ARE WE NATIONALLY CODIFIED?

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Masters of Environmental Studies
Individualized: Environmental Design
Spring 2020

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ABSTRACT

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The United Nations Environment Program (UNEP) declared that building construction, operation and maintenance accounts for 36% of the world's energy use and results in 39% energy-related carbon emissions annually. Buildings therefore provide such an enormous opportunity to conserve resources, reduce pollution, and make our communities more sustainable. Recognizing this opportunity, this paper is a deep dive into the policy trends and current building energy codes nationally towards net-zero and climate change goals. Climate action plans and goals are juxtaposed with their current status and rate of progress, to conduct a gap analysis. This analysis helps explore how close (or far) the regions' current codes are from reaching their net zero and climate action goals. The report concludes with possible future steps to take for each region, state or jurisdiction for a net-zero reality and to reach their proposed climate change goals. The recommendations made thus enable each region, as well as the United States to spearhead the pathway to a carbon neutral future.

1. INTRODUCTION

The science is clear. Communities around the globe are being impacted by climate change. Considered one of the greatest threats of the 21st century, climate change is resulting in an exponential increase of extreme heat waves, droughts, heavy precipitation, flooding, sea-level rise, wildfires and air pollution (Fig. 1).

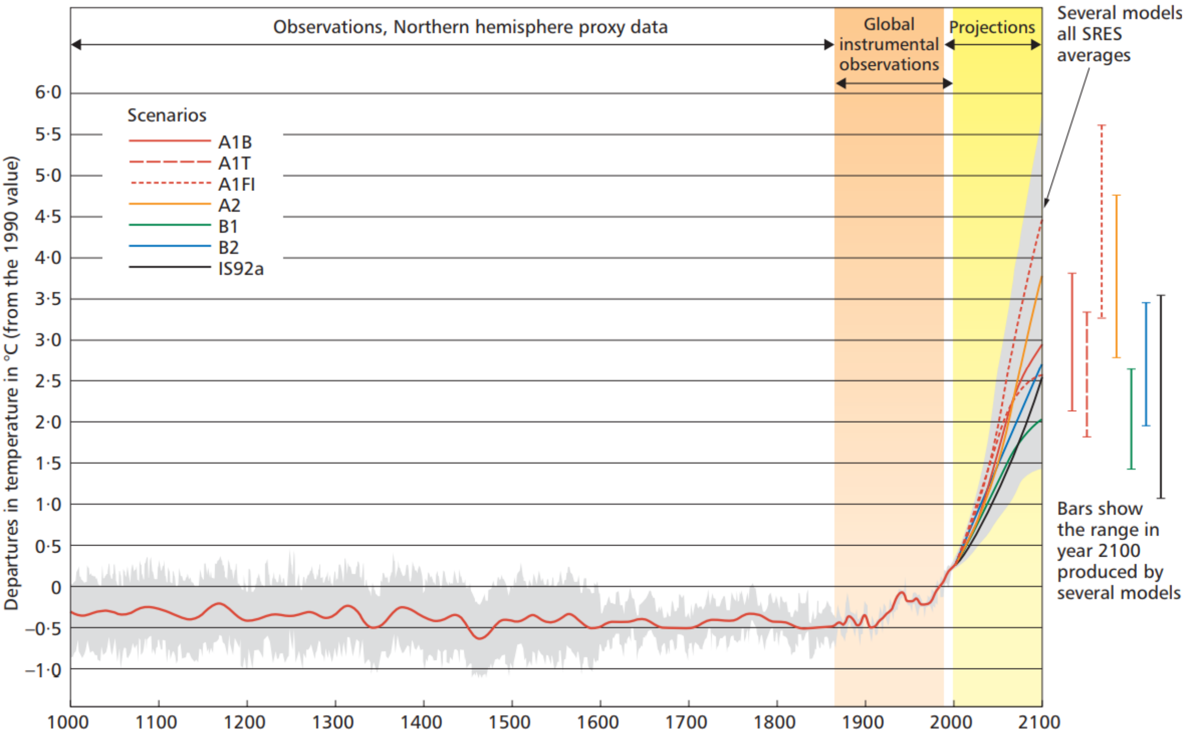

Figure 1: Variation in the earth's temperature from 1000 to 2100 (Source: DOE)

Buildings have extensive direct and indirect impacts on the environment. Buildings use water, energy, raw materials, generate waste, and give out potentially harmful emissions during their construction, occupancy, renovation, repurposing, and demolition. In the United States itself, residential and commercial buildings are responsible for 40% of the total energy consumption (U.S. Energy Information Administration).

Today, the world is undergoing an urban growth wave larger than ever before. About two thirds of the building area that exists today will continue to exist in 2050. The majority of the expected population of 10 billion will be living in cities by 2060. To house this tremendous growth, an additional 2.48 trillion square feet of new floor area is expected to be added to the building stock worldwide by 2060. This is the same as adding an entire New York City every month for 40 years! It is important that net zero standards are met while making way for this new building stock. Currently, building renovations affect only 0.5-1% of the existing buildings annually. A significant increase in the rate of existing building energy efficiency renovations and the generation and procurement of renewable energy is required to meet emissions reduction targets set by the Paris Agreement. These facts have prompted the creation and enforcement of stringent and progressive green building standards, certifications, and rating systems aimed at mitigating the impact of buildings on the natural environment through sustainable design (Architecture 2030).

Renovating an existing structure or building a new facility involves a large amount of construction materials, all of which need to be manufactured and transported to the site. Additionally, it contributes to a plethora of polluting agents throughout its construction as well as operation phase. Buildings provide such an enormous opportunity to conserve resources, reduce pollution, and make our communities more sustainable. Around the country an increasing number of cities, jurisdictions, counties and states are gearing towards better efficiency and creating a framework for greenhouse gas emission reduction goals. Building codes, policies, programs and energy codes are playing an important role in changing the zero-energy building landscape. This study conducted a meta-analysis of the green building codes and standards of progressive regions across the United States – New York, Boston and San Francisco

2. REVIEW OF LITERATURE

2.1. History of Code

In Babylon, during the reign of King Hammurabi in 1758 B.C the first written building code was carved into stone. The code deemed that the designers and builders were to be held accountable for the quality of their work.

Following up, with the great fires in London and Chicago in the years 1666 and 1871 respectively, building codes saw a lot of addressal towards the risk that a structure had to those adjacent to it, and also the public around it. Industrialization and settlements gave rise to dense populations and even denser developments in cities. In order to curb the rising risks that came attached with such close quarters, taller buildings and varying materials with flammable characteristics, new regulations for construction of common walls between buildings were introduced and other risky practices such as wooden chimneys were banned. Additionally, within the construction, codes were introduced or refined to ease the issues of light, ventilation, fire escapes, water supply, sanitary drains, railings and so on.

By 1905, a National Building Code was drafted to reduce the damage risk to real estate and its inhabitants by a U.S. insurance group called the National Board of Fire Underwriters – and it sparked the formation of organizations of building officials. The United States split into three regional code organizations of building officials around the year 1940, and they were coined under the name 'International Code Council (ICC).' They published their first set of codes called "I-Codes" near the end of the 20th Century and they contain the IBC – International Building Code, the IRC – International Residential Code, the IECC – International Energy Conservation Code as well as plumbing, fire and other codes (Eisenberg, 2007).

While most building codes address the minimum requirements that buildings need to meet in order to be built, the Department of Energy (DOE) has also developed additional guidelines for multiple types of commercial buildings that have guidelines known as the Advanced Energy Design Guides (AEDG) for achieving 50% energy savings compared to the minimum building codes (ASHRAE Standard 90.1-2004). The four North American professional organizations lead this development with the DOE. By 2013, the AEDGs expanded to cover small to medium office buildings, K-12 school buildings, medium to big box retail buildings as well as large hospitals.

2.2. Introduction to Code

As per the International Code Council's (ICC) assessment, thirty years from 2010, in 2040, the model energy codes for commercial and residential buildings will save –

- $126 billion in energy cost
- 841 MMT of CO_2 emissions
- 12.82 quads of primary energy

These savings equate to the annual emissions of –

- 177 million passenger vehicles
- 245 coal power plants
- 89 million homes

The energy efficiency of a building aims for adequate energy savings with optimum comfort conditions in mind. It is two-fold when viewed from the lens of sustainable development – the primary resource economy and reducing the emissions to the environment. While energy efficiency has always been present as a dormant entity, during the advent of the 19th century, awareness within the main sciences took a sensitive differentiation path that is now present today. While terminology might not have been as clear in the previous centuries, and people were not aware of terms like 'energy efficiency' there has been an unbroken chain from generation to generation of good practice codes. By the 20th century, with the help of media and standardization and enforced regulations the importance of energy efficiency was imprinted into the masses. It was not long before energy concerns and sustainable concepts infiltrated more areas of science and technology.

With the generations, and passing time, the codes evolved with new discoveries (whether it was new techniques of construction or new materials) and new expectancies and exigencies – to assist human needs better. Building and energy codes are topics of interest for governments and political sphere as they attempt to curb inefficient energy consumption techniques and cut their greenhouse gas emissions (Ionescu, Baracu, Vlad, Necula, & Badea, 2015).

2.3. Energy Codes

Energy codes do not just focus on efficiency. As stated earlier, they also affect and manage the interior comfort conditions. The codes affect moisture and therefore control rot, mold and mildew. The codes affect the air quality, fire safety and ultimately affect the resiliency of a structure. They work to first and foremost make a building safe, and then to make it comfortable for its inhabitants by addressing moisture management, indoor air quality, fire safety and extreme temperature and storms.

An extensive process is the precursor to every upgrade to the energy code. There is a developmental method that involves large consensus by professionals in building durability and science. This includes builders, architects, engineers, code officials and so on – people that are invested in the sustainability of the built environment and the well-being of its occupants – who both devise, utilise and enforce it upon themselves and each other. This code is the lowest standard – or the absolute minimum that needs to be incorporated into the buildings for them to be acceptable. It should be pointed out that each upgrade is an improvement to the existing code – to make it more stringent and also to introduce further safeguarding rules that were not present before. The codes are equipped to construct safe, resilient and habitable spaces and do so with the principles of physics for heat, air and moisture transfer (Brinker, 2018).

2.4. International Energy Conservation Code (IECC)

The International Energy Conservation Code (IECC), was created by the International Code Council in 2000 and they are updated and published every three years.

The need for a modern, up-to-date energy conservation code that sheds light on sustainable building envelopes and energy efficient HVAC systems that optimise performance has always been known by code officials. The IECC is therefore developed to meet these requirements with the use of code regulations that will result in a sustainable use of fossil fuels as well as renewable resources amongst all spheres or regional communities.

Separate attention is given to both commercial and low rise residential buildings – which are deemed to be three stories or less in height above grade – and each set of model codes are applied to buildings within those respective scopes. They are called the IECC – Commercial Provisions and the IECC – Residential Provisions.

The IECC – Residential Provisions are nationally adopted. The codes also cover existing buildings and address any additions, repairs, alterations or change of use.

These codes comprehensively outline the bare minimum regulations for energy efficient buildings using both prescriptive and performance related benchmarks and standards. They extend to include broad categories such as the possibility of use of new materials and energy efficient designs. The IECC is compatible with the Family of International Codes – a set of fifteen coordinated, modern building safety codes that help ensure the engineering of safe, sustainable, affordable and resilient structures.

The IECC codes include:

- **Conservation:** It has a proven track record of addressing energy efficient system installations for designing energy efficient building envelopes.
- **Ease of Use:** By following a uniform language in all their I-Codes, IECC makes it easy to understand and transition between codes.
- **Embrace of New Technology:** While prioritising the safety and well-being of the public, IECC continues to innovate and embrace new technology.

- **Correlation:** The ICC's family of codes can be easily correlated and used with the IECC.
- **Open and Honest Code Development Process:** Drawing expertise from a highly revered consensus of hundreds of building, plumbing and safety experts across North America, the codes are revised as part of a three-year cycle with the highly respected consensus code development process.

In June 2018, a unanimous conclusion was reached at the United States Conference of Mayors that supported the IECC as a cost-effective and sustainable strategy to reduce greenhouse gas emissions from buildings and lower energy waste. These energy efficiency codes have saved U.S. consumers over $44 billion and reduced 36 million tons of carbon dioxide emissions as of 2018. Fig. 2 shows the nationwide adoption of IECC.

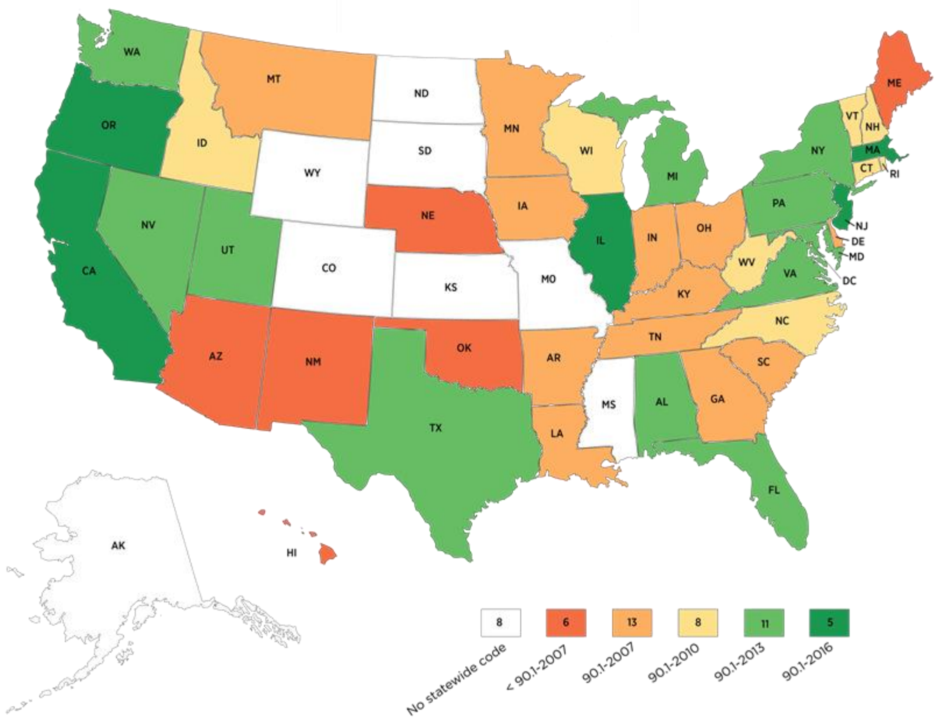

Figure 2: Adoption of IECC nationwide (Source: DOE)

The setting of sustainability standards that promote energy efficiency and prevent wasteful behaviour helps shape the buildings to be safer and more resilient. In an obvious chain of events, the carefully outlined guidelines and standards help prevent condensation that gives rise to structural rot. Additionally, the mold and mildew have an adverse effect on human health. Poorly circulated air can cause a build-up of harmful chemicals, cause respiratory ailments within its inhabitants and even show signs of sick building syndrome. Any internal renovation projects that cause build-up of VOCs which are often present in paints, finishes and other building materials (ref). Apart from gradually worsening threats, a large chunk of inhabitant safety that is put at risk due to poor ventilation or hermetically sealed environments can be attributed to fire and smoke safety. The codes also promote resiliency by creating an envelope that can withstand extreme temperatures allowing a sort of shelter for its occupants. A good example of this is *Superstorm Sandy*, which left 8 million people stranded without electricity, but allowed them to survive in their homes during blackouts triggered by heat waves or cold freezes.

> "Energy efficiency is as important today as it was 20 years ago. Our building codes play an integral role in helping communities save money and reduce waste. The IECC helps home builders, developers, architects, engineers and others in the building industry produce the quality buildings that consumers today want, taking into account energy efficiency and the latest building science." - Code Council Chief Executive Officer Dominic Sims, CBO.

2.5. Evolution of IECC

For the first twenty years, the Model Energy Code (MEC) and two sequential versions of the IECC barely made a dent in energy savings. However, between 2009 and 2012, these codes that previously showed 1%-2% of the gains in efficiency suddenly showed a 30+ percent energy efficiency boost. This was all due to the Energy Efficient Codes Coalition (EECC) that convened all the influential and influenced organizations such as government, business leaders, regional energy efficiency alliances, academics, utilities, think tanks, conservation groups, low-income housing groups, and energy consumers to support an increase in energy efficiency saving codes (Fig. 3).

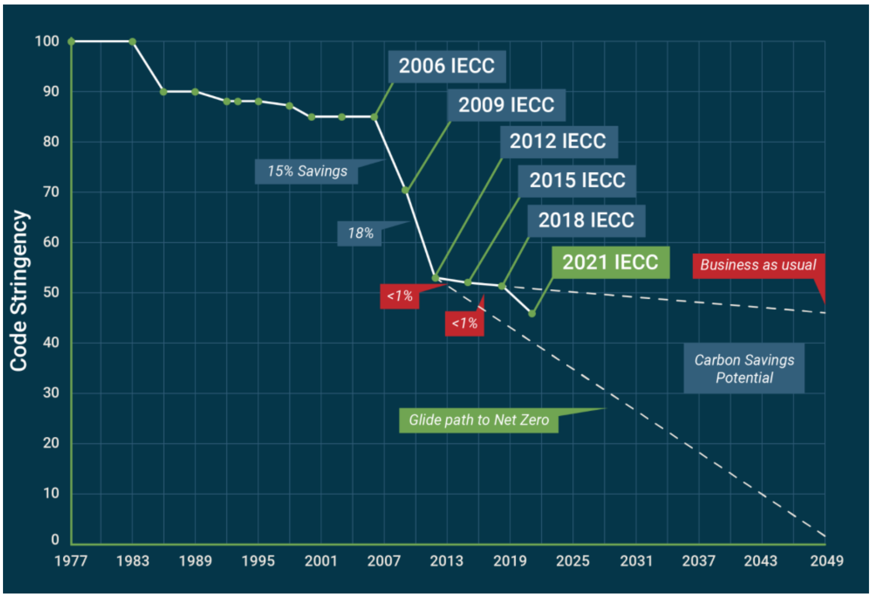

Figure 3: Efficiency improvement of IECC: Historic and projected (Source: ICC)

However, beginning in 2015 there was a halt in this progressive energy movement by anti-efficiency lobbyists during both the code cycles of 2015 and 2018, costing home and business owners thousands in lost revenue due to the weaker standards that are no longer feasible in terms of energy efficiency (Energy Efficient Codes Coalition).

3. METHODS

This study analyzed the policy trends and current energy/building codes at the national level towards net-zero and climate change goals. Current codes were explored to determine how far they are from reaching their net zero and climate change goals. There are three phases to the study:

Phase 1: Provides a brief history and background of building codes, with a focus on energy codes and IECC. The evolution and adaptation of these codes throughout the nation are examined.

Phase 2: City-specific analysis of building codes was performed, taking a deep dive into what codes are currently adopted in each city, their specific climate action plans and net zero goals and pathways. Finally, a gap analysis was conducted to determine where each city stands with respect to their 2030 goals. A model from Energy Efficient Codes Coalition's (EECC) 'Carbon Emission Calculator' was used to determine the projected emissions avoided in two scenarios:

- *Current Trend* – This accounts for the projected emission reduction when the city updates codes as per its current climate action goals and net zero pathways.
- *Aggressive Trend* – This accounts for the projected emission reduction when the city is made to aggressively remodel its policies to align with every new update of the energy code immediately.

Calculations were based on the assumptions for projected energy savings for future model energy codes (Table 1).

Table 1: Percentage savings over previous code with each code update.

Residential		Commercial	
IECC 2015	0.9%	ASHRAE 90.1-2013	8.7%
IECC 2018	0.5%	ASHRAE 90.1-2016	13.9%
IECC 2021	5%	ASHRAE 90.1-2019	5%
IECC 2024	5%	ASHRAE 90.1-2022	5%
IECC 2027	5%	ASHRAE 90.1-2025	5%
PassiveHouse	50%	PassiveHouse	40%

The percent reduction was calculated for emissions in previous years as well as projected emissions up to 2030. This was based on the results obtained in both the current and aggressive code adoption scenarios.

<u>Phase 3</u>: In the last segment of this study, the results obtained in Phase 3 for each city are discussed and compared in an effort to infer factors that might inform the results. A detailed set of recommendations are then listed to aid the cities, as well as the United States develop a toolkit to spearhead the pathway to a carbon neutral future.

4. CITY-SPECIFIC ANALYSIS

The United States does not have a unified, national building code. The Energy Policy and Conservation Act of 1975 (EPCA, 42 USC 6833) and the Energy Policy Act of 1992 (EPAct) defined a role for the Department of Energy (DOE) to develop and model building codes and conduct code determinations. However, this is the extent of DOE's involvement into building energy codes, apart from providing modelling analysis and support to other building organizations in North America. The DOE cannot enforce building energy codes nationwide.

Therefore, the effectiveness and potential of the codes are in the hands of state regulations. The policies and programs within a state are critical to the success of the energy efficiency codes. The states are therefore also a steppingstone to a national building code, should it ever be developed. They are testing spaces as they adopt stricter standards or struggle to meet certain efficiency standards. Code compliance is key to the success of building codes and lead to better building performance.

This study examined the building energy codes and practices in three progressive cities spread across the United States – New York, Boston and San Francisco.

4.1. New York

The megacity of New York has a population of over 8.6 million living in 1 million buildings, and has to contend with a plethora of building and infrastructure specific concerns. With their massive public infrastructure, a highly efficient mass transit system, dense living patterns, and capability for civic innovation, they are uniquely positioned and determined to be at the forefront of the world's sustainability movement. An improvement in energy efficiency of buildings will help address the growing shares of New Yorkers that are hit by the housing crisis. The unexploited energy-saving potential of the city's public housing can serve as respite to the rent-burdened locals. Such energy efficient investments in the building stock will aid the advancement of thousands of New Yorkers by opening doors to new job opportunities and stimulating economic activity whilst creating a healthier and more sustainable home to all.

Since buildings contribute to three quarters of New York's greenhouse gas emissions, the building sector plays an instrumental role in achieving its climate change goals. Today, New York City has already achieved 19% reduction in emissions from 2005 levels. ACEEE ranks New York City number 6 out of the 75 cities on their Clean Energy Score Card. Committed to advancing this number; New York has equipped itself with the necessary tools and resources (Slavin, 2004).

4.1.1. Codes Adopted

As of 2019, New York has adopted the following codes in the building sector:

- 2015 International Energy Conservation Code (IECC) with amendments

- 2009 International Building Code (IBC) with amendments
- 2015 International Existing Building Code (IEBC) with amendments
- ASHRAE 90.1-2016
- 2015 International Residential Code (IRC) with amendments
- 2009 International Mechanical Code (IMC) with amendments
- New York City Energy Conservation Code (NYCECC)

Now, together with being solar ready, new family homes will be about 32% more efficient and new commercial buildings will be about 9% more energy efficient. Conducting energy audits, benchmarking and deep energy retrofits every ten years has become mandatory for all privately owned buildings that are over 50,000 sq. feet. Sub meters must be installed for large commercial tenants and lighting upgraded in all non-residential buildings. The NYC Clean Heat program led the city to the best air quality that it has seen in 50 years. This is a result of enacting laws that enforce the phasing out of heavy fuel oils in buildings.

New York City has developed The NYStretch Energy Code 2020 as an instrumental tool for New York jurisdictions to back the State's energy and climate goals by enhancing the savings obtained through their local building energy codes. The code is scheduled to be adopted across the city from May 2020. While it is not mandatory, NYStretch Code can be adopted state wide as a model code that will serve as a more stringent standard to save energy.

4.1.2. Climate Change Goals

In line with the United Nation's target, New York City has assured a reduction of greenhouse gas emissions by 80% in the year 2050. As of today, the megacity is said to be on track to reduce its overall emissions by 40% by 2030. The city council put more stringent caps on the carbon emissions for buildings greater than 25,000 sq. feet, requiring them to come to a 40% overall drawdown in their emissions by 2030. 70% of the state's power must be generated from renewable resources by 2030.

In March 2014, the Office of Recovery and Resiliency (ORR) was created, making New York the first city agency in the country dedicated solely to resiliency. With its 257 initiatives to make the communities and infrastructure of the city more resilient, ORR is implementing the strategies laid out in 'PlaNYC: A Stronger, More Resilient New York.'

New York’s Green New Deal was another audacious step towards tackling climate change that is expected to bring about an additional 30% reduction in carbon emissions by 2030. 14 billion dollars are dedicated to this strategy, for:

- Shifting 100% of national power generation to renewable sources.
- Building a national energy efficiency smart grid
- Enhancing the energy efficiency of existing buildings and ensuring that new construction meets and exceeds the required standards of energy efficiency
- The decline of toxic greenhouse gases

Fig. 4 shows the city’s energy efficiency savings achievable potential by end use. In this way, the Green New Deal helps in creating jobs for technicians installing solar panels, electricians upgrading buildings, engineers designing smart grid solutions, and pipefitters upgrading water infrastructure. The plan includes investments in affordable housing and municipal infrastructure, which will be especially important to revitalizing urban communities and creating jobs across the country (One NYC, City of New York).

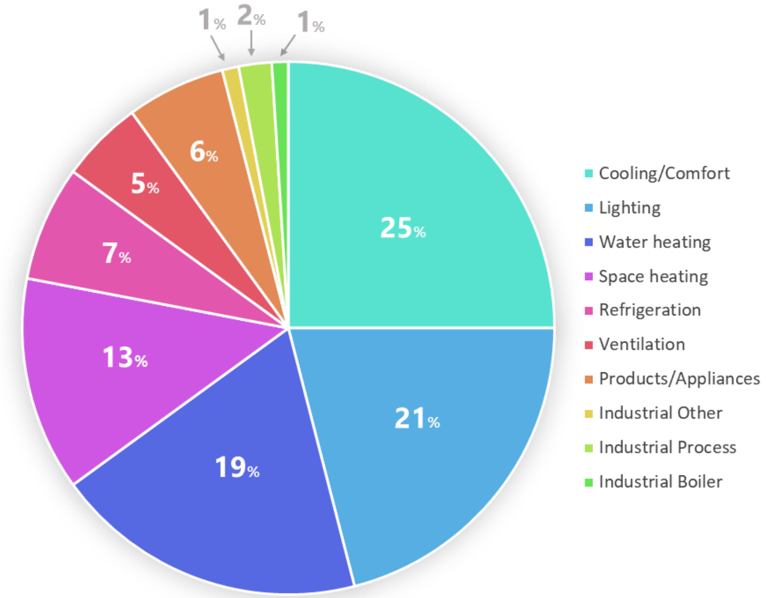

Figure 4: Energy efficiency achievable savings potential by end use

4.1.3. Net Zero Goals and Pathways

As a requirement of the Climate Leadership and Community Protection Act, the state targets to cut its global warming pollution 85% below 1990 levels by 2050, and offset the remaining 15%, possibly through measures like carbon offsets, to remove carbon dioxide from the atmosphere.

To achieve this 85% reduction, by 2025:

- City owned buildings with significant energy usage that show complete improvements in efficiency and the installation of 100MW of onsite renewable energy.
- New construction projects implemented cost effectively, using Passive House, net zero energy, carbon neutral strategies and the like to inform their standards and promote leading edge construction.
- Developing and meeting intermediate energy targets for existing facilities by voluntary reductions or new regulations like performance standards and measure-based targets that can be triggered when the reductions achieved are not sufficient.

Additionally, 100% clean energy resources should be ensured, for establishing direct connections with large scale renewable resources and scaling clean distributed energy and load management for efficient distribution. All new buildings must be required to be built to net zero energy to further pursue deep cuts in emissions and citywide energy efficiency mandates must be laid down. Programs like the Property Assessed Clean Energy (PACE) financing must be made available in New York City along with other financial incentives for the same.

4.1.4. Gap Analysis for 2030

With a clearer idea of New York's climate action plan and net zero pathway, a gap analysis was conducted keeping in mind the city's current trend of energy code implementation, as well as the case of applying more aggressive code changes (NYC Mayor's Office of Sustainability).

New York City expects an emission reduction of 40% from 2005 levels by 2030. Using Energy Efficient Codes Coalition's 'Carbon Emission Calculator', the following results were obtained in each of the two cases (Table 2).

4.1.4.1. Current Trend:

Table 2: State code updates (current trend)

Projected Residential Energy Code	Projected Effective Date	Code Compliance Rate
IECC 2015	Current	75%
IECC 2018	2020	75%
IECC 2021	2023	75%

Projected Commercial Energy Code	Projected Effective Date	Code Compliance Rate
ASHRAE 90.1-2016	Current	75%
ASHRAE 90.1-2016	2020	75%
ASHRAE 90.1-2019	2023	75%

Emissions avoided from 2005 – 2019 ($MTCO_2e$) = 8,182,904
Emissions avoided from 2020 – 2030 ($MTCO_2e$) = 791,285
Percentage reduction of metric tonnes of CO_2e in 2030 from 2005 levels = 23%

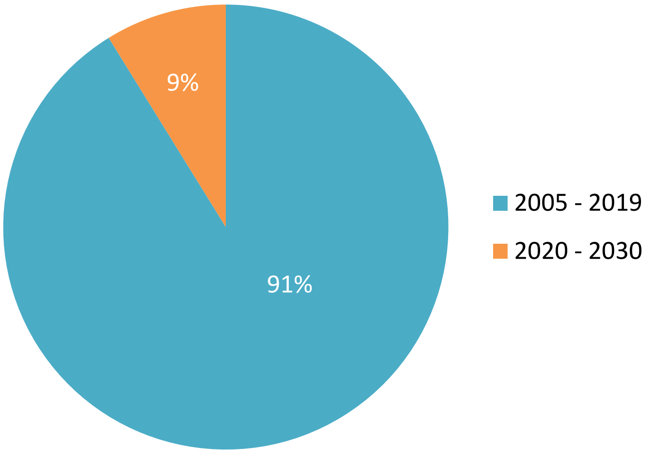

Figure 5: Amount of CO_2 avoided in New York City

Fig. 5 shows the massive fall in metric tonnes of carbon emissions avoided in more recent years.

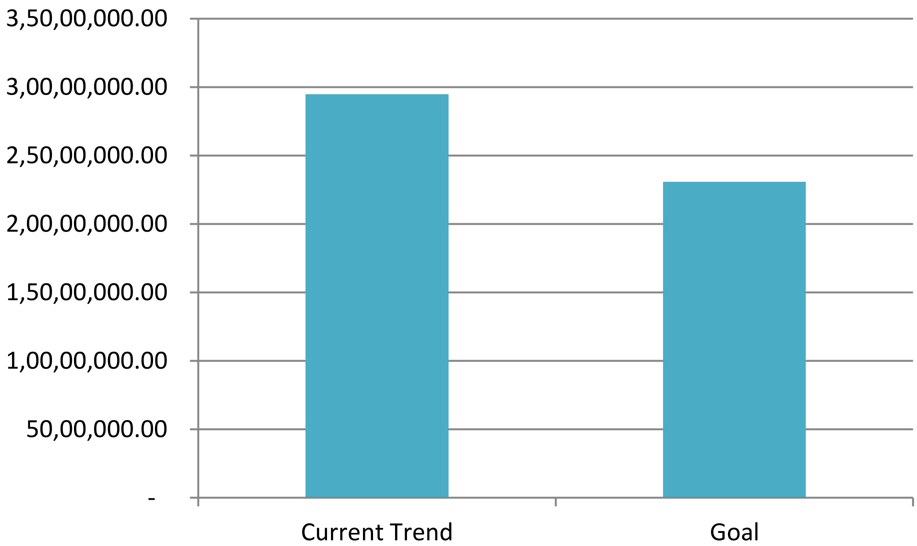

Figure 6: CO_2 levels in 2030 ($MTCO_2e$)

Based on the current trend of codes adopted in New York, the building sector contributes to a 23% reduction in carbon emissions by 2030, from 2005 levels. Fig. 6 shows how the projected CO_2 levels of the building sector are short about 6 $MMTCO_2e$ from the city's total emission reduction goals.

4.1.4.2. Aggressive Code Adoption:

Table 3: State code updates (aggressive trend)

Projected Residential Energy Code	Projected Effective Date	Code Compliance Rate
IECC 2015	Current	75%
IECC 2018	2020	75%
IECC 2021	2021	75%
IECC 2024	2024	75%
IECC 2027	2027	75%
PassiveHouse	2030	75%
Projected Commercial Energy Code	Projected Effective Date	Code Compliance Rate
ASHRAE 90.1-2016	Current	75%
ASHRAE 90.1-2019	2020	75%
ASHRAE 90.1-2022	2021	75%
ASHRAE 90.1-2025	2024	75%
PassiveHouse	2027	75%
PassiveHouse	2030	75%

Emissions avoided from 2005 – 2019 ($MTCO_2e$) = 8,182,904
Emissions avoided from 2020 – 2030 ($MTCO_2e$) = 1,468,798
Percentage reduction of metric tonnes of CO_2e in 2030 from 2005 levels = 25%

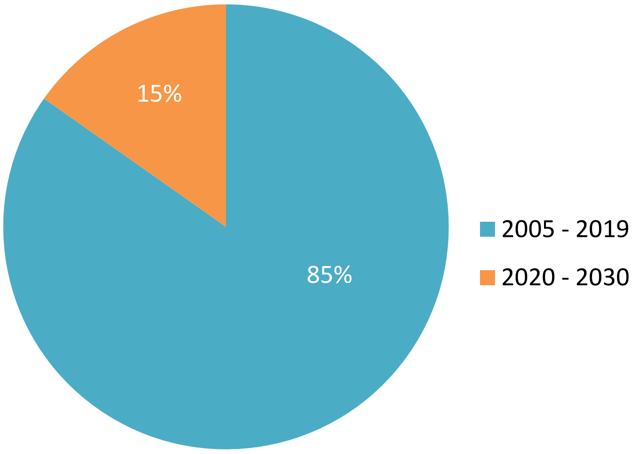

Figure 7: Amount of CO_2 avoided in New York City

Even with the implementation of aggressive code adoption strategies in the future, the projected amount of emissions avoided are merely 18% of the emissions avoided from 2005 to 2019 (Fig. 7).

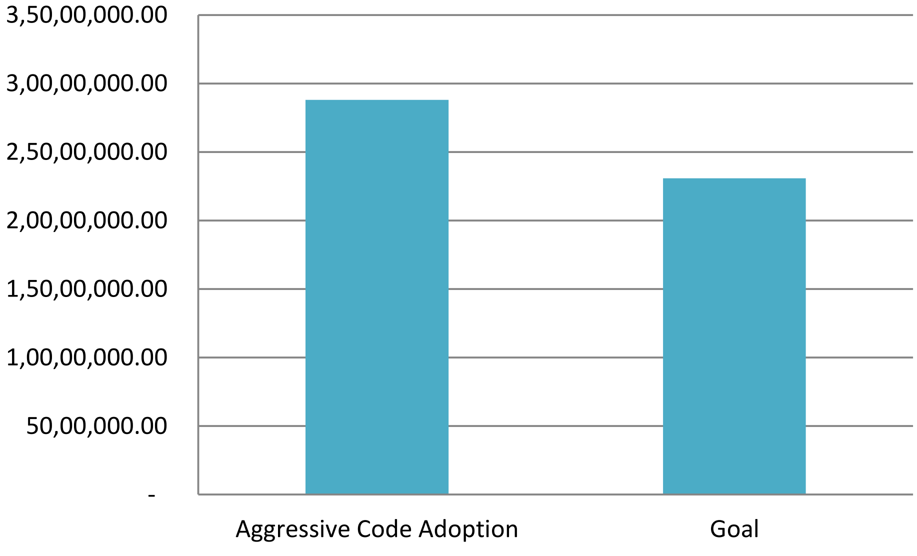

Figure 8: CO_2 levels in 2030 ($MTCO_2e$)

A projected CO_2 emission reduction of 25% is seen by 2030, from 2005 levels (Fig. 8). Aggressive code adoption resulted in an additional 2% decrease in emissions in the building sector as compared to the current trend.

4.2. Boston

Boston is home to over 86,000 buildings, which house a population of over 4.6 billion and are spread over more than 647 million sq. feet of area. With their diverse range of uses, this building stock strongly impacts the energy usage of the city. In fact, the building sector accounts for 71% of Boston's total greenhouse gas emissions. In the middle of a building boom, Boston is quickly expanding both its commercial and residential space and transforming neighbourhoods across the city. Since a great part of its residences were built before the establishment of the first building codes, they are not as well-insulated and airtight as the new building stock. They use older, less efficient equipment and result in greater energy usage and greenhouse gas emissions (Carbon Neutral Boston 2019).

The city began to update its Climate Action Plan in 2007, to reduce emissions and prepare for climate change. In 2017, its emission reduction goals were made more stringent, to achieve carbon neutrality. The latest 2019 update laid down a work plan for the next five years, to tread on the path of carbon neutrality. Today, the climate in Boston has undergone considerable change. Every Bostonian now lives within 10 minutes walking distance from a high quality public park. The Building Energy Reporting and Disclosure Ordinance (BEDRO) require all buildings in Boston that are over 35,000 sq. feet or have more than 35 units to report their energy and water usage to the city annually. Further, every five years the buildings must have demonstrated certain changes to obtain a 15% reduction in emissions or have a detailed study of options that aid the same. All municipal new construction and major renovation must achieve LEED Silver Certification and exceed baseline energy performance by 14% and 7% respectively. In such a scenario, Boston has made its way to the top of the ACEEE's Clean Energy Scorecard.

For space heating, cooling and hot water, the buildings of Boston rely heavily on the combustion of oil and natural gas. Therefore, a combination of low to zero greenhouse gas fuels and electricity and building efficiency should be used to tackle the issue. Fig. 9 shows a comparison of the proportion of greenhouse gas emissions from residential and commercial buildings by end use in 2015. It is much easier to control these factors in new construction while existing buildings pose a greater challenge. These existing buildings will continue to occupy 85% of Boston's projected building area in 2050 (Boston's Climate Action Plan, 2019).

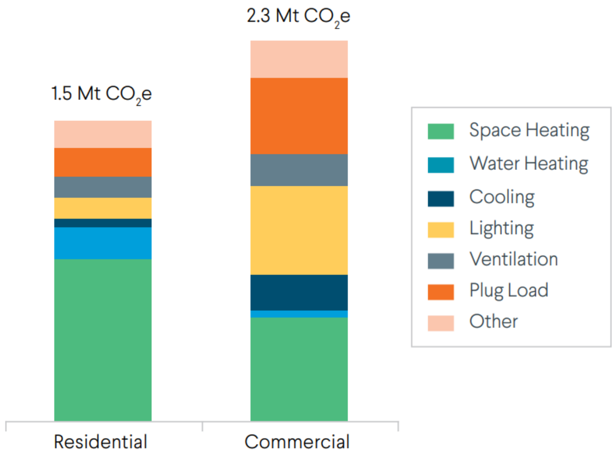

Fig. 9: Comparison of the proportion of greenhouse gas emissions from residential and commercial buildings by end use in 2015 (Source: Carbon Free Boston, 2019)

4.2.1. Codes Adopted

As of 2019, Boston has adopted the following codes in the building sector:

- 2015 International Energy Conservation Code (IECC) with amendments
- The Massachusetts State Building Code – 780 CMR
- 2015 International Existing Building Code (IEBC) with amendments
- ASHRAE 90.1-2016
- 2015 International Residential Code (IRC) with amendments
- 2015 International Mechanical Code (IMC) with amendments
- 2017 Mass Stretch Energy Code

Massachusetts became the first state to adopt a Stretch Code – a beyond-code appendix to the base building energy code. The stretch code is designed to bring about more cost-effective, energy efficient construction than the construction that results from the base energy code. It emphasizes the energy performance of the building. As of 2016, 186 cities in Massachusetts have adopted the stretch code, Boston included.

4.2.2. Climate Change Goals

As per the most recent revision of Boston's Climate Action Plan, the city has pledged to reduce communitywide greenhouse gas emissions by 50% below 2015 levels by 2030 and 80% by 2050.

Boston will work with state, regiona,l as well as local partners to accelerate a building sector-wide shift towards energy efficiency and fossil free building systems. State level policies will be advocated, including that of a zero net carbon (ZNC) building code and financial incentives to support this green movement. To decarbonise existing large buildings, a carbon emissions performance standard must be developed, focussing on:

- 100% reduction in yearly carbon emissions from large buildings in 2050
- 100% of buildings covered by the standard complete alternate compliance methods if have not reached their carbon emission goal
- Expanding mechanisms to finance retrofits, including exploring the possible creation of a local climate bank
- Guidance for deep energy retrofits and electrification must be developed, keeping in mind the historic portion of Boston’s building stock
- Working on improving energy efficiency even in buildings that are not covered by the standard

Fossil fuels dominated total energy use in 2015 and with goals of transitioning to clean energy in 2050, little energy is wasted (Fig. 10).

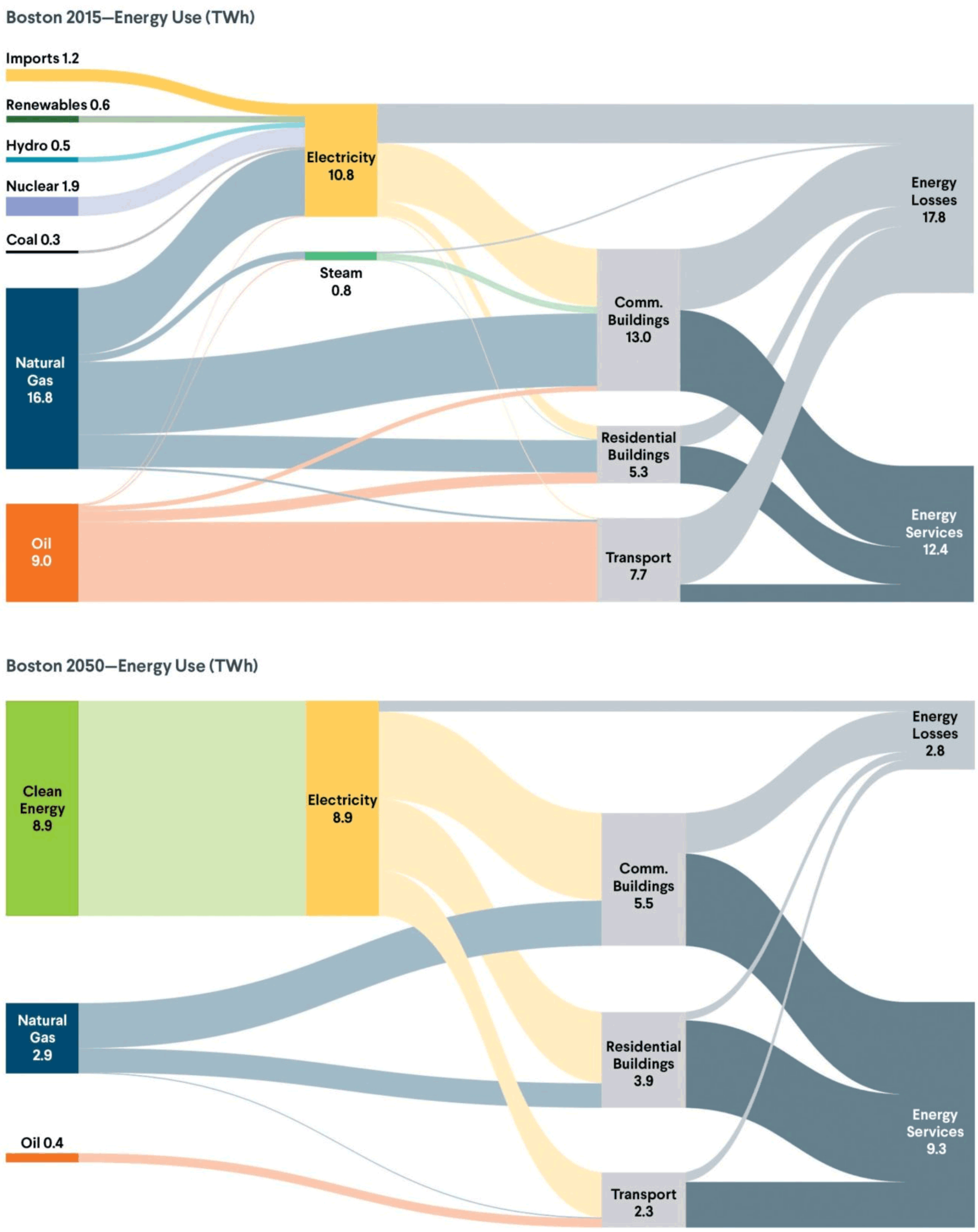

Fig. 10: Current energy use (above) and future energy use (below) in Boston (Source: Carbon Free Boston, 2019)

4.2.3. Net Zero Goals And Pathway

By 2050, Boston will establish state building policies that align with carbon neutrality. 100% of electricity bought will be carbon free. In this timeline, Boston is expected to add 112 million sq. feet of new construction that will satisfy the zero net carbon or carbon positive standards. The Carbon Free Boston Report of 2019 states that adoption of net zero carbon for new construction by 2030, and at least 80% of the existing building sector by 2030 are essential steps towards achieving this goal. Four out of every five buildings will need to implement deep energy retrofits and electrification by 2050 for Boston to reach carbon neutrality. As per Carbon Neutral Boston, all new publically funded affordable housing built after 2020 must be ZNC or NC ready. A 19% reduction in annual building emissions is expected from business as usual with the strengthening of building zoning requirements with net zero standards.

To achieve carbon neutrality, almost all existing buildings will need to undergo deep energy retrofits that are not fragmented, but designed for the building as a whole. Net zero buildings should be inclusionary and affordable. In this process, attention should be paid to the vulnerability of populations that might not be able to afford such an upgrade, will not be able to reap benefits of low utility bills and might have to be relocated to make space for higher cost dwelling units. To stimulate development along with achieving these objectives, the city must have programs that provide technical and financial support, workforce training and deployment of technology. When these programs work in coordination with perfectly timed building performance standards and regulations, the market will be driven to fully transform the building stock. The Board of Building Regulations and Standards (BBRS) approves a Zero Net Carbon stretch Code that allow municipalities in the state to adopt net zero policies for all new construction.

As part of Carbon Neutral Boston 2019, new municipal buildings must be constructed to net zero standards and should be using either ZNC on site, ZNC offsite or be ZNC ready or ZNC convertible. This will result in:

- Avoiding up to 17,000 tonnes of carbon emissions from municipal activities
- Better, healthier environments as a result of improving air quality around buildings
- Setting an example in the neighbourhoods with ZNC standards

4.2.4. Gap Analysis For 2030

Keeping in mind Boston's 2030 goal of reducing communitywide emissions by 50% from 2015 levels, the following calculations were carried out in each scenario:

4.2.4.1. Current Trend:

Table 4: State code updates (current trend)

Projected Residential Energy Code	Projected Effective Date	Code Compliance Rate
IECC 2015	Current	75%
IECC 2018	2020	75%
IECC 2021	2021	75%
Projected Commercial Energy Code	**Projected Effective Date**	**Code Compliance Rate**
ASHRAE 90.1-2016	Current	75%
ASHRAE 90.1-2016	2020	75%
ASHRAE 90.1-2019	2021	75%

Emissions avoided from 2009 – 2019 (MTCO_2e) = 950,602
Emissions avoided from 2020 – 2030 (MTCO_2e) = 344,074
Percentage reduction of metric tonnes of CO_2e in 2030 from 2015 levels = 15%

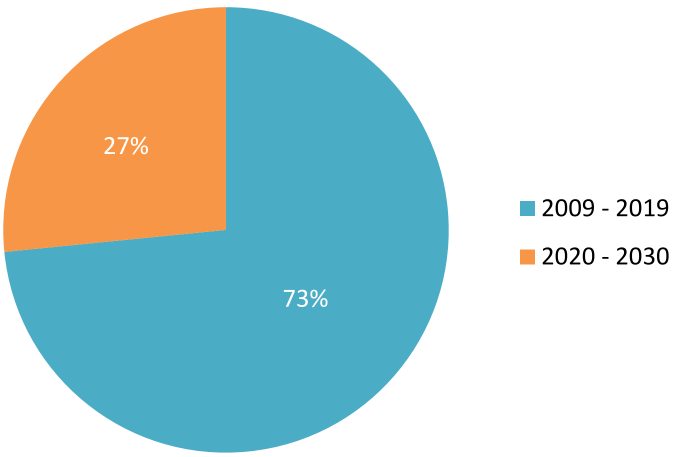

Figure 11: Amount of CO_2 avoided in Boston

The metric tonnes of carbon emissions avoided in more recent years (2020 – 2030) are projected to be nearly 3 times more than that in the last ten years (2009 – 2019) (Fig. 11).

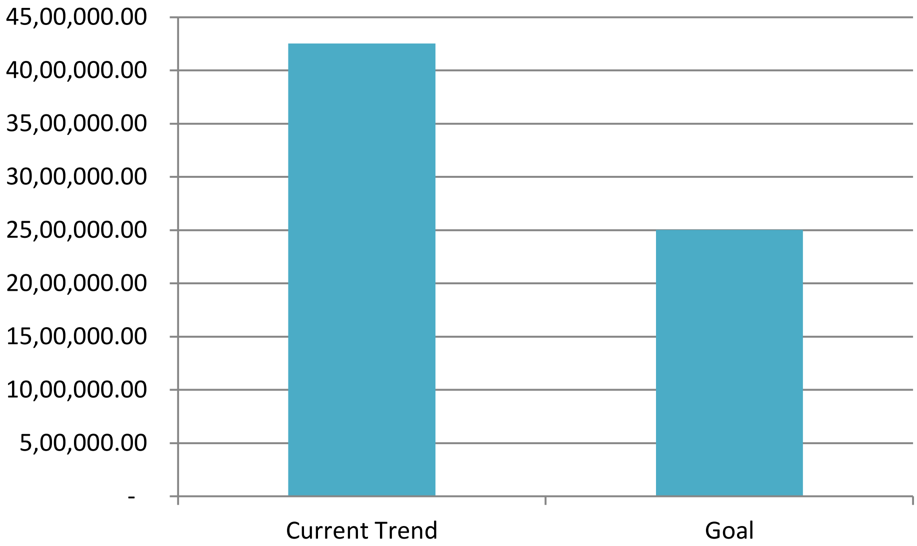

Figure 12: CO_2 levels in 2030 ($MTCO_2e$)

Based on the current trend of codes adopted in Boston, the building sector contributes to a mere 15% reduction in carbon emissions by 2030, from 2015 levels. Fig. 12 shows how the projected CO2 levels of the building sector are short of almost 2 MMTCO2e from the city's total emission reduction goals.

4.2.4.2. Aggressive Code Adoption:

Table 5: State code updates (aggressive trend)

Projected Residential Energy Code	Projected Effective Date	Code Compliance Rate
IECC 2015	Current	75%
IECC 2018	2020	75%
IECC 2021	2021	75%
IECC 2024	2024	75%
IECC 2027	2027	75%
PassiveHouse	2030	75%
Projected Commercial Energy Code	Projected Effective Date	Code Compliance Rate
ASHRAE 90.1-2016	Current	75%
ASHRAE 90.1-2016	2020	75%
ASHRAE 90.1-2019	2021	75%
ASHRAE 90.1-2022	2024	75%
ASHRAE 90.1-2025	2027	75%

PassiveHouse	2030	75%

Emissions avoided from 2009 – 2019 (MTCO$_2$e) = 950,602
Emissions avoided from 2020 – 2030 (MTCO$_2$e) = 456,333
Percentage reduction of metric tonnes of CO$_2$e in 2030 from 2015 levels = 17%

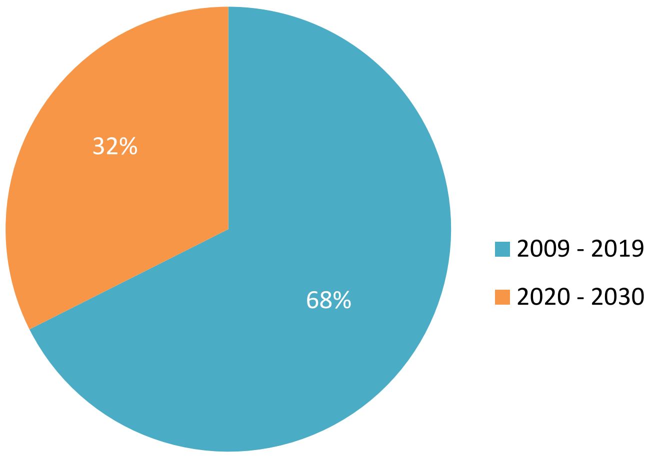

Figure 13: Amount of CO_2 avoided in Boston with aggressive code adoption

Even with the implementation of aggressive code adoption strategies, no major change is seen in the emission reduction during 2020 - 2030 as compared to that during 2009 – 2019 (Fig. 13).

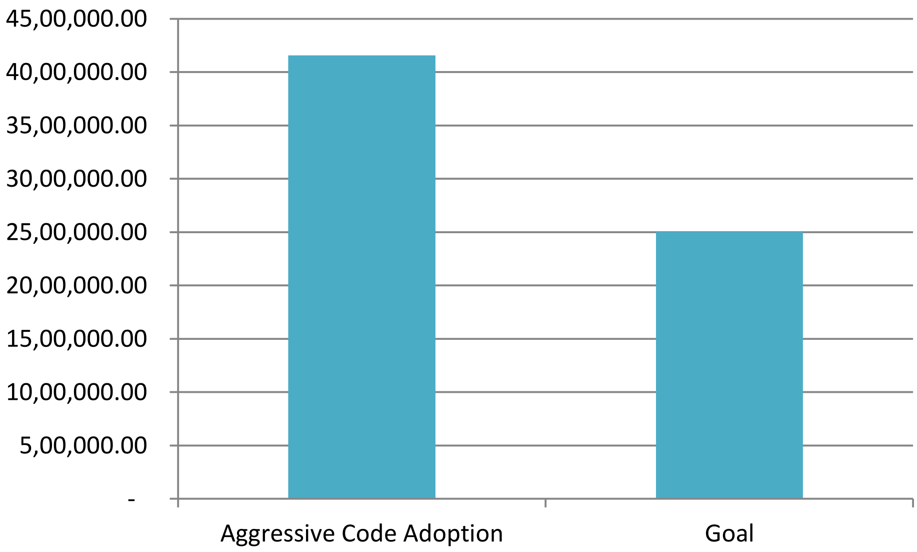

Figure 14: CO_2 levels in Boston 2030 (MTCO$_2$e)

A projected CO_2 emission reduction of 17% is seen by 2030, from 2015 levels. Aggressive code adoption resulted in an additional 2% decrease in emissions in the building sector as compared to the current trend (Fig. 14).

4.3. San Francisco

Since San Francisco's first Sustainability Plan in 1996, the city has been a forerunner in keeping up with climate change, making bold moves to protect the environment and cut down emissions. Every year, San Francisco adds about 4.5 million sq. feet of new buildings. Progressive green building codes lead to the construction of over 133 million sq. feet of LEED certified buildings between 2004 and 2016. The San Francisco Bay Area Regional Energy Network programs resulted in a collective reduction of electricity usage by 200 GWh since 2013, accounting for about 3.7 million dollars in energy savings. These early efforts played a part in reducing San Francisco's building sector emissions to just 44% by 2017. In the same year, the city outshined its 25% greenhouse gas reduction goals by dropping their emissions 36% below 1990 levels.

Most of the emissions come from the use of energy for space conditioning and water heating while electricity for lighting, plug loads and mechanical purposes accounted for less than 20% of total building emissions (Fig. 15).

Today, even with a rapidly increasing rate of build out and the increased use of electricity that come with personal electronic devices, the city has managed to cut building emissions by 51% from 1990 levels (Focus 2030, 2019). ACEEE's Clean Energy Score Card positions San Francisco at the second rank out of a total of 75 cities based on its progressive and energy efficient strategies communitywide.

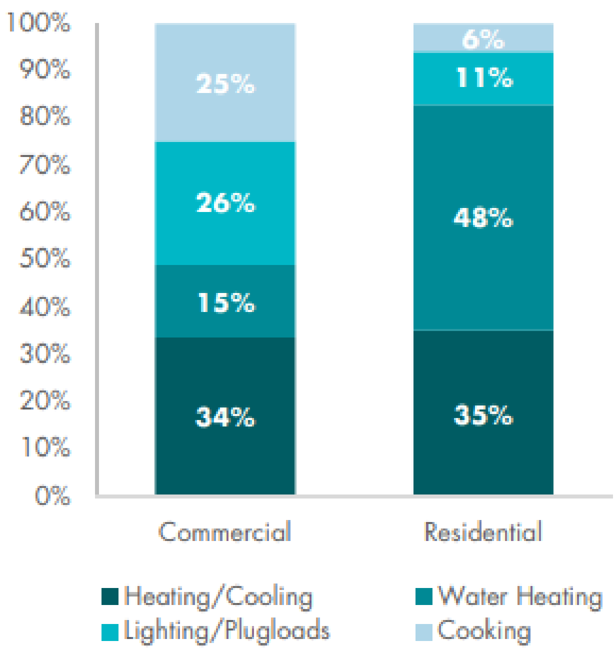

Figure 15: Building Emissions by End Use (Source: Focus 2030, 2019)

4.3.1. Codes Adopted

The California Building Standard Commission (CBSC) laid down a unique set of building codes for the state of California. Since then, the state and all its cities follow the California Building Codes (CBC) in place of the I-Codes. This stringent set of codes undergo revisions every three years. As of January 2020, San Francisco followed the building codes listed below.

- 2019 California Building Code with amendments
- 2019 CALGreen with amendments
- 2019 California Existing Building Code (CEBC) with amendments
- 2019 San Francisco Housing Code
- 2019 California Mechanical Code (CMC) with amendments
- 2019 California Electrical Code (CEC) with amendments

4.3.2. Climate Change Goals

San Francisco plans to reach the following milestones by 2030:

- Reduce greenhouse gas emissions by 68% below 1990 levels
- Achieve a 100% transition to renewable electricity, resulting in a 24% reduction in emissions in the building sector
- Implement net zero construction standards for all new construction

Further, by 2050 the city plans to:

- Reduce greenhouse gas emissions 95% below 1990 levels
- Have 100% efficient, all electric existing buildings
- Achieve a 100% transition to renewable energy

The city requires all new residential buildings to have a LEED Silver rating. For all municipal projects over 10,000 sq. feet, achieving the LEED v4 Gold certification is mandatory, while any project below 10,000 sq. feet must meet the alternative LEED Credits that might be outlined by the sponsoring city department (DSIRE).

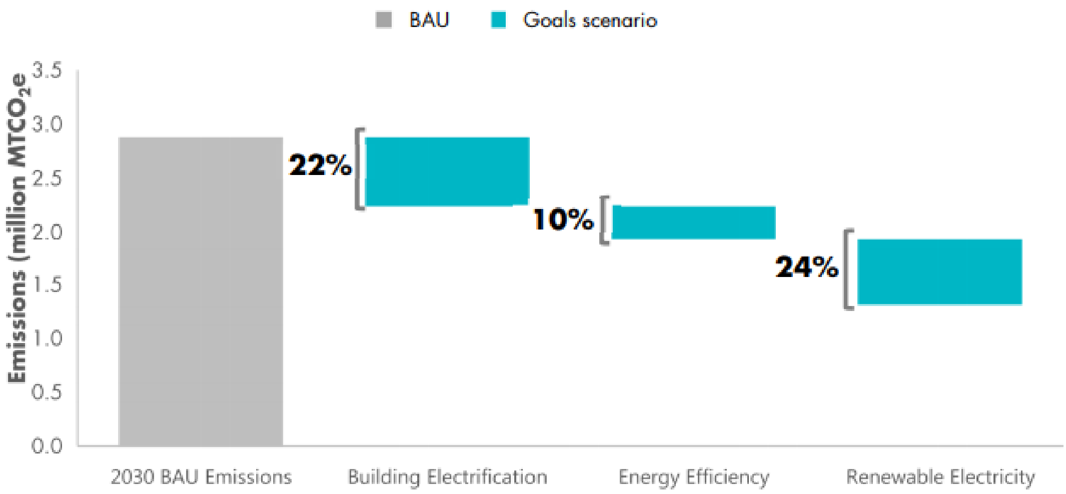

Figure 16: Potential emission reductions in the building sector by 2030 (Source: Focus 2030, 2019)

4.3.3. Net Zero Pathway and Goals

To meet San Francisco's emission-free, all-electric systems goal by 2030, the city needs to be conducting deep energy retrofits at a rate of 3% per year and eliminating the use of natural gas. By 2050, the city aims to meet a 95% emission reduction goal, leaving 5% of residual emissions. These emissions are to be tackled by implementing carbon positive strategies like carbon offsets and living roofs. All city departments are to now include photovoltaic or living roofs in most new construction projects. Making sure that all renovations, retrofits, and equipment replacements are electric is essential in achieving the city's net zero goals.

4.3.4. Gap Analysis for 2030

Keeping in mind San Francisco's emission reduction goal of 68% below 1990 levels by 2030, a gap analysis was conducted. San Francisco follows the California Building Codes as opposed to the IECC standards used in EECC's carbon emission calculator. A comparative study of the codes by the California Energy Commission states that 2016 CBC corresponds to the energy efficiency standards of IECC 2015 and ASHRAE 90.1-2013 with the former standard having a slight edge over the latter two. Therefore, assuming that each revision to the codes is similarly comparable, the following two scenarios of code adoption were considered.

4.3.4.1. Current Trend:

Table 6: State code updates for California impacting San Francisco (current trend)

Projected Residential Energy Code	Projected Effective Date	Code Compliance Rate

IECC 2018	Current	75%
IECC 2021	2021	75%
Projected Commercial Energy Code	Projected Effective Date	Code Compliance Rate
ASHRAE 90.1-2016	Current	75%
ASHRAE 90.1-2019	2021	75%

Emissions avoided from 2010 – 2019 ($MTCO_2e$) = 1,616,982
Emissions avoided from 2020 – 2030 ($MTCO_2e$) = 186,838
Percentage reduction of metric tonnes of CO_2e in 2030 from 1990 levels = 55%

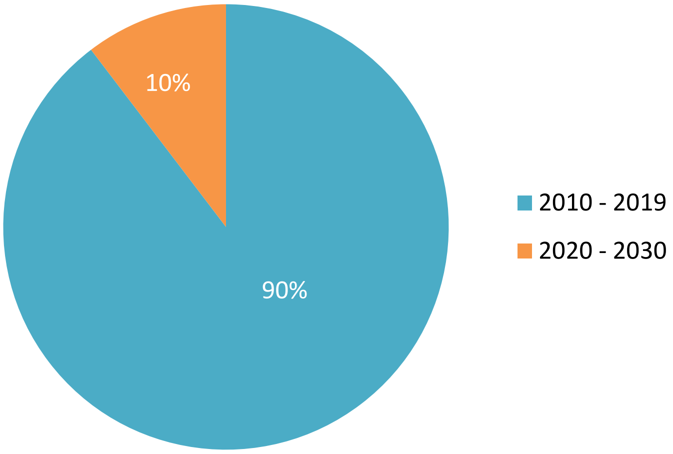

Figure 17: Amount of CO_2 avoided by San Francisco

Fig. 17 shows the massive decrease in the metric tonnes of carbon emissions avoided in more recent years.

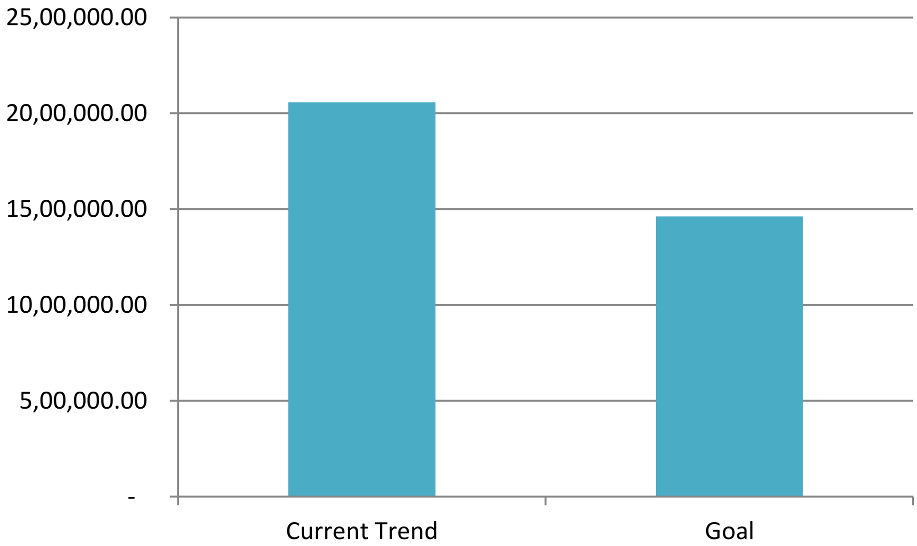

Figure 18: CO_2 levels in 2030 ($MTCO_2e$)

Based on the current trend of codes adopted in San Francisco, the building sector contributes to a 55% reduction in carbon emissions by 2030, from 1990 levels. Considering the city's 2030 emission reduction goal of 56% for buildings (Fig. 18) the city appears to be on track.

4.3.4.2. Aggressive Code Adoption:

Table 7: State code updates for California impacting San Francisco (aggressive trend)

Projected Residential Energy Code	Projected Effective Date	Code Compliance Rate
IECC 2018	Current	75%
IECC 2021	2021	75%
IECC 2024	2024	75%
IECC 2027	2027	75%
PassiveHouse	2030	75%
Projected Residential Energy Code	Projected Effective Date	Code Compliance Rate
ASHRAE 90.1-2016	Current	75%
ASHRAE 90.1-2019	2021	75%
ASHRAE 90.1-2022	2024	75%
ASHRAE 90.1-2025	2027	75%
PassiveHouse	2030	75%

Emissions avoided from 2010 – 2019 ($MTCO_2e$) = 1,616,982
Emissions avoided from 2020 – 2030 ($MTCO_2e$) = 260,742
Percentage reduction of metric tonnes of CO_2e in 2030 from 1990 levels = 57%

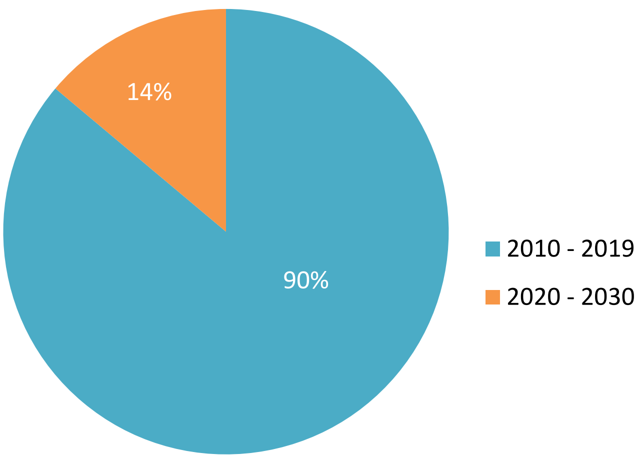

Fig. 19: Amount of CO_2 avoided in San Francisco using aggressive code

Even with the implementation of aggressive code adoption strategies in the years to come, the projected amount of emissions avoided are merely 16% of the emissions avoided from 2005 to 2019 (Fig. 19).

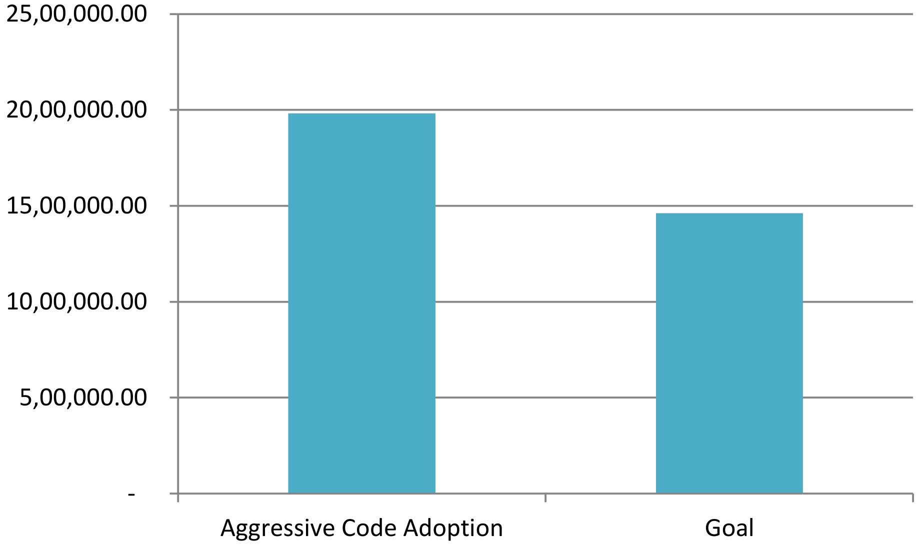

Figure 20: CO_2 levels in 2030 ($MTCO_2e$) in San Francisco

A projected CO_2 emission reduction of 57% is seen by 2030, from 1990 levels. Aggressive code adoption resulted in an additional 3% decrease in emissions in the building sector as compared to the current trend, not only achieving, but surpassing the city's goals.

5. RESULTS AND DISCUSSION

The projected emission reduction for all three cities in the period of 2020-2030 is a very small fraction of the emission reduction that has resulted due to efforts in the past (Figs. 5, 7, 11, 13, 17, 19). The last ten years appear to have achieved a drop that is almost 4 times that projected for the next ten years.

When examining the evolution of codes, it appears that about ten years ago the public became increasingly aware of the need for sustainable practices (reference). With pivotal steps like launching the most widely used and influential version of LEED credentials – LEED v3 in 2007, and transitioning from fluorescent lights and halogen bulbs to light emitting diodes (LEDs), the past ten years have seen a massive evolution in energy efficiency. As practices have slowly started to become less cumbersome on the grid, the scope for any further reduction in emissions has become limited. Population explosion and the excessive demands that come with it have further added to this burden. Another contributing factor might be the boomerang effect. While people are moving towards more efficient households and workplaces and an increased amount of energy savings, they are now using their resources more recklessly, taking undue advantage of their energy “savings”.

After juxtaposing the calculations from the previous section with each city’s climate action goals, the following results were obtained for each city:

- *New York:* This city is expected to see a 23% to 25% reduction in its greenhouse gas emissions. Comparing this with its communitywide emission reduction goal of 40% by 2030, New Yorkers seem to be just on track in the building sector to contribute towards their overall targets of emission reduction. Recent efforts like the NYStretch Code, the Green New Deal and the OneNYC 2050 plans seem to have set their city on the right path.
- *Boston:* Even in a situation of aggressively adopting each revision of the energy code immediately, the building sector of Boston is projected to reduce its emissions by 17% as opposed to its overall goal of 50% reduction. The building sector in the city makes up 71% of its overall greenhouse gas emissions, and such a small reduction figure will not do enough to help Boston reach its goals. As stated earlier, a considerable portion of Boston’s building stock was constructed before the 1950s. These buildings are less airtight, have poorer insulation and might use equipment that result in higher energy use and greenhouse gas emissions as compared to new construction. This may have significantly influenced the level of emissions in the city. Boston needs to develop more stringent policies to address their existing building stock.
- *San Francisco:* With an estimated reduction in emissions by 55% to 57% in the coming years from the building sector alone, San Francisco seems to be once again not only meeting but outdoing its 68% target for overall emission reduction. A personalised, stringent and mandatory code that governs its energy efficiency norms plays a very big role in pushing the city to achieve its milestone.

6. CONCLUSION AND RECOMMENDATIONS

A constant need for technological innovation and population control is due for the world to continue to steadily work towards their greenhouse gas emissions goals. Achieving the new levels of electrification and efficiency in new and existing buildings will only be derived by the elimination of natural gas and ensuring that all retrofits, renovations and replacement of equipment are electric.

Table 8 is a comparison of what different energy codes and rating systems entail. It is evident, that every new version of LEED depends on a version of ASHRAE 90.1 that is already a minimum of two years behind the year the rating system is launched. Similarly, in most states nationwide, their code entails provisions that are informed by versions of IECC and ASHRAE that are at least two years apart. It is necessary for authorities to bridge the gap and revise the updating cycles of the codes for them to work better with one another and accelerate energy efficiency.

Table 8: Make up of codes and rating systems

	v3	v4	-	v4.1
IECC	2009	2012	2015	2018
ASHRAE 90.1	2007	2010	2013	2016
LEED	2009	2016	-	2019

Facilitating energy efficiency policies and providing stakeholders with information on the same is one of the key roles of the government. Efforts made by the state and local government in this direction will help the developers and implementers of the code and all parties involved have a better understanding of its exact intent and desired outcome. Webinars and workshops will further help in educating the mass and providing technical expertise. Now, the necessary party can be held accountable in case of non-compliance with the code. A liability structure to support this practice will ensure the enforcement of required codes and standards (Slavin, 2004).

Codes that mandate and accelerate the states path towards adopting renewable energy must become more widespread and stringent. As discussed above, a complete transition to renewable energy is the most instrumental way for a city to get on the path of a carbon neutral future. Residual emissions may ultimately require the adoption of carbon positive means like carbon offsets and cap and trade (Carbon Neutral Boston). Adoption of the “stretch code” has benefited many states in achieving a significant reduction in their carbon levels and hastened their transition towards renewable energy. Mandating such a practice nationwide and promoting it with financial and energy related incentives will greatly impact their progress towards carbon neutrality.

When all these programs and practices work in coordination with one another and in a timely manner, they pave the way for a unanimously driven path towards a more sustainable tomorrow. The stakes are high. These risks are not remote, nor distant. They are here today and there is no better time for us to code up, decarbonize and rise renewed!

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