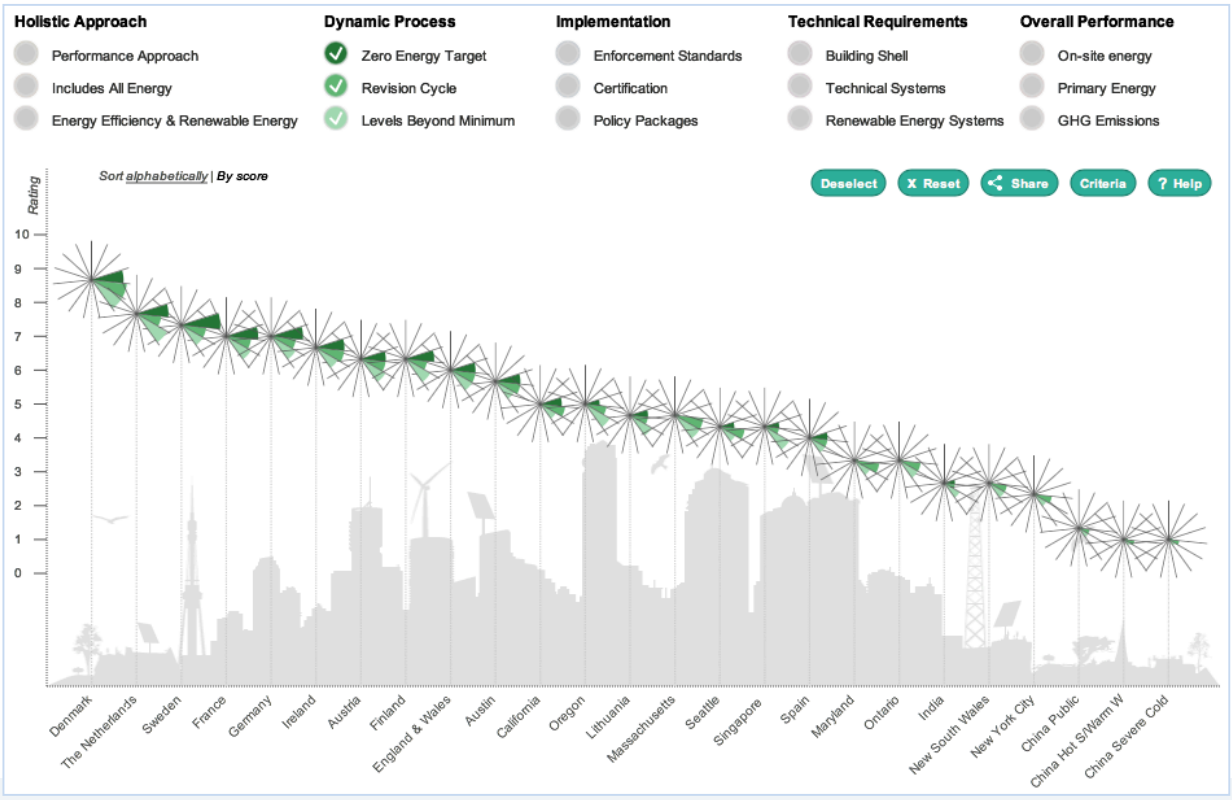

Figure 2: Results for Countries in the area of Dynamic Process including all three elements.

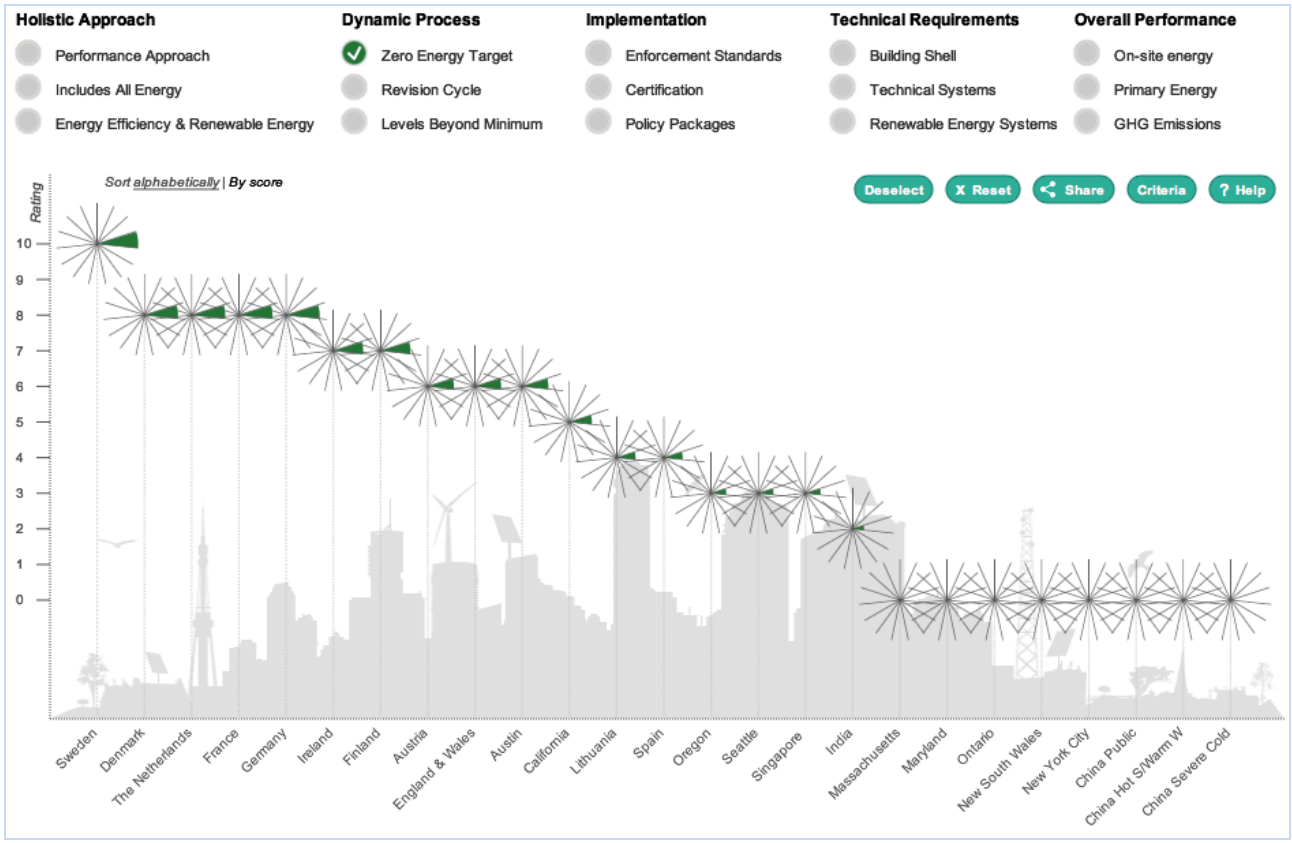

Figure 3. Zero Energy Targets

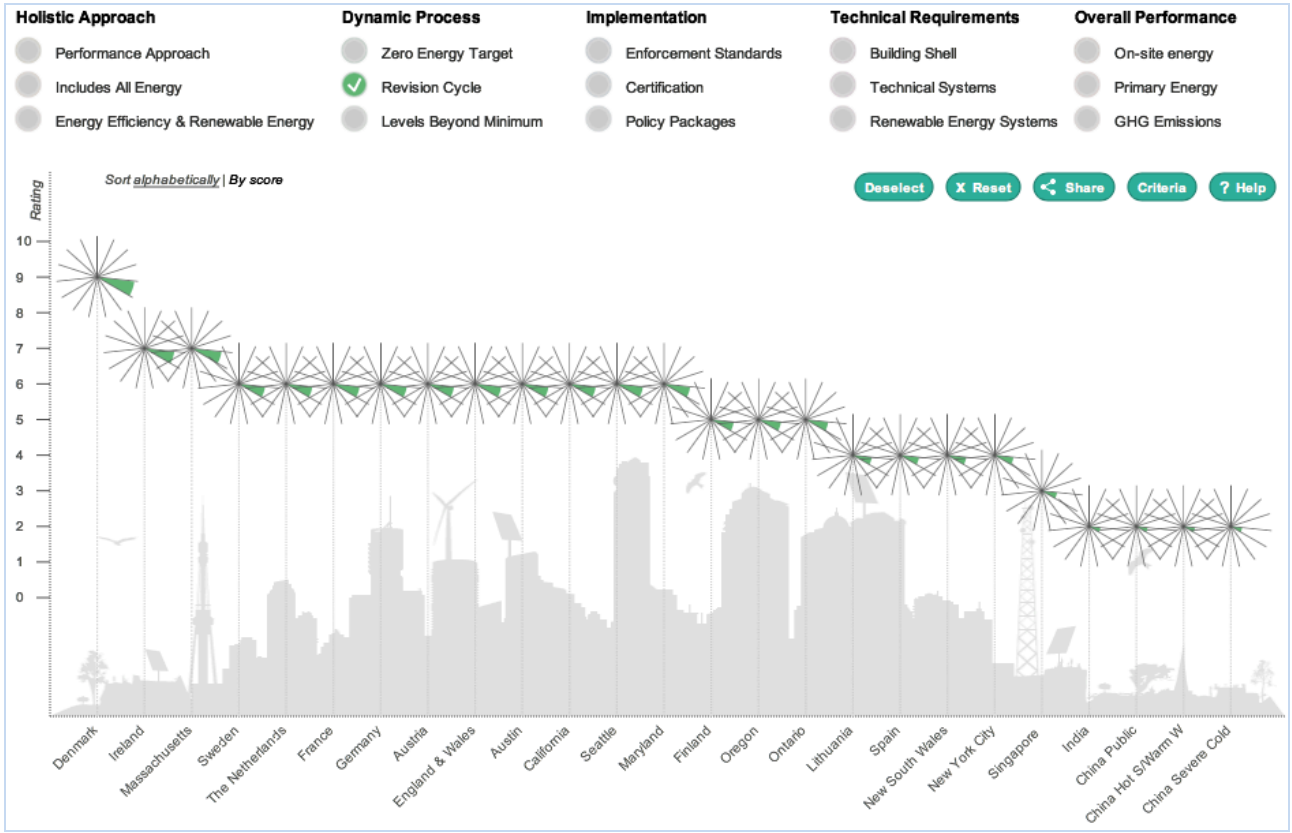

Figure 4. Revision Cycles

The highest score awarded under the theme of "dynamic process" was awarded to Denmark due to their long history of clearly defined future targets, the systematic revision of the code to reach those codes in addition to well-established complimentary policies such as energy performance certification. The Danish government places a clear emphasis on setting energy efficiency requirements for the long term rather than for short-term cost-efficiency. Such an approach allows builders to choose between building to the current minimum standard or to construct buildings that will continue to meet future minimum targets. For example, under the 2008 Danish Building Regulations, two low energy classes were defined that have/will become the minimum requirements by 2010 and 2015 respectively. The 2011 regulations (BR10) introduced a further low energy class that will be the requirement by 2020. Such long-term targets provide the market with sufficient time to prepare for the coming changes. The Netherlands and Germany have similarly outlined clear paths towards zero energy in 2020 with a number of scheduled revisions of the code to meet that target.

In the US, Austin, California and Oregon have demonstrated elements of dynamic process that support the move towards zero energy California has clearly defined a zero energy building (ZEB) as: *"The amount of energy provided by on-site renewable energy sources is equal to the amount of energy used by the building".* The state has set policy targets for all new residential buildings to become ZEB by 2020 and all commercial buildings to be ZEB by 2030. An Energy Efficiency Strategic Plan has also been put in place to support this transition. In Austin "Net Zero Energy Capable Homes" have been defined as *"homes that are energy efficient enough to be net zero energy homes with the addition of on-site or its equivalent, energy generation. This level of energy efficiency is approximately 65% more efficient than homes built to the City of Austin Energy Code in effect in November, 2006"* (City of Austin, 2007). The 2007 council resolution stated that all new single-family homes should be "net zero energy capable" by 2015. Although a guide to the potential measures that could be taken with each revision cycle to achieve the target was proposed, a realistic and binding roadmap was not established. By 2012 code improvements reduced the energy use in new single-family homes by 31% (City of Austin, 2012).

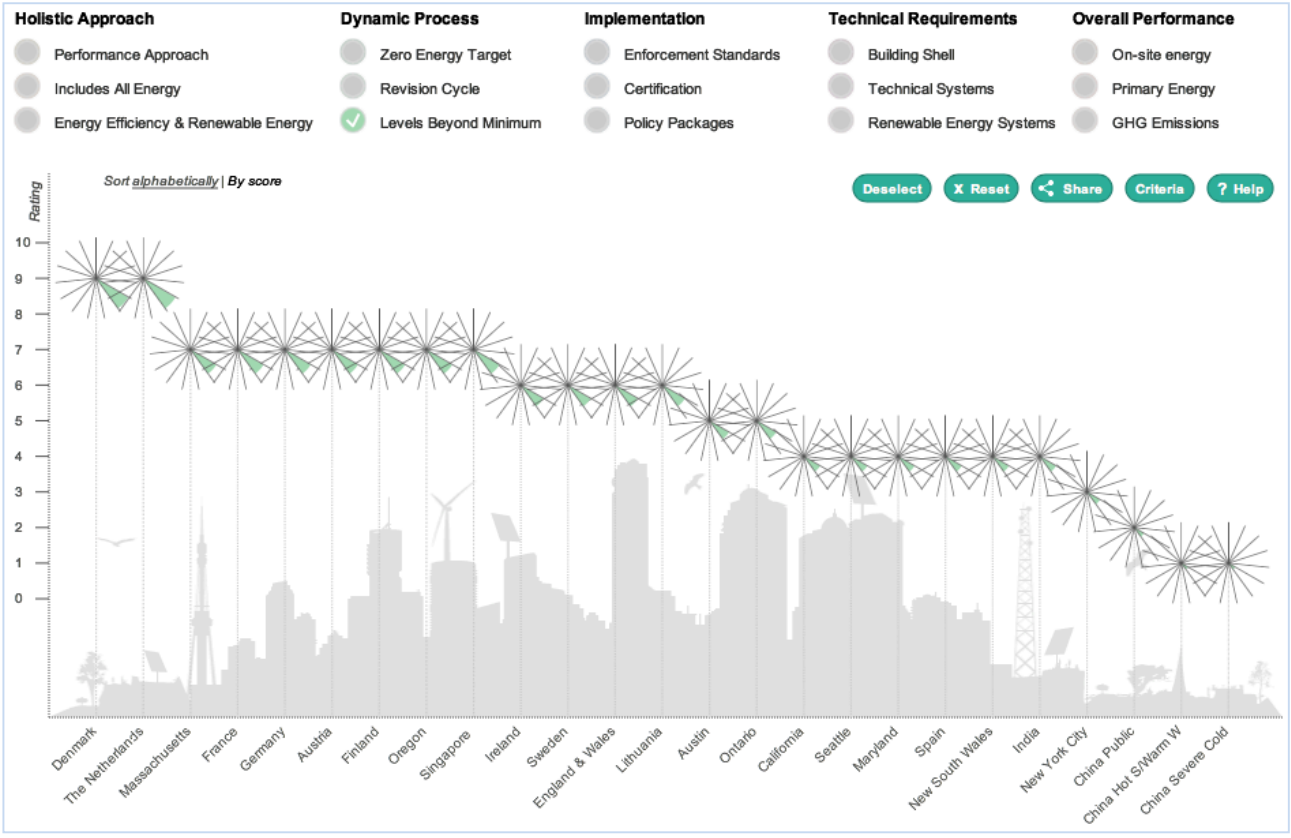

Figure 5. Levels Beyond Minimum

Singapore, Oregon and Massachusetts also scored very well under the criteria "levels beyond minimum" as they have included policies or schemes that encourage the construction of buildings beyond the minimum standard set in the code. The Singaporean government has released a building certification programme called Green Mark. It covers both new and existing buildings in the residential and commercial sectors. A number of supporting schemes initiated by the Government (GMIS-NB, GM-GFA), offer cash incentives to developers, building owners, project architects and M&E engineers who make efforts to achieve at least a Gold rating or higher under the Green Mark scheme in the design and construction of new buildings. The Oregon Residential Reach Code (ORRC) is a state code that has been developed to complement the mandatory Oregon 2011 Residential Specialty Code (ORSC). The reach code encourages projects to voluntarily go beyond the minimum standard and further reduce energy consumption. However, very few projects in Oregon have thus far elected to pursue this voluntary compliance path. State rebates are also in place to encourage developers to go beyond the minimum standard.

Insights from Policy Makers

Many jurisdictions have made progress in establishing a dynamic code process but challenges remain for some jurisdictions in establishing a binding target and establishing a clear roadmap for how that target will be achieved. As part of the dialogue on "how to" develop and implement a dynamic process, individuals involved in policy development in the Netherlands, Ireland and Seattle were invited to provide their perspectives. The Netherlands was selected for participation in the series given their long history in setting energy efficiency targets and establishing clear roadmaps for the market. Ireland was selected given the significant progress that the country has made in addressing energy efficiency since the late nineties. This case illustrates how quickly progress can be made given the right conditions. Seattle was invited to engage in the dialogue in order to share their experience of trying to establish a dynamic process against a back-drop of cheap energy costs and to provide insight to other jurisdictions that struggle with similar challenges.

The Netherlands

Since 1995, energy performance regulations/standards (EPN) have been in place in the Netherlands, pre-empting the requirements of the EPBD. The energy performance standard introduced in 1995 aimed to reduce energy consumption by 15% - 20% as compared with the regulations in place prior to 1995. For residential buildings this was represented as an energy performance coefficient (EPC) of 1.4. This figure was subsequently tightened in 1998, 2000, 2006 and again in 2011. This equates to a 40% reduction in energy consumption as compared with 1995 levels. In line with the requirements of the recast Energy Performance in Buildings Directive (2010), the Dutch Government has set the target of Energy Neutral Buildings by 2020. As part of the strategy towards Energy Neutral Buildings it is anticipated that the EPC for dwellings will be further tightened to 0.4 in 2015 (50% decrease in energy consumption compared to 2007) and again to 0.2 by 2018. With regulatory requirements moving closer to zero energy the need to illustrate the cost effectiveness of performance requirements has become more important. In 2011 under the framework of the European Union EPBD comparative cost-optimality methodology, the Netherlands introduced a more refined methodology for calculating the cost-optimality of code revisions.

During the webinar the importance of the strong political support for building energy regulations in the Netherlands was emphasised. Prior to the revision of the building code a number of feasibility studies are conducted in order to provide a strong evidence base for the logic of such measures. Using a series of reference buildings that reflects the Dutch building stock, the costs associated with the proposed energy performance level are calculated. Key stakeholders from the construction and housing sector are invited to consult on the proposed revisions. This participative aspect of the political process is credited with ensuring that stakeholders are broadly supportive of the energy targets introduced.

To date, in general, the strengthening of the energy performance requirements was not met with major opposition. This is related to the fact that constant product development, a growing market for energy saving materials and rising energy prices have all helped to ensure the cost efficiency of the energy savings requirements. During the webinar it was indicated that the cost-optimality methodology required by the European Union is a useful tool for communicating with

stakeholders about the costs associated with the proposed regulation, and to gauge the political will for implementing the measures based on the associated costs. In order to support the market to achieve the targets set, a series of government programmes and activities have been put in place (subsidies for energy performance advice, energy neutral buildings & efficient heating systems as well as green loans etc.). The programmes aim to support knowledge development and transfer whilst also reducing financial barriers. A number of industry agreements are also in place to support the development of markets for new and renovated energy efficient buildings. In April 2008 an agreement was signed between the government and several builders' associations with the objective of creating conditions for energy neutral new constructions by 2020. The agreement (Lenteakkoord) was renewed in 2012 under the Koepel Covenant and aims at a 50% energy reduction in new buildings over the period 2012-2015 (Ministry of the Environment & Infrastructure, 2013). Industry organisations have also implemented a knowledge transfer and stimulation programme for businesses associated with them, in order to bring the improvements of the energy performance up to the desired level.

In the case of the Netherlands it is clear that strong targets are supported by a holistic policy package including financial stimulus, knowledge transfer, and monitoring and innovation.

Ireland

Building energy efficiency regulations for dwellings have been in place in Ireland since 1979 (Rogan & Ó'Gallachóir, 2013) with targets first introduced in the 1997 revision of the building regulations. Ireland scored well under this theme as a result of the systematic strengthening of the building code since targets were first set in 1997. The code was revised in 2002, 2006, 2008, and 2011. The 2011 regulations improved residential efficiency by 60% relative to 2002 standards. The 2008 regulation also introduced a mandatory renewable energy contribution of 10kWh/m2/annum (O'Connor, 2013). These frequent revisions of the code form part of a broader strategy to achieve a 20% improvement in energy efficiency across all sectors of the economy by 2020.

The successful introduction of targets in Ireland coincided with the unprecedented economic boom as well as the broader energy efficiency debate at the international level (European Energy Performance in Buildings Directive (EPBD), Kyoto Protocol etc.). As a result of the economic boom there was significant market confidence and openness to new approaches to design and construction, which facilitated industry innovation. Energy efficiency was seen as providing businesses with a competitive advantage and as a result voices in the industry were supportive of the introduction of new regulations in this area. Major industry stakeholders such as the largest building insurance company actively supported the adoption of the regulations and engaged with the state energy agency by supporting an energy efficiency road show aimed at introducing builders and developers to the new standards. In an effort to support the implementation of the regulations and to encourage property owners to go beyond standards set in the code, a number of government grants and demonstration programmes were introduced. In 2001, *House of Tomorrow*, a multiannual demonstration programme was established to encourage the widespread uptake of sustainable energy planning and construction by the Irish construction sector. This ambitious scheme required contractors to achieve more than a 50% reduction in energy use and CO_2 emissions above the building regulations at the time (SEAI, 2003). Over the duration of the programme, 3000 homes were supported to incorporate energy saving measures, with levels of support typically between €5,000 and €8,000 per home. This scheme was the first of its kind and was viewed as providing a strong evidence base for the benefits of energy efficiency and the feasibility of such projects and supported learning by doing. It also highlighted the need to tighten the regulations in this area, and it built a clear case for doing so. A number of other grant schemes, tax credits and financing schemes have also supported the introduction of subsequent legislation.

Strong political consensus about the importance of energy efficiency was also critical in ensuring the implementation of such progressive measures. During the webinar, institutional trust and collaboration between different government departments were also highlighted as contributing to the development of the progressive regulations. Despite an economic collapse in 2008, energy efficiency is still viewed by all political parties as an economic opportunity and as something that can support economic regeneration.

During the webinar, on-going issues with enforcement of the building energy code were alluded to, and the need for further work in order to ensure that the targets are

achieved was emphasised. Other challenges that were identified included the need to improve site practices and to ensure the on-going training and up-skilling of trades people. Like in the Dutch case, the challenge relating to defining the cost effectiveness of new codes was also highlighted. Although the overall framework for calculating cost-optimality is provided by the European Commission, the assessment of input data (e.g. climate conditions, investment costs etc.) and the calculation of the results is done at the level of individual Member States (ECEEE, 2011). Member states must consider whether cost effectiveness should be calculated on the basis of the present energy prices, carbon prices and electricity mix (notably renewables), or on some measure of projected levels of these factors over the lifetime of the building. Member states must also decide whether to consider the perspective of the individual building owner or investor, or the societal cost/benefit perspective. In the Irish case, a societal perspective has been adopted.

Seattle

Washington State, in which Seattle is located, has set a target of 70% energy reduction by 2030 relative to current energy consumption. These targets are very progressive, particularly in the U.S context, but despite the ambition of the targets, no clear timeline for achieving the targets has been set in law. Seattle also has a long-term target of carbon-neutrality by 2050 and a number of medium term goals are in place to achieve this target. In general, small incremental changes have been made to the code on a three yearly basis. However, as highlighted during the webinar series, the disadvantage of small cuts to energy consumption every third year is that, once builders and engineers have become accustomed to one set of regulations, they are quickly changed. It was argued that the slow rate of change in requirements is one of the main barriers to achieving the targets outlined. For example, the energy target set for 2030 could be achieved through 3 large reductions of 25% every 5 years. Adopting an integrated approach to code development, whereby multiple issues are addressed simultaneously, was emphasised as important in helping to reduce the costs associated with energy efficiency improvements.

Given a residual level of scepticism about the science of global warming in the U.S., the necessity of being able to defend energy efficiency in terms of the financial return on investment and to explain the economic value to stakeholders as clearly as possible was emphasised. It was argued that in order to ensure market support for energy efficiency a strong business case must be built that illustrates that energy savings outweigh any additional construction costs. However, the challenge associated with building this case as a result of the cheap cost of fuel in the U.S. was also highlighted.

While many parts of the construction industry may be opposed to the introduction of more stringent energy efficiency measures, regulations also provide new opportunities for many parts of the construction sector and in the experience of Seattle, it is therefore important to gain support from all stakeholders that may benefit. One of the main barriers to the achievement of ambitious policy targets identified during the webinar, is the prescriptive nature of U.S building codes. It was argued that energy codes based on performance rather than multiple prescriptive requirements are more straightforward and therefore less threatening to those involved in the construction process. It was argued that if substantial energy efficiency improvements are to be achieved it is necessary to transition away from prescriptive codes towards performance based codes. In 2013, Seattle, introduced a "target performance path" for complying with the code. The target performance path sets an energy use target for each building type and provides the design team with the flexibility to reach the target as they see fit. The design team are required to submit an energy model in order to get their building permit and the actual energy consumption of the building is then monitored for the first year of operation to ensure that it operates within the energy frame.

Although many progressive measures have been adopted in Seattle, the need for more ambitious measures such as a fully performance based code and more dramatic cuts with each revision of the code, were highlighted during the webinar. The need for a holistic approach to the design and implementation of codes in order to ensure that targets are achieved was also emphasised. The importance of best practice sharing and learning from countries, states and cities that are at the forefront of building energy efficiency was also stressed as this helps to support the development of more progressive measures as well as redefining what the market view as "normal".

Conclusions

Legally binding, clearly defined targets are an essential basis for the development of ambitious policy measures. In order for targets to realistically be achieved they must be supported by a roadmap that clearly outlines how they will be met. Such targets and roadmaps clearly inform the market of the level of ambition in building codes that can be anticipated in the future, supporting a smoother transition towards zero energy. Many countries, particularly within the E.U. have implemented ambitious targets (some that go beyond the requirements of the EPBD) with supporting roadmaps, while in the U.S. a number of states have set targets (some binding and others nonbinding) but few have developed supporting roadmaps.

Binding targets supported by realistic roadmaps are essential for ensuring that energy consumption in buildings is consistently reduced in a strategic manner.

Some of the key conclusions that can be drawn from the section are the importance of building political consensus on the importance of such targets. During the webinar all jurisdictions stressed the need for energy efficiency to be elevated above politics and for consensus to be built around the issue. Doing so has enabled a number of the best-practice jurisdictions to advance the development of ambitious policy measures.

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The importance of demonstration projects was also highlighted as they help to build credibility about what is possible in terms of cost and technology and thus help to stimulate the market and in turn support political will for increasingly stringent building regulations. As building codes move closer to zero energy the issue of cost becomes increasingly important and jurisdictions have stressed the need for a clear methodology to illustrate the cost and benefits of the revision of the building code.

As building codes move towards zero energy clear methodologies are essential to assess and illustrate the cost effectiveness of the revision.

IMPLEMENTATION

The Importance of Proper Implementation

If building energy policies are to significantly reduce energy consumption at the necessary rate they must be properly implemented. Effective implementation is dependent on a number of factors including the close involvement of key stakeholders in the development of the code. A clearly defined control and verification system for assessing compliance that necessitates on-site inspection during and after the construction process and the adequate training of inspectors is also required. This should be supported by certification/energy rating of the building and penalties for non-compliance.

Analysis from the Tool

Enforcement is clearly the most challenging aspect of code implementation. The GBPN Policy Comparative Tool highlights the fact that significant issues exist across all jurisdictions with regard to the enforcement of the building code. The highest score awarded under this category was 5/10 and that was awarded to Sweden due to their post occupancy energy verification compliance option. Where the municipal building board has selected this compliance option, an interim permit of use is granted for the first two years of occupancy. Where non-compliance is found to exist, the regulations stipulate that the developer must desist from using the building until the issues are corrected. The compliance checking is closely related to the energy performance certificate, which is also granted based on the metered energy consumption of the building.

California, New South Wales, Denmark and the Chinese standards all scored 4/10, with all other codes scoring 3/10. The low scores are generally due to a lack of compliance statistics and energy verification requirements as well as limited training programmes for the up-skilling of the workforce. India did not receive a score under this criterion as enforcement systems have yet to be established in the regions that have adopted the code. None of the codes were found to have robust and independent compliance monitoring and all codes can significantly improve in this area.

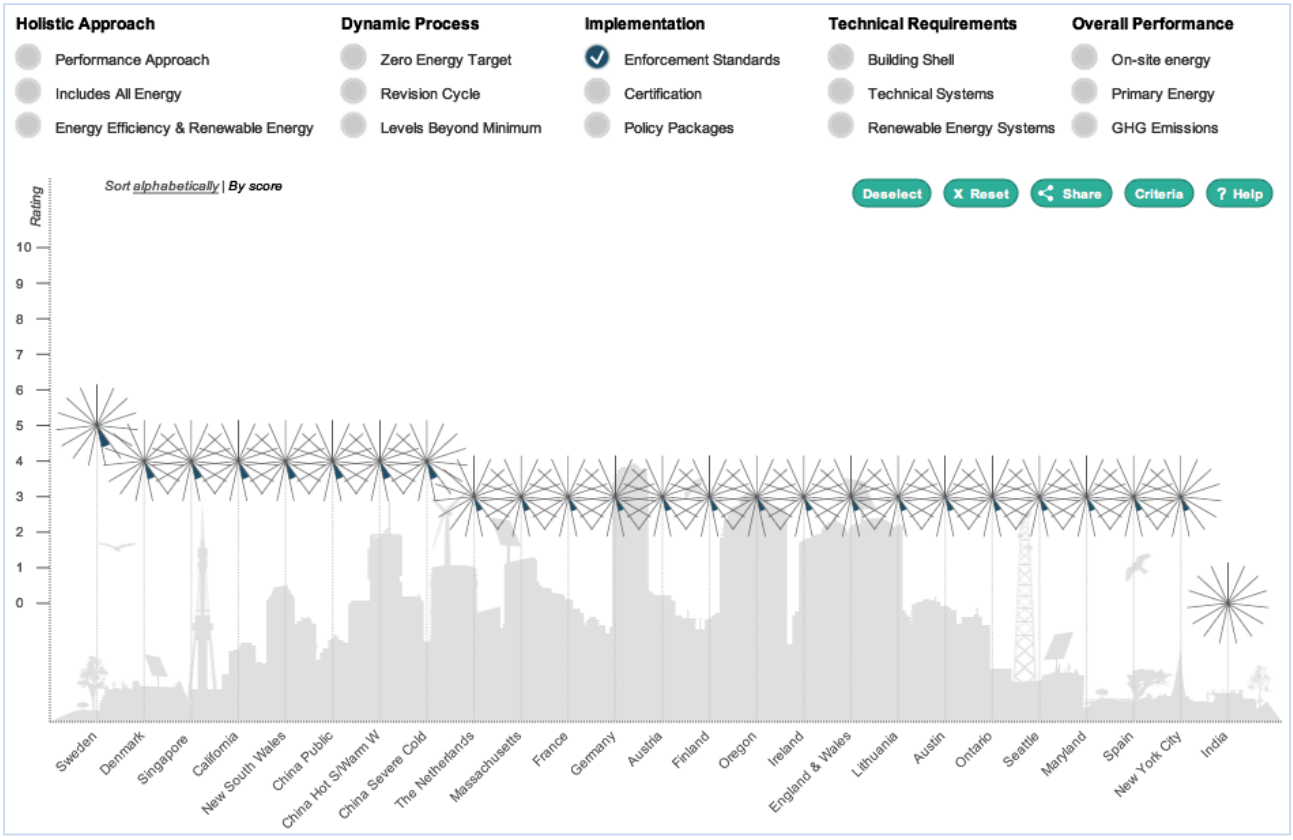

Figure 6. Enforcement standards

The main barriers to code compliance in the U.S. have been highlighted as follows:

Table 2. Barriers to Code Compliance in the U.S. (Meres, GBPN Webinar 3, 2014)

Lack of knowledge of the code/inadequate training
Constrained resources/inadequate funding
Lack of political will
Various paths for compliance *Prescriptive*- R-value and U-value options *Performance*- requires some knowledge of energy modeling *Outcome-based* - (proposed, but not yet in the model codes)
Not knowing what compliance issues exist

Although these barriers were identified for U.S. code enforcement, it is clear from the tool that many of these challenges are commonly faced by jurisdictions both in the U.S and the rest of the world. A clear understanding of the challenges faced by each individual jurisdiction was highlighted as essential for addressing enforcement and ensuring the proper implementation of the code. By conducting an assessment of the qualitative and quantitative issues it is then possible to develop a plan that addresses the areas of non-compliance by building on best-practices (Meres, 2014). Such a plan can form the basis of a solid enforcement regime.

Insights from Policy Makers

The implementation of dynamic building codes represents a challenge for many jurisdictions. However, as highlight in the analysis, a number of jurisdictions have developed robust compliance regimes to support the implementation of the building code. As noted above, Sweden is one of the first countries to establish a post-occupancy energy verification compliance regime and as a result of this ambitious measure they were invited to discuss the establishment and success of this regime during the webinar series. New York recently revised their compliance regime to develop a robust and well-resourced regime that supports the enforcement and implementation of ambitious compliance measures. In light of the comprehensiveness of the regime and its focus on the training of appropriate stakeholders, a representative from the New York City Mayor's Office was invited to share insights from their experience during the webinar series.

Sweden

As an early adopter of building regulations (1945), the Swedish have significant experience in the development of building regulations, in particular building energy codes. The 1988 building code (BFS 1988:18) introduced a new performance based approach that required an average overall U-value to be calculated for the whole building. This was a significant shift from the prescriptive approach used in previous codes, granting more freedom to building designers (Smeds, 2004). The most recent update of the building energy code in 2011 tightened the regulations to reflect the requirements of the Energy Performance in Buildings Directive Recast (2010) that all buildings move towards "nearly zero" energy by 2020. The new regulations tightened the performance requirements for all buildings apart from those heated by electrical means. It is anticipated that the regulations will be tightened again in 2015 in order to meet the 2020 target of 'nearly zero energy' buildings.

As outlined in the tool, Sweden has one of the most advanced enforcement regimes that focus on the actual energy consumption of the building. Enforcement of the building regulations in Sweden commences with the development of a control plan by the building board and the developer. Once the control plan is approved by the municipality permission is granted to commence works. At the end of the works the control responsible demonstrates to the building board that all controls in the control plan have been made. Depending on the competencies of the developers, the building board can require one of two methods for compliance: 1.) Control of calculated values during the development of the project 2.) Control of the measured values during the second year of occupancy. Developers may be required to implement both and where discrepancies are found they are required to adhere to the measured values. An interesting fact that was highlighted during the webinar is that, developers always factor a margin of safety into their projects (about 10% less energy use relative to the building code in the northern climate zones and 30-45% in the warmer southern climate zones). Where the building fails to meet the requirements of the code a number of sanctions may be imposed. Such a measure ensures that all buildings must go beyond the bare minimum. Where non-

compliance is found a developer may be refused final permission to occupy building (subject to correction), fines may be imposed, or in extreme conditions, a demolition order maybe imposed.. In order to eliminate the possibility of misrepresentation of the results, a certified control responsible is required to assess the different stages of the project, to ensure the controls due to the control plan has been made during the process.

Following the introduction of the EPBD, Sweden introduced a requirement that all new buildings must have an energy performance certificate within two years of use. Due to the law on energy certification of buildings (2006:985) the assessment must be conducted by a certified energy expert (Boverket, 2014). The certificate is granted based on measured energy consumption. Measured values are used due to the inaccuracies previously encountered with calculated values. These figures are now could be linked to the granting of the final compliance certificate. The municipality can decide between either compliance options, but in both cases an energy performance certificate must also be issued, and where a calculated values have been used they may be assessed in light of the measured values. Since the introduction of compliance control by measured values, a positive trend of reduced energy consumption has been identified in the certification register (Boverket, 2014).

Some of the challenges currently faced with checking compliance based on actual energy performance include the fact that buildings are often sold before they have been occupied for two years and therefore it may not be possible to achieve a clear picture of events. In this case certificates are issued based on calculated values. The certification database (Griffon) was previously managed by the local municipalities and it was found that many of them had not used their power to accurately check the certification. This database is now run by Boverket (The Swedish National Board of Building, Housing and Planning).

New York City

New York City has taken bold strides to develop and implement a progressive package of building energy measures. In 2007 Mayor Bloomberg introduced PlaNYC, a sustainability plan for the city. A core component of the plan is the Greener, Greater Buildings Plan (GGBP) that focuses on building energy efficiency. The GGBP is a holistic policy package that comprises of four energy efficiency laws. The laws focus on the following areas: NYC Energy Conservation Code (NYECC); Energy and Water Benchmarking; Energy Audits and Retro-commissioning; Lighting Upgrades and Sub-metering (ICLEI et al., 2012). The plan also includes progressive supporting initiatives on green workforce development and financing for renovation. Under the American Recovery and Reinvestment Act New York State has committed to submitting and implementing plans to achieve 90% compliance with building energy codes by 2017 through its participation in the State Energy Programme. New York City's work on enforcement of the energy code will also feed into achieving the state level targets.

The New York City energy code has changed a number of times over the past few years as a result of updates to the New York State Energy Conservation Construction Code (2007 and 2010) and the city's adoption of its own energy code and associated rules in 2009 (Viridian Energy & Environmental, 2011). Following these legislative changes, all construction projects (with a few minor exceptions e.g. historical buildings) are required to demonstrate compliance with the NYCECC in plan submissions, through a statement of compliance, energy analysis and progress inspections. An initial energy analysis is required prior to the granting of the permit and this can be conducted using tabular analysis; REScheck or COMcheck; energy modelling or an alternative format if approved by the department. Progress inspections must also be carried out throughout the construction process (NYC Energy Conservation Code, 2009). Prior to sign off there must be a declaration of completed progress inspections as well as an "as-built" energy analysis. All new buildings must comply via prescriptive or performance-based approach. The regulations also apply to renovations; however, unaltered portions of the building are not required to comply. In theory, any repair to a building should also be covered by the code.

The ambitiousness of these compliance measures represents a challenge for actual enforcement but the city of New York has developed a strong supporting system to ensure the full implementation of these measures. Following the introduction of the GGBP, New York City launched a working group of 30 partners called "Amalgamated Green" to identify the training needs of the key stakeholders to implement the plan (PLANYC, 2012). Energy code enforcement is supported by the provision of half-day training sessions provided by Urban Green and the American Institute of Architects New York Chapter

New York City Department of Buildings provides two day trainings in person and online to code enforcement officials and practitioners.

The enforcement regime is financed through the issuance of permits. As outlined in the webinar, in 2011 close to half a million plan reviews were conducted and total about 143,000 work permits were issued. These permits generated approximately $165 million in revenue, and much of this was allocated towards the salaries of the personnel that examined the plans and conducted inspections required for permitting. Following the update to the code in 2009 a new energy code enforcement unit has been opened at the Department of Buildings to help meet demand. All plan review is done by Department of Buildings (DOB) but some on-site process inspections are done by third party companies. The DOB maintains a 20% random selection rate for checking compliance. This was highlighted as a significant feature of the revised compliance regimes during the webinar as it is essential for ensuring the quality of the compliance checking and ensuring that no violations have been overlook. Where non-compliance issues that would warrant amendment to the plans are found, the department has the power to place a stop work order on the permit until the compliance issues have been resolved. In the case of a serious breach of compliance, an individual's filing privileges may be removed by the DOB.

One of the significant strengths of the NYC's implementation of the NYCECC has been the development of a well-structured and well resourced compliance regime that includes training for the appropriate stakeholders. The NYC compliance regime is relatively young and as of yet no data is available on whether compliance rates have in fact increased under the new regime, but it will be interesting to see how this progresses.

Conclusions

As we can see from the tool, proper implementation of the building energy code is one of the most difficult aspects of ensuring the effectiveness of the building code. Policy makers are faced with a myriad of challenges when it comes to implementation ranging from disjointed governance structures, under resourced enforcement bodies to a lack of training and education of stakeholders. The key lessons that can be learnt from the best practice regions is the importance of a well structured and well resourced compliance regime that adopts a targeted approach to enforcement and compliance.

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The training and building of capacity amongst key stakeholders including builders and architects is also essential to ensure the skills necessary to implement the codes. If we are to ensure that energy reduction targets are to be achieved, it is important to understand the actual impact of the various policy measures.

The collection of actual measured energy consumption data as part of the compliance regime can help to monitor and evaluate the effectiveness of the measures over time and provide a solid basis for the improvement of future policy measures. It is argued that as we move closer to zero energy the operating characteristics and tenant behaviour become more important than the design components, and in this case it becomes more important to consider the operational performance of the building (Edelson, GBPN Webinar 2, 2013). Another key point from the Swedish case is that by rigidly enforcing the building code developers are more likely to build beyond the minimum standard in order to ensure that they are not at risk of penalisation.

To ensure the full implementation of ambitious policy measures, they must be fully supported by an appropriate compliance regime that incorporates awareness raising, training and development of key staff and that monitors and evaluates the progress measures.

CONCLUSIONS & RECOMMENDATIONS

This paper provides critical insights into some of the current best practices in the development of building energy codes and supporting policy packages globally. The paper draws on the main findings of the GBPN Policy Tool for New Buildings and insights from the webinar series to provide a deeper understanding of the practical aspects of developing best practice building codes. The strengths and weaknesses of the various codes are highlighted to illustrate how other code developers can build on these insights to develop and strengthen progressive buildings codes in the future. It is clear from the research that every jurisdiction has its own specific regional differences but there are a number of key messages that have emerged under the different themes that apply to all jurisdictions irrespective of location or political context.

- Ambitious targets that are supported by realistic roadmaps provide a strong foundation for the development and implementation of progressive policy packages that aim to achieve the abatement potential of the building sector.
- The tool and the webinar series have highlighted the importance of a holistic approach to code design and implementation. Such an approach should combine stringent performance requirements with financial supports, training and awareness raising, and monitoring and evaluation to achieve to achieve targets set.
- The importance of political consensus on the need for imperative action on building energy efficiency cannot be underestimated. It is extremely important to depoliticise this issue and to demonstrate the inherent value for countries or regions in addressing the energy efficiency of the building stock.
- Progressive performance requirements must be fully supported by an appropriate compliance regime that incorporates awareness raising, training and development of key staff and that monitors and evaluates the progress measures.
- It is important to involve all stakeholders in the process and to ensure that a balance is met between the stringency of measures imposed and the mechanisms that are in place to ensure the implementation of the measures.

By continuing to gather and share information on best practice examples it is possible to demonstrate the technical and economic feasibility of such projects and to continue to inspire other jurisdictions to follow suit and implement equally progressive measures. Each jurisdiction is different but the key conclusion is that all jurisdictions can learn from each other and from the valuable insights provided by the GBPN Policy Tool for New Buildings.

Based on this research a number of recommendations can be made to support policy makers in the development of ambitious building energy codes and supporting policy packages:

1. Depoliticise energy efficiency in order to ensure broad political consensus on the importance of such measures.
2. Establish ambitious legally binding targets that are supported by realistic policy roadmaps. Such targets set a goal towards which all activities can be orientated.
3. A holistic approach to code development and implementation is essential if stringent performance requirements are to be achieved. A holistic approach ensures an appropriate balance can be met between "sticks, carrots and tambourines".
4. A robust and well-resourced enforcement regime is crucial for ensuring the implementation of the code. This system should be based on an analysis of where challenges with compliance lie. The compliance regime should also consider actual energy consumption.
5. The up-skilling of stakeholders involved in construction is a key factor in ensuring the success of such a system. This should be taken into consideration as part of any compliance regime.
6. Involve as many stakeholders as possible in the development and implementation of the code to ensure buy in from all parties. Communication should however, be targeted to ensure that key stakeholders are engaged at the critical part of the process.

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About GBPN

The Global Buildings Performance Network (GBPN) is a globally organised and regionally focused network whose mission is to provide policy expertise and technical assistance to advance building energy performance and realise sustainable built environments for all.