

https://dspace.org/

# Investigating the climate change mitigation contributions made by building efficiency tools used in the formal South African residential sector

**Oberholzer, Cornelia Malan**

**2020**
https://hdl.handle.net/10539/31204

Downloaded from a DSpace repository. https://dspace.org/

**UNIVERSITY OF THE WITWATERSRAND, SCHOOL OF ARCHITECTURE AND PLANNING**

# Investigating the climate change mitigation contributions made by building efficiency tools used in the formal South African residential sector

Cornelia Malan Mey (née Oberholzer)

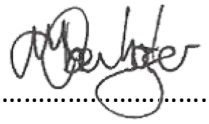
Supervisor: Dr B. Boshoff

A research report submitted to the Faculty of Engineering and the Built Environment, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Master of Architecture (Sustainable and Energy Efficient Cities).

Johannesburg, 2020

# CANDIDATE'S DECLARATION

I declare that this research report is my own unaided work. It is being submitted for the Degree of Master of Architecture in Sustainable and Energy Efficient Cities to the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination to any other University.



……

22 October 2020

# ABSTRACT

The building sector's levels of greenhouse gas emissions and energy consumption is a significant contributor to South Africa's overall carbon emissions. This influences SA's ability to meet its Paris Agreement commitments, which aims to limit the effects of global climate change. This research focuses on the climate change mitigation strategies that are employed by the building sector, specifically the potential impact of *mandatory* and *voluntary* building energy efficiency regulations, standards, initiatives, and certifications common to South Africa's residential market. Internationally, research on the impact of green building tools tends to focus on the commercial sector rather than the residential sector, due to limited energy data availability. Within this context, and given the exploratory and evaluative nature of this research endeavour substantial reliance has had to be made on various grey literature for this research. A review of the South African building efficiency tools shows that there is potential for a 16% reduction in the energy intensity of the residential sector by 2030. This will, however, be offset by the projected increased building floor area and is as such insufficient to meet our Paris Agreement commitments, thus more ambitious targets are required. Given the growth of the residential sector and the potential impact of the various tools, a focus on improved and timeous mandatory regulations for new builds is crucial so as to meet our climate commitments.

*Key Words: Climate change mitigation, residential sector, building energy efficiency tools, green buildings*

# DEDICATION AND ACKNOWLEDGEMENTS

*Hierdie navorsingsverslag dra ek aan Philip en Amelia Mey op. Sonder Philip se geduld en aanmoediging, en Amelia se glimlaggies, sou ek nooit klaar gemaak het nie.*

The words of appreciation and gratitude are conveyed to the following people, who through supervision, criticism, advice, and support made this study possible.

- My supervisor, Dr Brian Boshoff, for your professional support, expert input, and great suggestions.
- My employer, André Harms, for giving me the space and free reigns to follow my curiosity.
- My husband and child, for your constant support and distraction.
- Roelien Bakker, for keeping Amelia entertained.
- My family, in-laws included, and friends, whom I did not want to disappoint, especially after making them listen to my gripes.

# TABLE OF CONTENTS

Candidate's declaration ..... ii

Abstract ..... iii

Dedication and Acknowledgements ..... iv

Table of Contents ..... v

List of figures ..... viii

List of tables ..... ix

List of acronyms and abbreviations ..... x

1. Introduction and conceptual framework ..... 1

1.1. Introduction ..... 1

1.2. Background ..... 1

1.3. Problem statement and rationale for the study ..... 3

1.4. Research Question ..... 4

1.5. Research methods ..... 4

1.6. Conceptual framework and research report structure ..... 7

2. Literature review ..... 9

2.1. Introduction and overview ..... 9

2.2. The Paris Agreement and Nationally Determined Contributions ..... 9

2.3. The climate change impact of the building sector ..... 12

2.4. Mitigating the climate change impact of the building sector ..... 14

2.4.1. Building Efficiency Codes and Standards ..... 16

2.4.2. Energy Efficiency Improvement Targets ..... 17

2.4.3. Building Efficiency Performance Information and Certifications ..... 18

2.4.4. Building Efficiency Incentives and Finance ..... 20

2.5. The financial case for energy-efficient building design ..... 21

3. Building efficiency tools utilized in the South African residential sector ..... 24

3.1. Mandatory / National Energy Efficiency Strategy ..... 24

3.1.1. National Building Regulations and Standards ..... 26

3.1.2. Energy Performance Certificates ..... 28

3.1.3. Appliance minimum energy performance standards ..... 29

3.1.4. Public energy efficiency educational programs ..... 30

3.2. Voluntary / Market-driven Energy Efficiency strategies ..... 32

3.2.1. Solar PV – Small Scale Embedded Generation ..... 32

3.2.2. Green Building Certification ..... 33

3.2.2.1. EDGE certification ..... 35

3.2.2.2. Net Zero certification ..... 36

3.2.3. Green financing aimed at improved residential energy efficiency ..... 38

3.2.3.1. Green home loans ..... 38

3.2.3.2. Green bonds ..... 39

3.3. Concluding summary ..... 41

4. South Africa's Residential Sector Paris Commitments and GHG Emissions ..... 43

4.1. RSA's Nationally Determined Contributions ..... 43

4.2. The carbon footprint of the RSA energy mix..... 44

4.3. Residential sector energy demand ..... 47

4.4. Residential building sector composition..... 50

4.5. Concluding summary ..... 52

5. Findings, Analysis and Conclusions..... 53

5.1. Impact of individual building energy efficiency tools..... 53

5.1.1. Impact of National Building Regulations and Standards ..... 54

5.1.2. Impact of Energy Performance Certificates..... 57

5.1.3. Impact of Appliance Minimum Energy Performance Standards..... 59

5.1.4. Impact of public energy efficiency educational programs ..... 61

5.1.5. Impact of Small-Scale Embedded Generation ..... 62

5.1.6. Impact of EDGE certification ..... 64

5.1.7. Impact of Net Zero certification ..... 65

5.1.8. Impact of Green financing..... 67

5.1.9. Summary table of the impact of common residential building efficiency tools in South Africa..... 68

5.2. Conclusion - Overall climate mitigation contribution..... 72

Reference List ..... 75

# LIST OF FIGURES

Figure 1 – Mandatory and voluntary building efficiency tools in the South African built environment discussed in this report ..... 3

Figure 2 - Research Report conceptual framework and overview, with coloured dots indicating topic linkages ..... 7

Figure 3 - Global share of buildings and construction final energy and emissions in 2017 ..... 12

Figure 4 - Floor area additions to 2060 by key regions ..... 13

Figure 5 - Estimated economic mitigation potential by sector in 2030 ..... 15

Figure 6 - Building energy codes by country in 2017-18 ..... 16

Figure 7 - NDC and buildings policy coverage for 2017-18 ..... 17

Figure 8 - Chapter outline, split into mandatory and voluntary building efficiency measures ..... 24

Figure 9 - Hierarchy of interventions for energy-efficient buildings, with the most cost-effective at the base ..... 31

Figure 10 - CICERO Shades of Green classification ..... 40

Figure 11 - Chapter outline, split into mandatory and voluntary building efficiency measures ..... 41

Figure 12 - Comparison between the 2018 and planned RSA installed capacity mix for 2030 ..... 45

Figure 13 - Carbon intensity of the building sector in 2015 ..... 47

Figure 14 - Building investment at constant 2010 prices in million Rands ..... 50

Figure 15 - Urban high-medium income household electricity consumption patterns . 60

Figure 16 - Energy intensity reduction potential of different building efficiently tools commonly used in South Africa ..... 72

# LIST OF TABLES

Table 1 - Correlation between construction size and 'green premium' in South Africa 22

Table 2 - Summary table of Residential Certification tools and their uptake in South Africa ..... 34

Table 3 – Calculating the percentage of residential energy sourced from electricity ... 49

Table 4 – The building sector and the residential market's carbon emissions in 2006 . 49

Table 5 - Investment in the building sector in 2018 ..... 50

Table 6 – Annual investment in residential buildings split per building type for 2007 and 2017..... 51

Table 7 - Dwelling types in South Africa in 2018 split between formal and informal .... 52

Table 8 - Increase in housing between 2016 and 2030 ..... 56

# LIST OF ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| CICERO | Centre for International Climate Research |
| $CO_2$ | Carbon dioxide |
| CSS | Consulting for Sustainable Solutions |
| DEA | Department of Environmental Affairs |
| DHS | Department of Human Settlements |
| DME | Department of Mineral Resources and Energy |
| DPW | Department of Public Works |
| dti[1] | Department of Trade and Industry |
| EDGE certification | Excellence in Design for Greater Efficiencies |
| EPCs | Energy Performance Certificates |
| EU | European Union |
| GBCSA | Green Building Council of South Africa |
| GDP | Gross Domestic Product |
| GHG | Greenhouse gas |
| GlobalABC[2] | Global Alliance for Buildings and Construction |
| HIFSA | Housing Impact Fund of South Africa |
| ICMA | International Capital Markets Association |
| IEA | International Energy Agency |
| IFC | International Finance Corporation |
| IHS | International Housing Solutions |
| INDCs | Intended Nationally Determined Contributions |
| IPEEC | International Partnership for Energy Efficiency Cooperation |
| IPPC | Intergovernmental Panel on Climate Change |
| IRP | Integrated Resource Plan |
| $kW_p$ | kilowatt peak |
| LEED | Leadership in Energy and Environmental Design |
| MEPS | Minimum energy performance standards |
| MUR | Multi-Unit Residential tool by the GBCSA |
| MW | Megawatt |
| MWh | megawatt-hours |
| $MW_p$ | megawatt peak |
| NBR | South African National Building Regulations |
| NDCs | Nationally Determined Contributions |
| NDP 2030 | National Development Plan Vision 2030 |
| NEES | National Energy Efficiency Strategy |
| NERSA | National Energy Regulator of South Africa |
| OECD | Organisation for Economic Co-operation and Development |
| OMAI | Old Mutual Alternative Investments |
| RSA | Republic of South Africa |

[1] Acronym as per organization's own usage convention
[2] Acronym as per organization's own usage convention

| | |
|---|---|
| SAGEN | South African-German Energy Programme |
| SALGA | South African Local Government Association |
| SAPVIA | South African Photovoltaic Industry Association |
| SEA | Sustainable Energy Africa |
| SSEG | Small Scale Embedded Generation |
| TJ | Terajoule |
| UNEP | UN Environment and International Energy Agency |
| UNFCCC | UN Framework Convention on Climate Change |
| UP | University of Pretoria |
| USGBC | US Green Building Council |
| WorldGBC[3] | World Green Building Council |
| WRI | World Resource Institute |

[3] Acronym as per organization's own usage convention

# 1. INTRODUCTION AND CONCEPTUAL FRAMEWORK

## 1.1. Introduction

> "[T]he one thing we need more than hope is action. Once we start to act, hope is everywhere." (Thunberg, 2018)

The above was the concluding statement of a TEDx talk by climate activist Greta Thunberg, which has been viewed over five million times to date. In this talk, she emphasised that the technologies to solve the climate crisis have existed for a long time. It is the *will* to take urgent, decisive, and far-reaching action that is needed and lacking. This research report examines the actions that are being taken to mitigate the climate change impact of cities, and specifically the impact of the suite of *mandatory* and *voluntary* building efficiency tools in South Africa's residential market. Urban cities have been chosen as the focus of this research report, as it is projected that 66% of the world's population will live in cities by the year 2050 (WRI, 2016). The world's level of urbanisation is important as countries' levels of carbon dioxide emissions, and hence climate change impact, are anticipated to increase with increased population levels (Li & Lin, 2015 ; Zhang, et al., 2017; Bai, et al., 2019).

## 1.2. Background

The World Health Organization has called climate change "the greatest threat to global health in the 21st century" (WHO, 2015), and this may necessitate a global response to the climate change crisis, akin to that required of the COVID-19 pandemic (Bir, 2020). Disadvantaged and vulnerable populations, especially the poor in Africa and Asia, will be hardest hit by climate change, with an increased risk to their "health, livelihoods, food security, water supply, human security, and economic growth", as detailed in an Intergovernmental Panel on Climate Change (IPCC) special report (IPCC, 2019, p. 11). These risks are due to the hot extremes projected for most places and the anticipated future severe droughts or heavy precipitation, depending on the region. The world's

ecosystem itself is being disrupted, with the increase in pests and diseases being observed, and the extinction of vulnerable species (Scholes, et al., 2015).

Globally, cities are responsible for more than 70% of carbon dioxide emissions (UN-Habitat, 2016) and with increasing urbanisation "there will be a deadly collision between urbanization and climate change" (UN-Habitat, 2011, p. 183). While urban centres are seen as major environmental culprits given their high resource requirements and greenhouse gas emissions (UN-Habitat, 2016), they are also seen as a critical part and potential driving force towards climate change mitigation (Graham & Rawal, 2019). As will be discussed in the literature review, compared to other sectors, the building sector presents the most significant opportunity for low-cost energy and emission reduction (WRI, 2016). Given that buildings last for generations and have long renovation cycles, there is a "need for early and rapid investment to prevent locking in carbon intensive investments" (CBI, 2017, p. 12). This research report focusses specifically on the residential building sector, as the International Energy Agency (*ibid*.) has projected that residential floor area will increase by 75% between 2015 and 2050.

In South Africa's built environment, several *mandatory and voluntary* building efficiency tools aim to reduce the energy usage and carbon footprint of the sector. Several significant or common tools are discussed in this report, as summarized in Figure 1 below. From a *national* policy point of view, the key policy document is the National Energy Efficiency Strategy (NEES). The NEES aims to tighten the *mandatory* National Building Standards (SANS 204-1, 2008) and its energy efficiency requirements as provided in SANS 10 400 XA, to broaden the scope of Energy Performance Certificates (SANS 1544, 2014), and to raise the minimum standards for household appliances.

*Voluntary* measures include self-generating clean energy for self-consumption, green building certifications, and green financing. Typical green building certifications in South Africa include the Green Star Certification and Net Zero tools by the Green Building Council of South Africa (GBCSA), and the EDGE certification ('Excellence in Design for Greater Efficiencies') tool by the International Finance Corporation. Green financing includes green bonds, such as those issued via the Climate Bonds Standard and

Certification Scheme, which aim to provide investment vehicles into low or zero-emission buildings.

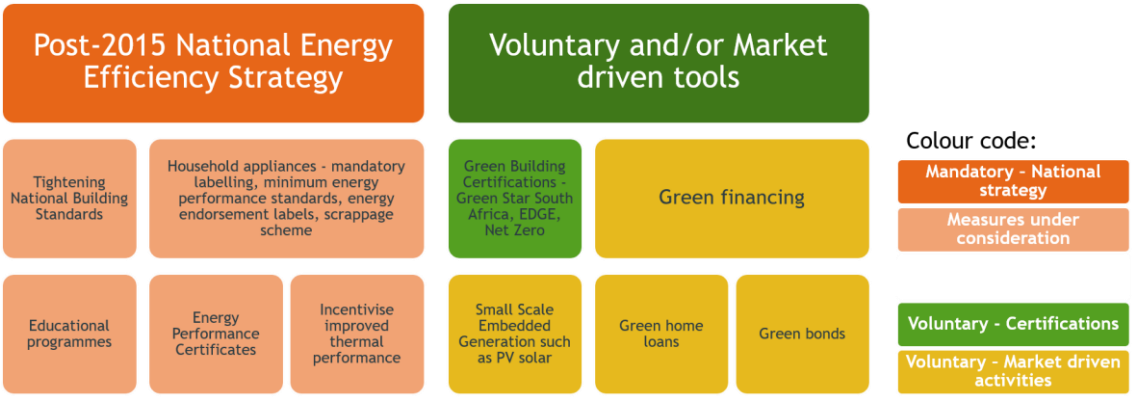



*Figure 1 – Mandatory and voluntary building efficiency tools in the South African built environment discussed in this report*
*Source: Author's own summary*

## 1.3. Problem statement and rationale for the study

With the continued increase in urbanisation, cities have the opportunity to act as centres for positive sustainable growth, through the advancement of low carbon, energy-efficient cities (UN-Habitat, 2016). There is, however, no 'silver bullet' to meet this challenge, but instead, a range of interventions are needed in the built environment (Graham & Rawal, 2019). Interventions include stand-alone impactful measures such as a decarbonised electricity grid (Hawken, 2017), or packaged tools such as mandatory and voluntary building standards and certifications. These packaged tools typically require or incentivise a bundle of smaller energy efficiency measures.

This research firstly examines the building efficiency tools South Africa is employing in the formal residential sector to, in part, meet our climate change commitments, and secondly assesses the impact of such tools. The intent is to determine which of the commonly used tools have the largest carbon reduction potential, and whether it is sufficient in both scope and urgency to meet our commitments, especially given the continued growth in the residential sector.

While this research report focusses on the specific energy efficiency tools and their potential impact, it is important to note that several barriers to the implementation of such tools often exist. While it is outside of the scope of this report to evaluate these barriers, some of the typical barriers that become evident in the analysis of the South African policies include a lack of political commitment and inadequate cooperation between political actors (Clar, et al., 2013).

## 1.4. Research Question

The key research question is what the contribution of *mandatory* standards and policies, *voluntary* certification schemes, and green financing in the South African residential sector are towards climate change mitigation.

The sub-questions that stem from the central theme above include the following:

- What carbon reduction targets has South Africa committed to and how do these green building efficiency tools align with those targets?
- Which building efficiency standards and policies, and certification schemes, are commonly utilised in South Africa?
- What is the composition and growth projection of the residential market and how does this influence a tool's impact?
- Are the energy intensity reduction targets that have been set achievable?
- Are mandatory OR voluntary building efficiency tools more impactful?

## 1.5. Research methods

Qualitative research methods were employed for this research report, primarily through the application of desktop research and secondary data analysis. Relevant materials used in this review consisted of articles, theses, reports, and other documents obtained from the WITS Library database and on the internet. As an initial search, relevant documents were identified through the application of a database keyword search for terms associated with the climate change mitigation potential of green building tools.

Search terms included climate change, Paris Agreement, building sector, residential sector, green building tools, and building efficiency. Preference was given to more recent literature so as to reflect current research on and approaches to the topic. To expand the relevant literature for review, several of the references used in the initial texts were additionally evaluated for their relevancy to this topic.

My position as a professional working in the South African building sector as a 'green building and sustainability' consultant, with a specific focus on *voluntary* green building certifications provided the starting point for this research. It was evident from the initial search for relevant academic material that internationally, research on the impact of green building tools tends to focus on the *commercial* sector, rather than the *residential* sector. This may be due to the fact that residential energy consumption data are limited across the world (CBI, 2017) and this worldwide trend of limited energy data availability, and subsequently research output, is evident in South Africa too. The paucity of relevant literature that relate specifically to the South African residential sector, and the exploratory and evaluative nature of the present research endeavour, required a heavy reliance on grey literature for its review. This documentation primarily consists of reports and policy documents from both governmental and non-governmental agencies, which were identified and sourced either through internet search terms, or because they were referenced or referred to in the sourced journal articles.

It is important to note that this review utilises sources with varying degrees of credibility, and this may influence the final accuracy and validity of results obtained. For example, statistics and assessment reports by the Intergovernmental Panel on Climate Change are considered highly credible, as the IPCC assesses and summarises published climate change research that has been undertaken worldwide. This could be contrasted with statistics provided by state-owned entities regarding residential energy and electricity consumption, which are inconsistent (UNEP-SBCI, 2009). Thus, educated assumptions need to be made regarding which data to use. Data obtained from Statistics South Africa and the Quantum database, which were used in this study, are considered to be accurate, although they may contain some unknown biases.

In the final chapter the formal building efficiency tools common in the South African residential market are analysed to determine what their actual or potential impacts are towards climate change mitigation. The tools' impact, in terms of the energy intensity reduction of the residential building sector, is evaluated based on several factors. The factors considered are the emission reduction focus areas that the tools align with, and the tools' recency, target market and reach, and finally targeted or achievable savings. The emission reduction focus areas considered are energy efficiency, low carbon energy supplies and the use of low carbon building materials. The targeted or achievable savings (in energy intensity reduction of the overall residential market) has been calculated by considering the composition and growth projections of the residential market that the specific tool targets or typically reaches, and the potential savings offered by each tool, based on the literature reviewed.

## 1.6. Conceptual framework and research report structure

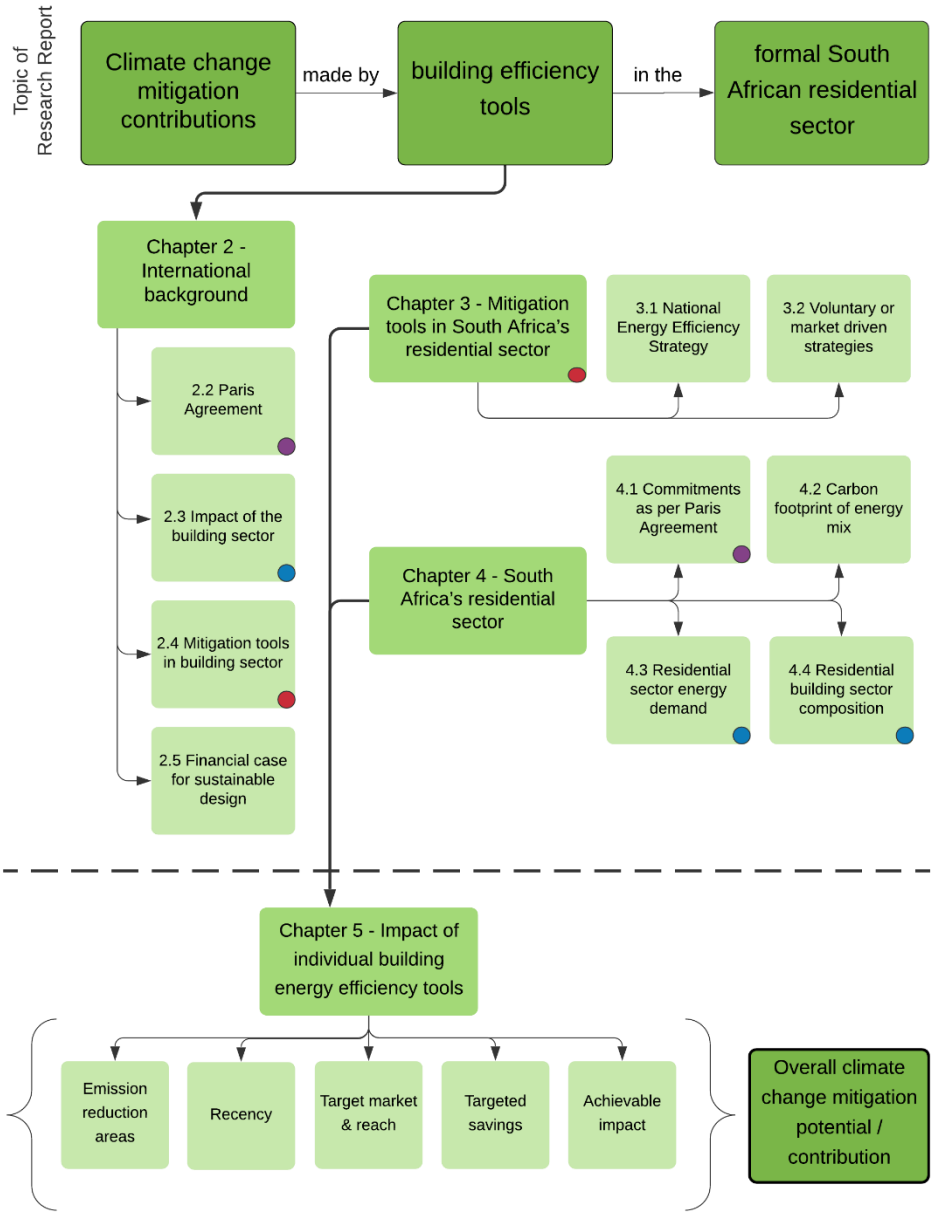



*Figure 2 - Research Report conceptual framework and overview, with coloured dots indicating topic linkages*
*Source: Author's own summary*

As illustrated in Figure 2 above, the literature study in Chapter 2 provides an international background with the climate change mitigation commitments made under the Paris Agreement. Then the carbon emission impact of the building and residential sector is discussed, creating the impetus to focus on this area. The chapter further looks at the climate change mitigation tools used in the building sector internationally and

their impact on the mitigation of climate change. Finally, an overview is provided of the financial and other co-benefits that accrue to building owners and operators who choose to 'green' their buildings and portfolios.

Chapter 3 delves into the *mandatory* and *voluntary* building efficiency tools utilised in the South African residential sector that can mitigate climate change. These include a detailed overview of the post-2015 National Energy Efficiency Strategy and the v*oluntary* or market-driven measures used in the private sector. Chapter 4 provides context to the South African residential sector, by examining our commitments under the Paris Agreement, the carbon footprint of our national energy supplier, and the residential sector's energy demand, composition, and growth projections.

The final chapter, Chapter 5, brings the two preceding chapters together by analysing the building efficiency tools utilised or proposed in South Africa, within the context of the size and composition of the residential market. It also concludes the research report by providing an overall view on the climate change mitigation impact of these tools.

# 2. LITERATURE REVIEW

## 2.1. Introduction and overview

This literature study intends to provide an international background and introduction to the chapters to follow, as the impact of and response to climate change is similar in South Africa than the rest of the world. Firstly, the climate change mitigation commitments made under the Paris Agreement are summarised and the scope and impact of these commitments clarified. This study focusses on the building sector, its climate change impact, and the mitigation tools used in response. The section considers the global growth of the building sector and how it impacts the climate and the tools used internationally to combat it. Lowering the energy intensity, and subsequently, the carbon footprint of buildings is, however, not solely done in response to the climate crisis. There are several financial and other co-benefits to 'greening' a building, and this is considered in the final section of this chapter.

## 2.2. The Paris Agreement and Nationally Determined Contributions

The impacts of global warming on natural and human systems have already been observed (Scholes, et al., 2015), and some of the projected impacts may be long-lasting or even irreversible. If global temperatures continue to increase at the current rate, global warming is likely to reach +1.5°C between 2030 and 2052, which will result in hot extremes in most places, heavy precipitation in several regions, and droughts in others (IPCC, 2019). The Intergovernmental Panel on Climate Change (IPPC) states that disadvantaged and vulnerable populations will be hardest hit by climate change, as they have a reduced capacity to deal with the increased risks to "health, livelihoods, food security, water supply, human security, and economic growth" (IPCC, 2019, p. 11). Countries in Africa would need to devote 5% to 10% of their Gross Domestic Product just to adapt to these negative impacts (DPW, 2018).

These global warming and climate change risks and impacts can be addressed through increased, accelerated and far-reaching climate mitigation action (IPCC, 2019), which is the intent of the Paris Agreement (Climate Focus, 2015; Paris Agreement, 2015). The Paris Agreement was adopted by parties at the UN Framework Convention on Climate Change (UNFCCC) on 12 December 2015, with 195 countries having ratified the agreement by October 2019 (United Nations Treaty Collection, n.d.). The agreement aims to hold "global average temperature to well below 2°C above pre-industrial levels" and to pursue "efforts to limit the temperature increase to 1.5°C above pre-industrial levels" (Paris Agreement, 2015, p. 29). Additionally, greenhouse gas emissions are to peak as soon as possible, with a rapid reduction afterwards (Paris Agreement, 2015, p. 30).

All parties to the agreement were to develop their own country-specific climate mitigation plans and commitments and must provide progressively more ambitious Nationally Determined Contributions (NDCs) every five years (Climate Focus, 2015). Intended NDC's (INDCs) were submitted by 97% of Parties to the UNFCCC by 18 April 2016, representing 94.6% of carbon dioxide ($CO_2$) emissions worldwide (UNFCCC, 2019). In May 2016, the UNFCCC secretariat published a report on the aggregate effect of the submitted INDCs, which shows that the current INDC's are insufficient to meet the least-cost 2°C scenarios by 2025 and 2030. It goes on to state that "much greater emission reduction efforts" will be required to hold temperatures below the 2°C level (UNFCCC, 2016, p. 13).

Similarly, a study by Fawcett *et al*. (2015, p. 1169) concludes that a continuation of current weak policies that target a 2% annual improvement in $CO_2$ emissions per unit of GDP, provides no chance to limit warming to +2°C. It shows that while current NDC pledges stabilise the total yearly global $CO_2$ emissions, they only provide an 8% probability of limiting warming to +2°C. If the NDC pledges are "progressively tightened" from 2030 onwards, as per the intent of the Paris Agreement, the probability increases to 30%. The study (Fawcett, et al., 2015) references literature that indicates that a

probability of over 66% is feasible, but would require negative global emissions[4], requiring large-scale use of bioenergy and carbon capture and storage.

The UNFCCC itself has been criticised (Ciplet & Roberts, 2017), with its progress and potential for climate change mitigation challenged by Chandra Bhushan, New Delhi's deputy director-general of the Centre for Science and Environment (Bhushan, 2019). He argues that its move from a top-down legally binding Kyoto Protocol to the bottom-up voluntary Paris Agreement has weakened the global effort towards climate change mitigation and that efforts should be redirected elsewhere.

On 4 November 2019, the Government of the United States formally submitted their intention to withdraw from the Paris Agreement, effective 4 November 2020. The global community had been prepared for this since U.S. President Trump's election (Zhang, et al., 2017), with Trump having announced his intentions on 1 June 2017. This withdrawal comes as an addition to the roll-back of several U.S. policies targeting climate change, which is projected to result in greenhouse gas emissions being at least 3% higher in 2030 than with the policies still in place (Climate Action Tracker, 2019a). Despite this, Climate Action Tracker still estimates that by 2030, U.S. emissions will be 13% below 2005 levels. This is due to the increased emissions from rollbacks being offset by lower emissions from their electricity generation sector, where lower-cost gas and renewable energy continue to replace coal-fired generation. New solar PV installations accounted for 40% of new generation capacity in the U.S. in 2019, with residential solar installations achieving a 15% annual growth, its highest level to date (SEIA, 2020). Despite the U.S.' withdrawal from the Paris Agreement, it is anticipated that global transformation towards climate change mitigation and the development of low-carbon technologies will continue, despite lower investment from the U.S (Zhang, et al., 2017).

[4] Achieving 'negative global emissions' require the active removal of greenhouse gasses from the atmosphere, beyond that of reduced or zero emission strategies and technologies.

## 2.3. The climate change impact of the building sector

Global levels of urbanisation have increased rapidly from about 29% to 49% in the last half-century, and South Africa was already 66% urbanised by 2018 (Statista, 2020). Global emissions from fossil-fuel burning have increased by almost 500% in the same period, with 2016 being the hottest year in recorded history, exceeding 2019's level by just 0.04°C. Urban cities are essential in the conversation about global emissions as they account for between 60% and 80% of the world's energy consumption and generate 70% of the human-induced greenhouse gas emissions (UN-Habitat, 2016). The construction and operation of buildings is a leading contributor to these emissions, accounting for 36% of the world's energy use and 39% of the carbon dioxide emissions in 2017, as illustrated in Figure 3 below (IEA & UNEP, 2018, p. 11).

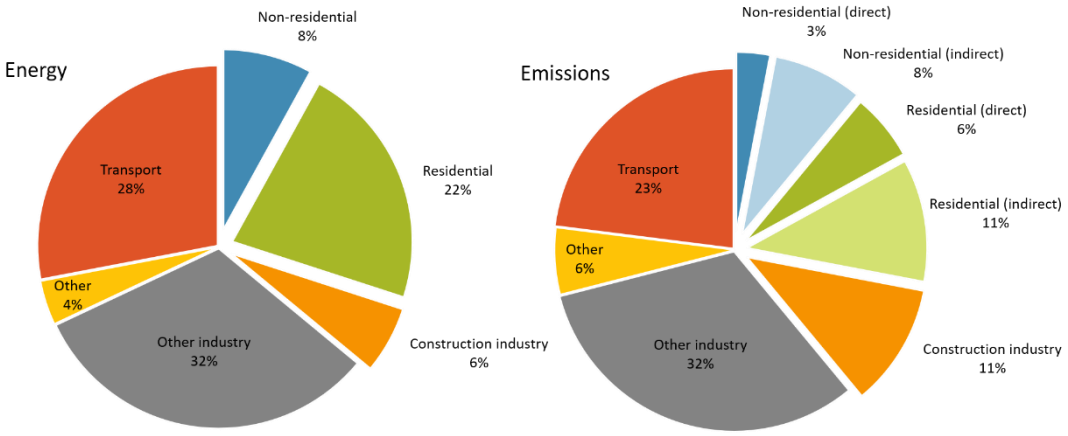
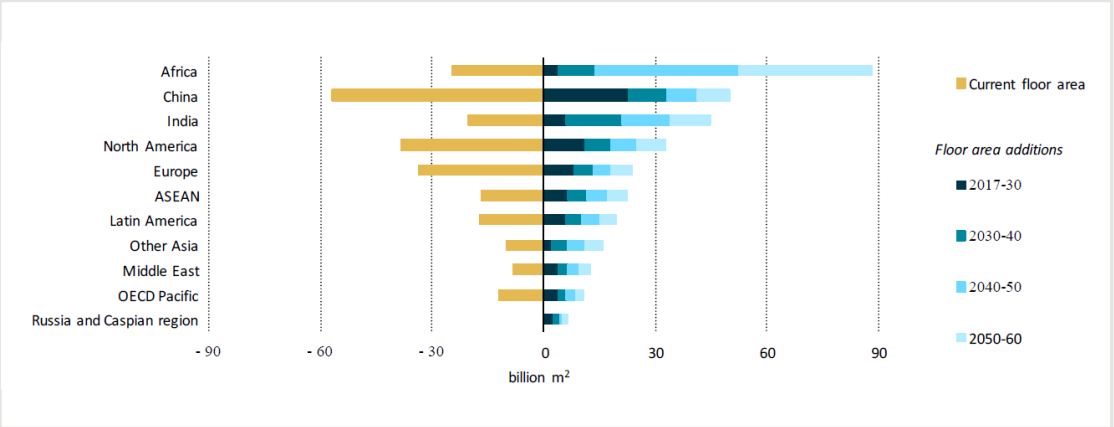



*Figure 3 - Global share of buildings and construction final energy and emissions in 2017*
*Adapted from IEA & UNEP (2018, p. 11)*

The International Energy Agency (CBI, 2017, p. 10) has projected that residential floor area will increase by 75% between 2015 and 2050, with similar growth levels projected for non-residential buildings. Africa, Asia and India are expected to show particularly rapid building growth, with floor area in Africa expected to more than triple by 2060, as seen in Figure 4. Despite improved energy efficiency of buildings globally, the energy needs of the building sector as a whole continue to increase due to the floor area growth outpacing the improvements achieved (CBI, 2017, p. 10; UNEP & IEA, 2017).




Notes: OECD Pacific includes Australia, New Zealand, Japan and Korea; ASEAN = Association of Southeast Asian Nations.

*Figure 4 - Floor area additions to 2060 by key regions (UNEP & IEA, 2017, p. 8)*

The built environment can be viewed as high-inertia infrastructure, where investment and construction decisions made today can lead to a detrimental lock-in of carbon intensive investments for decades to come (Akerman & Hojer, 2006; UNEP & IEA, 2017). This is because buildings tend to last decades, sometimes generations, with the thermal envelope[5] and roofs receiving very infrequent renovations during the usable life of buildings (CBI, 2017).

The Global Alliance for Buildings and Construction (GlobalABC) states that the current building stock will represent around 65% of the global stock by 2060 (CBI, 2017, p. 10; UNEP & IEA, 2017), thus highlighting both the massive growth of new construction projected, and the importance of low carbon strategies not only for new builds but for existing buildings too. Retrofitting existing buildings offers the most substantial potential for greening the building sector in so-called 'developed countries', such as the Organisation for Economic Co-operation and Development (OECD) countries. With the massive increase in floor area projected in non-OECD countries (see Figure 4), in part due to the significant housing deficit currently experienced, a focus on high performing new builds should be prioritised in those regions (UNEP, 2011). Existing residential buildings in the European Union (EU) that are between 40 and 75 years old have the

[5] In countries where there is a large temperature difference between the inside and outside of buildings, thermal insulation of the envelope elements, such as walls, roofs and windows, becomes a key means of passively reducing the energy required to maintain comfortable temperatures inside (Szokolay, 2014).

highest energy use in the sector (Caceres, 2018), and overall residential buildings represented 70% of the total building energy use in 2017 (IEA & UNEP, 2018). Figure 3 above illustrates this substantial contribution residential buildings make to the final energy use and total emissions globally.

To stay within the +2°C limit set by the Paris Agreement[6], the International Energy Agency (IEA) is advocating that the current rate of building retrofits be tripled to 3% per year, with a focus on "deep retrofits" (CBI, 2017, p. 10). "Deep retrofits" aim to increase the energy efficiency gains above the 10% to 15% levels typically achieved by standard upgrades, to improvements of between 50% and 70% (GlobalABC & UNEP, 2016; UNEP & IEA, 2017). The objective of building retrofits should be to upgrade the current stock to highly efficient and low carbon buildings. The IEA is also calling for all new builds to be net zero operating emissions by 2025 in cold climates, and by 2030 in hot climates (GlobalABC & UNEP, 2016). The World Green Building Council 'Advancing Net Zero' project sets the target as 2030 for all new builds and 2050 for existing buildings (WorldGBC, 2017a).

## 2.4. Mitigating the climate change impact of the building sector

As urbanisation brings about fundamental changes in cities' production and consumption patterns, cities can be both part of the problem, and also the solution to climate change. It offers many opportunities to develop mitigation and adaptation strategies, with the economies of scale making it less expensive and easier to take action to minimise both emissions and climate hazards (UN-Habitat, 2016). As illustrated in Figure 5 below (WRI, 2016), bottom-up studies have shown that compared to other sectors, the building sector presents the most substantial opportunity for cost-effective energy and emission reduction by 2030.

[6] The Paris Agreement aims to hold "global average temperature to well below 2°C above pre-industrial levels" and to pursue "efforts to limit the temperature increase to 1.5°C above pre-industrial levels" (Paris Agreement, 2015, p. 29).

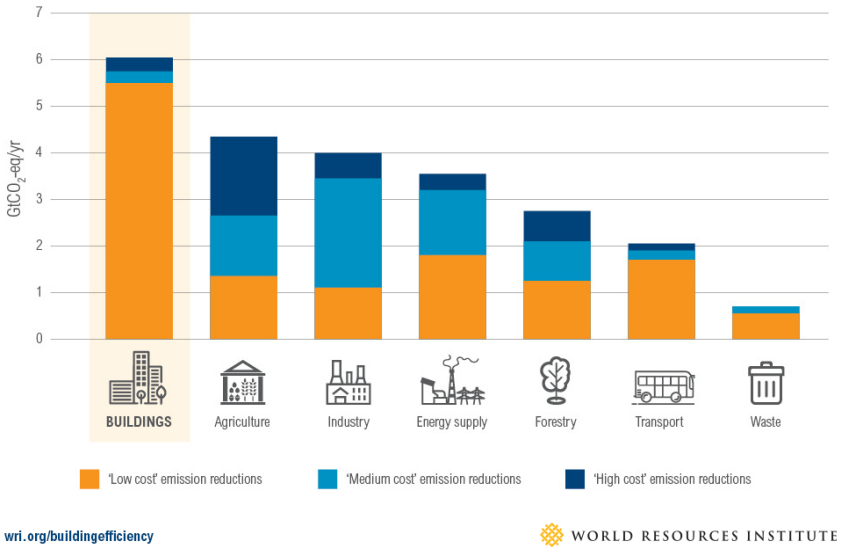



*Figure 5 - Estimated economic mitigation potential by sector in 2030 (WRI, 2016, p. 17)*

It has long been recognised that no single technology or intervention can provide all of the mitigation potential required, irrespective of the sector considered (IPCC, 2007; UNEP, 2011). Well known carbon emission reduction strategies in the built environment include stand-alone and impactful measures such as decarbonising the grid (Hawken, 2017), or a package of measures such as *mandatory* and *voluntary* building standards and certifications that require or incentivise a bundle of individual measures.

In the World Resource Institute's report titled "Accelerating Building Efficiency: Eight Actions for Urban Leaders" (WRI, 2016, p. 56), the first four of the eight actions identified as ways to deliver accelerated building efficiencies are (1) Building Efficiency Codes and Standards, (2) Efficiency Improvement Targets, (3) Performance Information and Certifications, and (4) Incentives and Finance. These speak directly to the building efficiency tools that are the focus of this research report and are elaborated upon in the subsections that follow. These priorities broadly align with the key strategies identified by other institutes, including the roadmap provided by the Global Alliance for Buildings and Construction (UNEP & IEA, 2017).

### 2.4.1. Building Efficiency Codes and Standards

*Voluntary and mandatory* energy codes or certification schemes for the building sector have been in use in over 80 countries across the world for the last 30 years (Wong & Kruger, 2017; IEA & UNEP, 2018), with the rise correlated to the oil crisis of the 70s (Caceres, 2018). A precursor to building certification and energy rating schemes was the implementation of household appliance efficiency ratings, which provide accurate energy consumption information of the appliances (Wong & Kruger, 2017).

As of 2018, 69 countries worldwide have mandatory or voluntary building energy codes or standards (see Figure 6 below), but this still leaves two-thirds of countries without either (IEA & UNEP, 2018, p. 20). More than half of the new buildings expected to be constructed between now and 2060 are projected for so-called 'developing countries' that do not have any mandatory building codes requiring minimum energy efficiency levels in place (UNEP & IEA, 2017, p. 8).

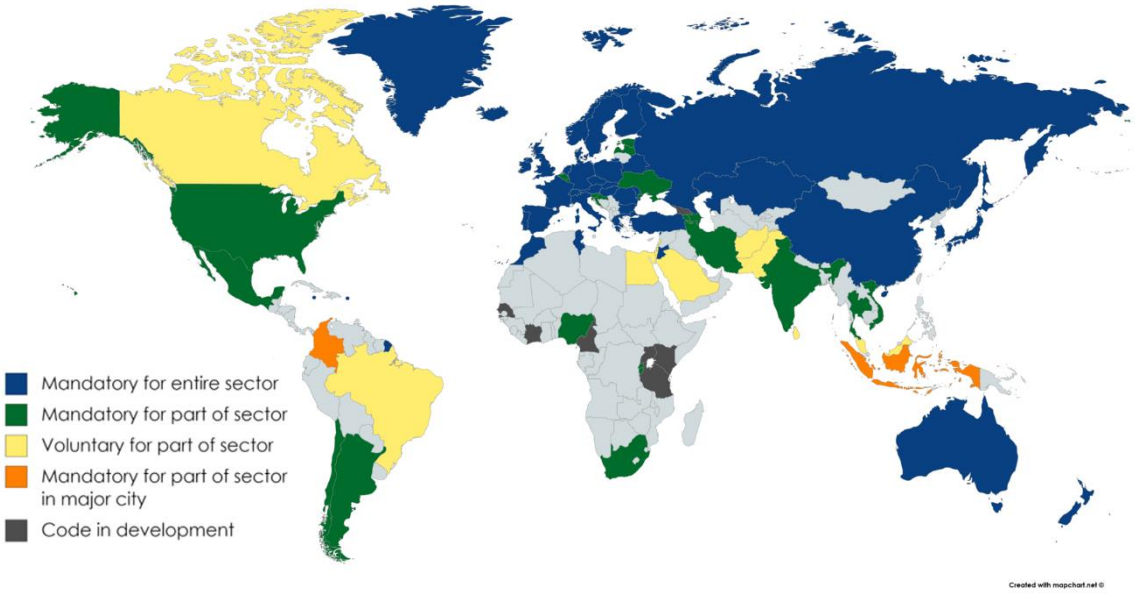



*Figure 6 - Building energy codes by country in 2017-18*
*Adapted from IEA & UNEP (2018, p. 20)*

### 2.4.2. Energy Efficiency Improvement Targets

Of the 194 nationally determined contributions (NDCs) submitted as part of the Paris Agreement, only 70% referenced the building or construction sectors (Figure 7), despite these sectors contributing to nearly 40% of the global greenhouse gas (GHG) emissions (UNEP, 2018a). Over 50% of NDCs referenced building energy efficiency, while 26% mentioned low carbon energy supplies (IEA & UNEP, 2018), and only 5 NDCs (2.5%) mentioned low carbon construction, despite it providing a third of the carbon reduction potential (CBI, 2017). Most of these do not provide specific targets or policy actions on reducing the impact of buildings, even for those countries that have such policies in place (UNEP & IEA, 2017). The lack of targets was identified as a critical gap to be addressed as part of the support provided by the GlobalABC to countries in the update to their NDCs (IEA & UNEP, 2018).

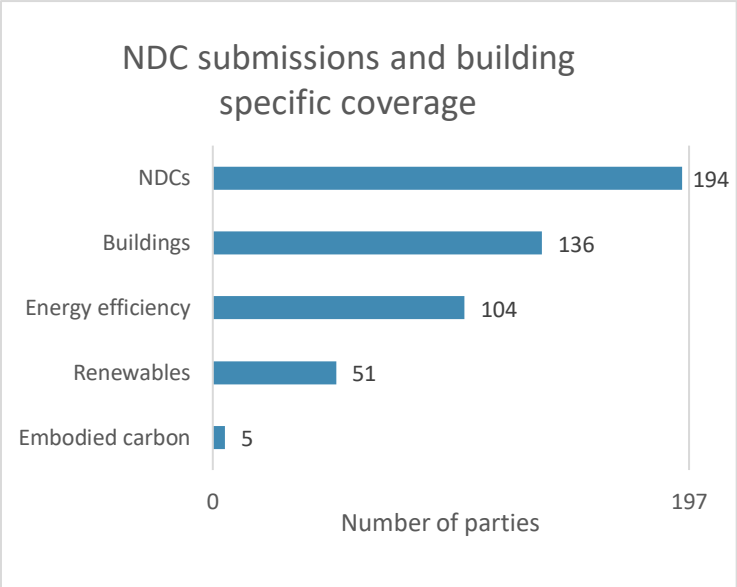



*Figure 7 - NDC and buildings policy coverage for 2017-18*
*Adapted from IEA & UNEP (2018)*

The European Union (EU) does not provide any building-specific targets or measures (UNEP & IEA, 2017) but offers economy-wide targets in the form of their '20/20/20 climate/energy targets' (European Commission, 2010), adopted in 2008 as part of their Europe 2020 strategy. The EU targets set for the year 2020 and 2030 respectively is a 20% and 32.5% increase in overall energy efficiency compared to business-as-usual

(BAU), increasing renewable energy use to 20% and 32%, and a GHG emission reduction of 20% and 40% compared to 1990 levels (European Commission, 2018, p. 66).

The EU is on track to exceed its 2020 GHG emission reduction target, and its use of renewable energy doubled to 17% between 2004 and 2016. Overall, energy demand did however increase in 2015 and 2016 due to higher heating demands attributable to colder winters (European Environment Agency, 2017). The increased energy demand also resulted in lower average efficiency levels, and the EU must subsequently reduce energy consumption by 3.9% in the four years between 2016 and 2020 to meet its 2020 targets (European Commission, 2018).

### 2.4.3. Building Efficiency Performance Information and Certifications

Quality building performance information can provide stakeholders with the ability to make informed decisions on actions to improve their buildings' efficiency. Certifications, which are often voluntary, can provide public recognition and increased value to highly efficient buildings (WRI, 2016, p. 74). Green building rating tools or certifications are used in 85 countries and focus on evaluating the design (expected) or operational (measured) energy use of buildings. They are broadly voluntary outside of the EU, but the uptake is growing amongst the high-end building sector (IEA & UNEP, 2018). Where building codes typically provide the minimum (often mandatory) building standard, several voluntary rating tools offer certification against best-practice standards (DPW, 2018).

Energy Performance Certificates (EPCs) provide performance information as well as certification and have been used across the world to improve building energy efficiency and inform stakeholder decisions since the 1990s by providing transparency to both owners and potential buyers (Pasichnyia, et al., 2019). EPCs serve to benchmark buildings against regulatory standards or industry benchmarks and to establish a database of building energy performance. Mandatory EPCs have been implemented in all 28 EU member states (Buildings Performance Institute Europe, 2014), and are used worldwide, including in the United States ('Energy Star'), Australia (NABERS and

NatHERS), Singapore ('Energy Smart'), Japan ('Energy Smart'), Brazil (RTQ-C), Turkey, and India ('Energy Conservation Building Code').

In the EU, EPCs are required when buildings are newly constructed, or advertised for rent or sale, and must be placed in a visible location in public buildings (Wong & Kruger, 2017). EPCs using estimated ratings based on the building features, or measured ratings determined through energy meter readings, typically provide a grade between A and G (most to least efficient). EPCs intend to provide accurate and valuable information with regards to building energy performance (Caceres, 2018), and a true reflection of this can only be obtained through energy consumption data. Studies have shown that design ratings are rarely an accurate reflection of energy performance, although more accurate estimates are possible based on the estimation methodology used (Wong & Kruger, 2017). Given consistent assumptions between buildings, design ratings do however allow for the comparison of the relative potential energy efficiency of different building designs.

Globally, green building certifications are typically voluntary, and they intend to promote and reward environmental sustainability in buildings (Yigit & Acarkan, 2016). The World Green Building Council (WorldGBC) has around 70 member Councils around the world, which together administer 54 different green building rating tools (WorldGBC, 2019b). Internationally there are several additional tools used that are not managed by WorldGBC.

The World Green Building Council has committed to supporting the goals of the Paris Agreement through the development of their global 'Advancing Net Zero' project. The dual goal is that all new buildings achieve a 40% reduction in embodied carbon emissions and have an operational energy consumption of net zero[7] by 2030, and all existing buildings should operate net zero by 2050. The fundamental principles of this project are to measure and disclose carbon emissions firstly, secondly to prioritise and improve

[7] 'Net zero' requires that a building produces at least as much emission-free energy, from sources such as PV solar, as it uses from emission-production sources.

energy efficiency, then supply the remaining energy need through renewables, and lastly to expand the programme to include embodied energy and zero water and waste (WorldGBC, 2018a). The requirement that the actual impact is quantified and verified through the use of metered consumption data counteracts the criticism that modelled predictions do not correlate well with actual emission intensity reductions (CBI, 2017; Wong & Kruger, 2017; Khosla & Janda, 2019). As of September 2019, the commitment has been signed by 63 organisations, including 31 businesses, 6 states and regions and 26 cities (WorldGBC, 2019c) representing over 130 million people globally (IEA & UNEP, 2018).

### 2.4.4. Building Efficiency Incentives and Finance

Incentives and financing promote the uptake of green new builds and the energy-efficient retrofitting of existing buildings, by alleviating the burden of the additional upfront costs whose benefits tend to only accrue over time (WRI, 2016). Section 2.5 below delves deeper into the perceived and actual size of this upfront 'green premium' and the benefits that are linked to green buildings.

*Financial incentives* can take the form of grants (such as the German 'Kfw Energy-Efficient Renovation' programme), rebates (Singapore's 'Design for Efficiency Scheme'), tax incentives (Brazil's 'Qualiverde Program') and green mortgages (pilot by 37 European banks) (Climate Action, 2018).

*Non-financial* incentives are often aimed at developers of new builds in high-density cities, where green features or energy efficiency measures are encouraged. The incentive can take the form of allowing extra height or floor area, such as Delhi's 'Sustainable Buildings Incentive Scheme' which can award a bonus 1% to 4% coverage (WRI, 2016, pp. 80-82).

Internationally, the year 2017 saw a slowdown in the rate of energy efficiency investments with a 4.1% increase (2.5% adjusted for inflation), compared to the 6-11% annual growth rates from 2014 to 2016. Overall energy efficiency accounts for only

around 8% of total spending on buildings, with residential buildings receiving only half of the total investments, despite contributing to three-quarters of the global building energy use (IEA & UNEP, 2018).

The Climate Bonds Initiative (CBI) is an organisation with the stated objective to promote investment into projects that support climate change mitigation, through the development of a large and liquid green bond market. This is intended to make it less expensive to finance climate projects and reduce fragmentation in different sectors while supporting governments in accessing debt capital markets (CBI, 2017, p. 2).

## 2.5. The financial case for energy-efficient building design

The case for green buildings is often not only made based on emissions mitigation requirements but also with the financial cost/benefit or 'Total Cost of Ownership' of it presented in support of the business case, especially in the absence of mandatory requirements (UNEP, 2011, p. 20).

There is a widespread perception that green buildings attract a cost premium as high as 15% to 20%, which has hampered the progress of green buildings globally (Hoffman, 2016; Bruni, 2017). Internationally, the typical cost premium for green buildings is in actual fact only between 0% and 4%, based on studies in the last decade (WorldGBC, 2013). A study of 170 green buildings in the USA showed a green premium of only 1.5% (UNEP, 2011). By considering a building's 'Total Cost of Ownership', the upfront costs may be shown to be offset by reduced long-term operational costs and other additional benefits, with a payback period of between 5 and 10 years (UNEP, 2011). An extra CAPEX investment of only 2% has been shown to provide a return on this green investment of 10 times the initial cost (WorldGBC, 2013; IFC, 2017), with the building itself commanding a higher market value due to its operational efficiency.

Recent South African research on the GBCSA's Green Star SA Office v1 and v1.1 tool has also shown that the perceived cost premium of over 15% is not an accurate reflection of the average green building costs in South Africa. It has been shown that the 'cost of

building green' is typically only around 3.9% of the total project cost (ASAQS, GBCSA & UP, 2019). As shown in Table 1 below, there is also a strong negative correlation between green costs premium and construction size, with larger projects having a much lower average premium than smaller projects, at an average 'green premium' of 2.4%. Early indications via the GBCSA's EDGE Residential tool, show an additional green cost premium of 3%, although they also clarify that this would vary with project specifications (GBCSA, 2017).

*Table 1 - Correlation between construction size and 'green premium' in South Africa*

| Green cost premium (%) vs. Construction area ($m^2$) | Min | Average | Max |
|---|---|---|---|
| **Total** | 1.1% | 3.9% | 14.2% |
| **< 5 000 $m^2$** | 3.4% | 5.1% | 12.2% |
| **< 10 000 $m^2$** | 1.7% | 4.0% | 14.2% |
| **< 25 000 $m^2$** | 2.7% | 5.2% | 12.0% |
| **< 50 000 $m^2$** | 1.1% | 3.2% | 5.0% |
| **> 50 000 $m^2$** | 2.0% | 2.4% | 3.9% |

*Adapted from ASAQS, GBCSA & UP (2019)*

Much research has been done on the benefits different stakeholders receive from green buildings throughout the building life-cycle, many of which are deemed significant or compelling (UNEP, 2011; WorldGBC, 2013; IEA & UNEP, 2018). Financially, owners and owner-developers benefit from green buildings through increased building value (between 0 and 30%) due to higher rental rates (0% to 17.3%), lower operating expenses (e.g. 25% to 50% energy savings) and higher occupancy rates (0 to 23.1%) (WorldGBC, 2013; Bruni, 2017). Research by MSCI (2018) on the South African commercial office market showed that Green Star certified prime and A-grade offices had a total return of 11.6% in 2017 versus 8.0% for non-rated offices, enjoyed higher capital growth, higher net income and lower vacancy rates.

The International Energy Agency (IEA) has produced an extensive report on the "multiple benefits" or "co-benefits" of proposed or implemented energy efficiency measures, intended to allow policymakers to evaluate suitable options (IEA, 2014, p. 8). The report has a list of 15 prominent benefits, but notes that different countries have different economic and social conditions which would influence the value and relative importance that they assign to the various benefits. So-called 'developing countries' with emerging

economies often focus on poverty reduction and sustainable growth, which can be aided through energy-efficient designs. These focus areas can be achieved through improved access to existing energy infrastructure, economic growth, due to improved industrial productivity, improved affordability of services such as lighting and cooking, reduced local pollution and enhanced climate change resilience (IEA, 2014, p. 23).

# 3. BUILDING EFFICIENCY TOOLS UTILIZED IN THE SOUTH AFRICAN RESIDENTIAL SECTOR

In support of climate mitigation through lowered energy intensity, there are several *mandatory* and *voluntary* building efficiency tools and measures in the Republic of South Africa (RSA), including codes, certifications, and market factors used in the country. Of specific interest to this study are those used in the residential sector. This chapter will provide an overview of some of these tools, as outlined in the diagram below, with the final chapter analysing their role in meeting RSA's Paris Agreement commitments.

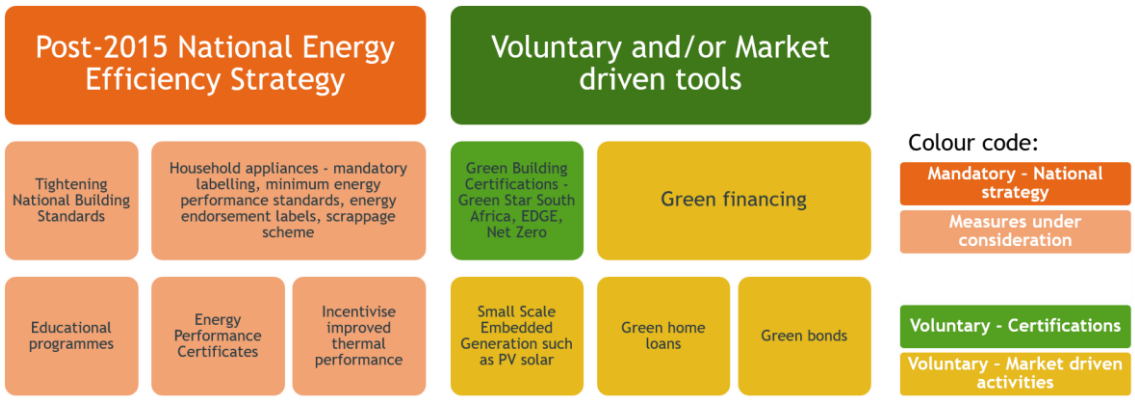



*Figure 8 - Chapter outline, split into mandatory and voluntary building efficiency measures*
*Source: Author's own diagram*

## 3.1. Mandatory / National Energy Efficiency Strategy

The Post-2015 National Energy Efficiency Strategy (NEES) was developed to respond to the dual scenario of increased energy demand and a commitment to a reduced environmental footprint, as per South Africa's National Development Plan 2030 and its Paris Agreement commitments. The Post-2015 NEES aims to "encourage continued growth by **reducing energy *in*efficiency as a barrier** to future progress" (emphasis in original), through the promotion of energy efficiency as a 'first fuel'[8] (DEA, 2016, p. 3).

[8] The 'first fuel' concept is one that evolved from considering energy efficiency as a 'hidden fuel source', as the ability to use energy more efficiently allows the unused portion to be applied to other needs. As

The Post-2015 NEES document was published on 23 December 2016 for public comment, a follow-up on the NEES first published in 2005 and updated in 2011 (DEA, 2016).

The Post-2015 NEES document address several sectors, and for the residential sector provides a targeted overall energy intensity reduction of 33% by 2030 from a 2015 baseline. The overall target of 33% comprises of a targeted 20% improvement of the average energy performance of the residential stock overall, and a 33% improvement in the energy efficiency of new household appliances. Measures to improve the energy performance of the residential stock include **progressive tightening of the building efficiency standards** (see section 3.1.1), issuance of **energy performance certificates** (section 3.1.2), financial incentives for **improving the thermal performance**, and **educational programmes** (section 3.1.4). The measures related to **household appliances** (see section 3.1.3) include mandatory labelling, the successive tightening of minimum energy performance standards, energy endorsement labels, and a scrappage scheme for old inefficient appliances.

It is concerning that the National Energy Efficiency Strategy document intended to provide the path from 2015 onwards was only published in December 2016 for public comment, approved in November 2018, and not yet promulgated as of end 2019. It has been deemed a "partial achievement" by the DoE's 2018-2019 Annual report (Parliamentary Monitoring Group, 2019). Given that the strategy document's implementation plan designates 2016-2017 as year 1 for implementation (DEA, 2016, p. 38), it is clear that the targets set are already in jeopardy. The time it takes for policy documents and legislation to be passed and subsequently updated creates an impediment in achieving the aims of these documents and dilutes their impact. This 'dilution' is discussed in more detail in the section that follows.

---

the energy use avoided by IEA member countries in 2010 was larger than any one fuel source, including coal, energy efficiency can be considered as the 'first' or largest fuel (IEA, 2014).

### 3.1.1. National Building Regulations and Standards

Successive tightening of the building efficiency regulations and standards constitutes a large portion of the targeted 20% improvement in the average energy performance of the residential sector, as it is based on a 38% tightening of the South African National Building Regulations (NBR) energy efficiency standards by 2030.

In September 2011 the South African National Building Regulations (NBR) were updated to include a section on the required energy efficiency, designated 'Part XA – Energy Usage in Buildings'. This section requires that all new buildings or major refurbishments are designed and built so that their passive design (orientation, shading, services, and building envelope) ensure efficient use of energy, and that at least 50% of hot water generation (by volume) take place without the use of electric resistance heating[9]. These minimum requirements are to be met through the methods detailed in national standard SANS 10400-XA, with the intent that this standard is updated every five years to become gradually more stringent (Ecolution Consulting, 2019). There are suggestions that even the best-practice norm of 3 to 5 years between updates is not optimal (Gray & Covary, 2015). The update of the NBR is currently overdue, as eight years have passed since the promulgation of the previous version, with the Department Public Works stating that an update is "urgently needed" (DPW, 2018, p. 15). In January 2020 a draft version of the updated standard was released for public comment, with comments closing on 24 March 2020.

Holm, Johannsen, and Harris (2007) were commissioned by the RSA Department of Minerals and Energy to review the proposed 2011 update to the NBR before its promulgation. They estimated that the proposed standard provided an energy improvement of between 32% and 58% over the existing residential stock at that time.

[9] The conventional approach to water heating for domestic use uses an electrical element inside a geyser to heat water ('electric resistance heating'). SANS 10400–XA Regulations requires that all new buildings utilise other means of heating at least 50% of the water, such as solar water heaters, heat pumps and gas geysers.

The final details of the promulgated standard (SANS 10400-XA, 2011) differed to the version studied by Holm *et al*. but it is estimated that the updated standard still provided an energy improvement of at least 16% (Ecolution Consulting, 2019). The current standard is however losing effectiveness in providing continued energy savings, as the current standard is at times less stringent than what is becoming the industry construction norm. A proposal to update certain sections of the current version commissioned by the GIZ in 2015 (Gray & Covary, 2015) showed that for the commercial sector, the annual maximum energy consumption is too generous to be effective in improving the market's energy efficiency, and using these values as a compliance path is problematic.

Gray and Covary's study showed that the average business-as-usual new-build office in 2015 was already 33% more efficient than the maximum energy consumption allowance, with a sample of hotels using on average only half of the allowed maximum, despite the inclusion of operation energy (which is excluded from the allowance). In the current draft version of the standard, which closed for public comment on 24 March 2020, the proposed maximum annual electricity consumption for a Johannesburg office drops from a current maximum allowance of 200kWh/$m^2$ to 110kWh/$m^2$ in the new draft version. A hotel in Johannesburg's energy consumption allowance has an even larger drop from 650kWh/$m^2$ for the current standard, to 110 kWh/$m^2$ in the proposed (SANS 10400-XA (draft), 2020). Maximum annual energy consumption is not specified for residential buildings in either of the two SANS 10400-XA versions, with these buildings are required to meet minimum efficiency requirements that relate to their passive design and hot water generation.

Municipalities are responsible for assessing and approving building plans and their adherence to the NBR, and concern has been expressed about the ability of officials in smaller municipalities to assess compliance (SEA, 2017; Ecolution Consulting, 2019). This is due to a lack of capacity, experience and understanding, funding, and willingness (Gray & Covary, 2015). In addition to major capacity building by the construction industry (SEA, 2017), through the C40 programme (ASHRAE SA Chapter & SEA, 2020) and the Swiss

Development Corporation (Gray & Covary, 2015), there has been a recent proposal to investigate the use of the EDGE modelling software tool ('Excellence in Design for Greater Efficiencies') to simplify SANS compliance checking (GBCSA, 2019a). The NEES also proposes the use of Energy Performance Certificates (EPCs) as a "simple means" of checking NBR compliance but does not elaborate on how this would be achieved (DEA, 2016, p. 25).

As of 2014, low-cost state-subsidised housing has been required to meet NBR standards as well, after the release of the improved norms and standards for stand-alone residential dwellings built by the government (DHS, 2014). For 20 years prior, these houses were constructed without insulated ceilings and weather-proofing, thus providing inferior thermal insulation to the homes. The updated standard requires the installation of ceilings and insulation, plastering or rendering of walls, and smaller windows with energy efficiency safety glass panes (SEA, 2017).

### 3.1.2. Energy Performance Certificates

The minimum efficiency requirements of the NBR apply only to new buildings and to major refurbishments of old buildings, but not to the existing buildings that make up the overwhelming bulk of the South African market (SEA, 2017, p. 72). To address the need for energy efficiency improvements in the existing building market, residential Energy Performance Certificates (EPCs) are proposed. EPCs are proposed in conjunction with medium-term financial incentives for undertaking thermal retrofits. For lower-income groups, such as those who received state-subsidised housing, direct grants for thermal retrofits are being considered. Additional financial incentives under consideration include rebates against Transfer Duty, low-interest loans, and partial grants (DEA, 2016).

Energy Performance Certificates (EPCs), as discussed in section 2.4.3 of the literature review, is a tool used worldwide that requires the owners of buildings to display the energy performance of a building, providing either estimated or measured energy consumption per unit of measurement. South Africa's Department of Energy published draft EPC regulations for public comment in 2018 (Parliamentary Monitoring Group,

2018b). EPCs would allow landlords to systemically analyse their building's stock energy performance while populating a country-wide energy intensity database of the building sector and supporting the government's national energy efficiency strategy.

The proposed mandatory EPCs (SANS 1544, 2014) are not required in the residential sector and are for existing commercial buildings used for entertainment, public assembly, theatres, indoor sports arenas, places of instruction, and offices only. These buildings must be operational for at least two years and have a total net floor area of over 2 000 $m^2$ for government buildings and 1 000 $m^2$ for private buildings.

EPCs are however used extensively in the residential sector in several countries, and it may extend to the residential sector in South Africa too in the future, as per the measures to be assessed for feasibility under the post-2015 NEES. EPCs have been shown to not only improve the energy efficiency for residential buildings, but highly efficient residences attract a sales premium of up to 10% acting as economic incentives for developers to innovate further (Wong & Kruger, 2017). An EPC's effectiveness in reducing energy intensity can be increased through the provision of cost-effective recommendations on how to improve the building's energy efficiency (Wong & Kruger, 2017; Caceres, 2018), something which is not required in the current South African scheme.

### 3.1.3. Appliance minimum energy performance standards

As per the post-2015 NEES strategy document (DEA, 2016, p. 19), the goal is to transform the market for appliances to more energy-efficient models, through the application of both push and pull strategies. The four specific strategies are minimum energy performance standards (MEPS) that are successively tightened, a scrappage scheme for old inefficient appliances (the 'push' strategies), mandatory labelling, and energy endorsement labels (the 'pull' strategies). The target is to ensure that all new appliances purchased by 2030 consume on average 33% less energy relative to a 2015 baseline.

Energy efficiency labels have been used in over 50 countries for decades, and have been shown to have a positive effect on overall residential energy efficiency (Wong & Kruger, 2017). In South Africa, mandatory energy efficiency labelling requirements were put into place in 2014 (dti, 2014), which are intended to allow consumers to make informed decisions about the relative energy efficiency of an appliance, before making a purchase (DEA, 2019). Another measure that is under consideration is the introduction of energy endorsement labels, such as the "notable" American government-backed 'Energy Star' programme (Wong & Kruger, 2017, p. 310), which label appliances as top-performing, or not, in their category.

As part of the introduction of mandatory labelling in 2014, minimum energy performance standards (MEPS) were introduced for air conditioners, heat pumps, dishwashers, electric ovens, refrigerators and freezers, tumble dryers, washer-dryer combinations, and washing machines. Appliances that do not meet the MEPS are prohibited from entering the South African market. To remain effective, MEPS must be reformulated and tightened regularly so that inefficient products are no longer available on the market, which is part of the post-2015 NEES measures. The NEES intends to announce the trajectory well in advance so that manufactures can respond in time.

As a measure to remove old inefficient appliances, the NEES proposes an incentive scheme to scrap old appliances. This would be specifically aimed at the second-hand appliance market, which lower-income households may consider due to its lower upfront cost, despite its higher long-term operations costs.

### 3.1.4. Public energy efficiency educational programs

There are many campaigns with information to allow homeowners to improve the energy- and water efficiency in their own home, whether these are new or existing. The order in which energy efficiency priorities should ideally be addressed for the most cost-effective approach is often demonstrated through the use of a pyramid structure (Vieira, 2006; Matt Power for Green Builder Media, 2016; SEA, 2017). In these tiered structures (see Figure 9 below), a good architectural passive design that minimises the need to use

energy for heating/cooling and lighting forms the basis, followed by energy-efficient equipment and energy conservation, and lastly the use of renewable energy. This is in line with the GBCSA's (Green Building Council South Africa) definition of Net Zero Carbon buildings, which require firstly a "building that is highly energy-efficient, and the remaining energy use is from renewable energy" (GBCSA, 2019b). This is also reflected in the three priorities of embodied energy, energy efficiency and low carbon energy sources for low emission buildings by the (CBI, 2017), as discussed in section 4.1.

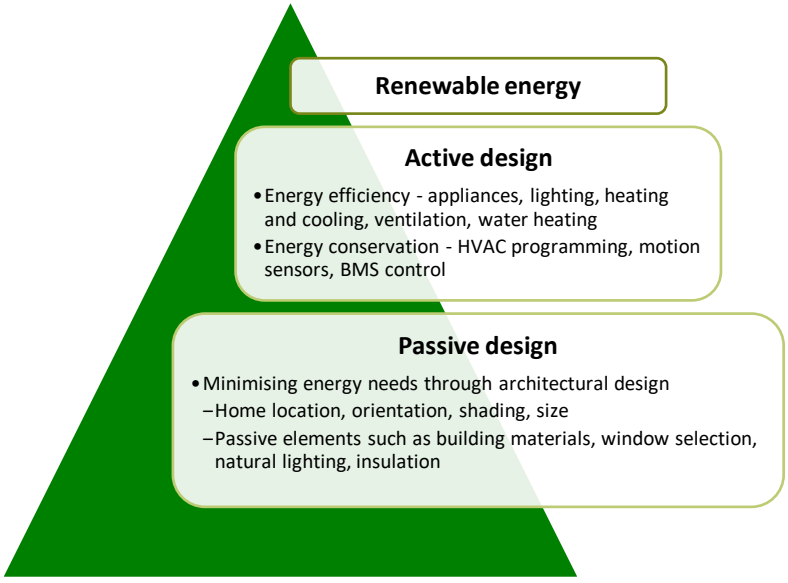



*Figure 9 - Hierarchy of interventions for energy-efficient buildings, with the most cost-effective at the base Adapted from Vieira (2006), Matt Power of Green Builder Media (2016) and SEA (2017)*

At a city level, the City of Cape Town has a campaign and educational website aimed at household energy efficiency, which additionally lists resources from sources such as the GBCSA, Eskom's 49M campaign, and the local authorities of eThekwini Municipality and Nelson Mandela Bay Municipality (City of Cape Town, 2018). A home-owner resource efficiency education drive, named the 'My Green Home' campaign, was conducted by the GBCSA in 2014, with the main co-funding from the German government through the South African-German Energy Programme (GBCSA, 2014). The focus of this campaign was household energy efficiency, the main focus of the major funder, although water efficiency and other sustainability-related issues were also addressed. Nedbank has released the second edition of their 'Smart Living Guide' (Nedbank Limited, 2017) aimed at middle to high-income homeowners, which provides a range of

behaviour change and technology interventions to allow homeowners to reduce their ecological footprints and save resources.

## 3.2. Voluntary / Market-driven Energy Efficiency strategies

### 3.2.1. Solar PV – Small Scale Embedded Generation

The pace of newly installed small and medium scale private generation of solar electricity in South Africa is increasing, with 150 to 200 $MW_p$ capacity[10] estimated to have been installed in 2018, from an overall installed capacity of around 430 $MW_p$ just the year before. This is due to two key factors, namely the above-inflation increases of electricity prices of over 300% in the last decade, and the fall in the international price for solar PV installations, to around a quarter of what they were seven years ago. Locally the cost of PV for both residential and commercial (sub-utility) is projected to drop below the cost of an ESKOM supply by 2020 (GreenCape, 2019).

The Draft Integrated Resource Plan 2018 (IRP) had an annual cap on embedded generation of 200 MW, which was flagged as a concern during the public hearings on the IRP (Parliamentary Monitoring Group, 2018a). Stakeholders were of the opinion that the allocation was insufficient, had no technical basis, and was already exceeded by pending applications at the National Energy Regulator of South Africa (NERSA). On 2 May 2019, the RSA Energy Minister authorised NERSA to process the licenses of pending SSEG projects of a combined 500 MW capacity, without requiring the developers to request permission from the Minister to deviate from the IRP (SAPVIA, 2019). After this, the promulgated IRP 2019 was updated to increase the Small Scale Embedded Generation (SSEG)[11] cap to 500 MW per annum (DME, 2019).

[10] $MW_p$ which denotes megawatt peak, is a typical measure of a solar PV plant generating capabilities under standard test conditions.

[11] Small Scale Embedded Generation (SSEG) typically refer to PV solar systems installed at residential, commercial, or industrial sites, where the electricity generated by the systems is intended to be consumed onsite.

As the on-selling of electricity makes up a large portion of municipalities' income and can be used to cross-subsidise poor households, municipalities may not have an incentive to promote the use of alternative fuel sources out of concern of the impact. However, appropriately developed cost-reflective tariffs reduce the effect of reduced electricity sales to less than 2% of total revenue. Some municipalities require that PV systems contain reverse–feed blocking so that excess PV power cannot be fed back into the grid, but this can be counterproductive, as this can lead to systems that are installed without official permission and grid defection (SEA, 2017).

The South African-German Energy Programme is offering several rounds of municipal SSEG Programme Development support. It focusses on municipal capacity building, establishing their SSEG application and approval processes, and adapting their funding and operating models in response to increased SSEG installations and the potential loss of income due to inappropriate tariff structures (SAGEN, 2019). As per the South African Local Government Association (SALGA), by October 2018, forty-two municipalities allowed SSEG installations, up from only ten in 2016. This represents 25% of the municipalities with distribution licences issued by NERSA (GreenCape, 2019).

### 3.2.2. Green Building Certification

Sustainability consultants, green building specialists and GBCSA Accredited Professionals provide specialised insights, solutions and consulting services for a variety of industries and building types. In the residential sector, it tends to focus on resource utilisation audits, technical sustainability consulting and green building certification. While individual upper-income households can and do pursue green building certification, certifying entire residential developments provides the benefit of scale given the fixed cost involved (Ecolution Consulting, 2019). The commercially available residential green building certifications available in South Africa include the GBCSA's 'Multi-Unit Residential' (MUR) tool and 'Net Zero' certification, the US Green Building Council's (USGBC) 'LEED v4 for Homes or Multifamily Midrise' and the International Finance Corporation's EDGE Residential tool ('Excellence in Design for Greater

Efficiencies'). EDGE certification for residential properties is locally facilitated by the GBCSA.

*Table 2 - Summary table of Residential Certification tools and their uptake in South Africa*

| Ratings Body | Residential rating system | Launch date | Number of residential buildings | Trends observed<br>Quoted from (Ecolution Consulting, 2019) |
|---|---|---|---|---|
| GBCSA | Green Star New Build MUR Tool | 2011 | Six projects consisting of a total of 315 units | - Low uptake<br>- High-end property market |
| USGBC through GBCI | LEED for Homes or Multifamily Midrise | 2005 | None in South Africa | - Low uptake<br>- High-end property market |
| GBCSA | EDGE Residential | 2017 | 11 148 certified units, with at least another 16 000 registered in 2020 | - Significant growth in uptake in a short period<br>- Global players<br>- Lower cost and simpler implementation and documentation |
| GBCSA | Net Zero | 2017 | One residential project with 5 units | - Interest from industry, especially in the commercial sector<br>- Showcases environmental leadership, aligns with global carbon reduction goals, and direct support by World Green Building Council |

*Adapted from CSS (2019) and Ecolution Consulting (2019)*

As per Table 2 above, only EDGE has seen a significant uptake in South Africa, notably in the gap or affordable housing market (CSS, 2019). The EDGE certification and other 'design' ratings derive their rating levels from estimated or modelled energy performance based on building features, which is poorly correlated to actual operational performance or emission intensity and has been criticised on this basis (CBI, 2017; Wong & Kruger, 2017; Khosla & Janda, 2019). Given consistent energy modelling assumptions, 'design ratings' do however allow for the comparison of the relative potential energy efficiency of different building designs.

Research by MSCI (2018) showed that Green Star certified prime and A-grade offices consumed only 1% less electricity, but 24% less water than non-certified offices. Green Star awards projects points for proposing or installing systems that reduce the building's energy consumption, it is not mandatory to reach a minimum amount of points in the energy section to achieve certification. EDGE requires a minimum of 20% electricity savings to achieve certification, although these savings are calculated based on a simplified energy model.

Operational green building ratings, such as Net Zero Carbon, which validate their energy performance or emission intensity through actual energy meter readings are considered preferable to design ratings (CBI, 2017; Wong & Kruger, 2017; Khosla & Janda, 2019). Net Zero certifications carry additional support in that it is compatible with the rapid decarbonisation of the building sector to meet the targets of the Paris Agreement (CICERO, 2015; CBI, 2017; WorldGBC, 2017a). Both of these certifications can be used for either residential or commercial buildings, and are accepted certification standards or proxies for inclusion in CBI green bond portfolios (see section 3.2.3.2 for details).

#### 3.2.2.1. EDGE certification

EDGE certification ('Excellence in Design for Greater Efficiencies') is used in 140 countries across the world, developed by the IFC to stimulate the update of energy-efficient buildings in developing countries. EDGE positions itself as both a free online assessment tool and a certification system, so that architects and engineers can quickly identify low-cost, high-return design alternatives before (or instead of) committing to perusing certification. EDGE can thus help determine, at a concept level, the financial viability of a project's green building initiatives early in the design stage (GBCSA, 2017).

The online assessment tool has been localised for South Africa concerning the local climate, utility costs, standard construction and system specifications, in addition to building regulations, thereby allowing it to accurately calculate a building's inputs and consumption (IFC, 2018a). The EDGE assessment tool then presents the building's potential utility savings and its reduced carbon footprint against a base case (IFC, 2018b). To pursue certification the EDGE standard of 20% less energy use, 20% less water use, and 20% less embodied energy in materials compared to a base case building must be achieved, which is then independently verified and certified by the GBCSA. In 2019, additional levels of certification became available in the form of EDGE Advanced and EDGE Zero Carbon, which require 40% less energy use and 100% carbon neutral, respectively.

Current notable names in the field of EDGE residential certification in South Africa include International Housing Solutions (IHS), the Development Bank of Southern Africa's Green Fund, in collaboration with Nedbank (Nedbank Limited, 2017), the Housing Impact Fund of South Africa (HIFSA), Old Mutual Alternative Investments (OMAI) and Balwin Properties. In 2019 there were 29 registered EDGE projects with the GBCSA (representing nearly 10 000 residential units), and many of them have a link to the companies and funds mentioned above (CSS, 2019). In 2020 Balwin Properties announced the EDGE registration of another 16 000 residential units, in conjunction with a 'green home loan' product from ABSA (Engineering News, 2020a). The total number of units is over and above the projects making use of the free tool for high-level assessments and design optimisation.

#### 3.2.2.2. Net Zero certification

Net Zero Carbon buildings have net zero emissions, typically by being a highly energy-efficient building with very low energy demand, the remainder of which is met through zero carbon energy sources such as PV solar. While there are a variety of definitions for Zero Energy or Zero Carbon buildings (D'Agostino & Mazzarella, 2019), they typically all require that a building produces at least as much emissions-free energy as it uses from emission-production sources (CBI, 2017; GBCSA, 2019b; WorldGBC, 2019e).

The South African National Development Plan Vision 2030 (NDP 2030) set the objective of creating a zero emission building standard by 2030, through the progressive strengthening of energy efficiency standards of the National Building Regulations (Government of South Africa, 2012). The GBCSA's (Green Building Council South Africa) Zero/Net Positive certification programme that was launched in 2017 aims to accelerate the transformation of the market towards this goal. Projects in South Africa can pursue Net Zero certification as part of other certifications offered by the GBCSA, such as Green Star or EDGE, or as a stand-alone submission. As of March 2018, there had been six certified and four registered projects with the GBCSA, one of which was an upper-income multi-unit residential project in Johannesburg (GBCSA & WorldGBC, 2018). As

of May 2019, there have been 388 buildings certified as Net Zero in nine countries across the world (WorldGBC, 2019a).

The GBCSA's Zero/Net Positive certification scheme allows various levels of, and pathways to certification. The levels relate to whether the energy consumption is modelled on the base building emissions only or whether it is modelled or measured for both the base building and the tenants' emissions combined. The pathways reflect the GBCSA's preference that Zero/Net Positive certification be achieved first through energy efficient buildings, then on-site renewable energy production, before considering off-site renewables or carbon offsets. New builds and major refurbishments able to pursue modelled certification based on the design or as-built specifications, and existing buildings are able to pursue certification based on actual measured energy consumption data (GBCSA, 2019b).

Johannesburg, Tshwane, eThekwini and Cape Town in South Africa have committed to developing net zero carbon policies and bylaws to enable the achievement of net zero carbon for all new buildings by 2030 and all buildings by 2050. These policies and municipal bylaws are currently in development and planned for implementation end 2020. These enabling bylaws and policies, alongside appropriate National Building Regulations could allow net zero buildings to be realised at scale (ASHRAE SA Chapter & SEA, 2020; Terblanche, 2019).

### 3.2.3. Green financing aimed at improved residential energy efficiency

#### 3.2.3.1. Green home loans

Green home loans (or green mortgages) are the financing of new homes or homes that want to pursue renovations, where the home has some existing or targeted energy efficiency or sustainability rating. Banks would typically offer improved rates or increased loan amounts due to reduced insolvency risks associated with such properties. The risk reduction is due to an improved ability by the owner to repay the loan due to lower utility bills, and increased property values due to its 'green value' (WorldGBC, 2017b). Research in several countries with established rating systems such as Energy Performance Certificates shows that the 'green value' or 'green premium' can be up to 10.2% for the most efficient buildings, and homes are easier to sell. Correspondingly a decline in energy efficiency has been shown to lower the sales price (Wong & Kruger, 2017).

The EU's building stock is dominated by existing buildings, and improving the energy efficiency of existing residential homes are considered essential to achieving their carbon emission targets (United Kingdom , 2019). As part of this, green mortgages are being piloted to encourage residential retrofits and improve their energy efficiency. The minimum performance threshold for new builds is 'nearly net zero' buildings or a 20% improvement over national standards, or a 30% energy demand reduction for renovations (WorldGBC, 2018b). In South Africa, no national incentives exist, although two banks are offering 'green loans'. Nedbank is offering an extension to their home loan product, where renewable and energy-saving products from a specific supplier can be rolled into home-owners' home loans (Nedbank Limited, 2019). Most recently, ABSA and Balwin Properties have announced the 'Absa Eco Home Loan', which provides preferential interest rates on the 16 000 EDGE Certified homes (see section 3.2.2.1) under development by Balwin (Engineering News, 2020a). The homes are aimed at the middle- to upper-income segment, as it is priced between R 700 000 and R 1 600 000 (BusinessTech, 2018; Balwin Properties, 2020).

#### 3.2.3.2. Green bonds

Green bonds are financial instruments that allow the raising of debt to finance eligible green projects or activities. Of the $46 billion capital that has been raised on the green bond market, 28% has been allocated to the building sector. In South Africa, three bonds have been issued under the Johannesburg Stock Exchange's green bond requirements since its launch in late 2017, of which one was for a certified green building portfolio (CSS, 2019). Green bonds benefit the issuer in that they are often oversubscribed, allow a company to market its 'green credentials', and can often be sold at a premium. In return, the proceeds are ringfenced for socially responsible activities, as per the bond mandate (Bagnoli & Watts, 2019).

To prevent possible 'greenwashing' of the proceeds from green bonds (Blanding, 2019), the Climate Bonds Initiative (CBI) established a standards and certification scheme to ensure that CBI certified bonds finance only low carbon projects that are consistent with the rapid decarbonisation path needed to meet the Paris Agreement targets (CBI, 2017). This sets stricter requirements than those of the Green Bond Principles developed by the International Capital Markets Association (ICMA) (CSS, 2019). The CBI's preferred pathway to certify low carbon buildings requires that a property portfolio is within the top performing 15% of buildings in the market (in terms of the baseline emissions intensity), and its performance is such that at the midpoint of the bond term, it is on a trajectory to net zero carbon by 2050. Ongoing independent monitoring and verification of the portfolio's carbon reduction impact is required on an annual basis (CBI, 2017).

To establish an initial baseline emissions intensity for a city and sector (residential, non-residential), a representative sample of buildings is required for the sector in the city. Operational data for the residential sector are however very limited across the world, and as such, the CBI provides alternative methods of showing compliance with the decarbonisation criteria. A residential portfolio must either commit to significant

upgrades that result in emission reductions of between 30% and 50% (depending on the bond term), or all the buildings must be certified under an approved proxy[12] (CBI, 2017).

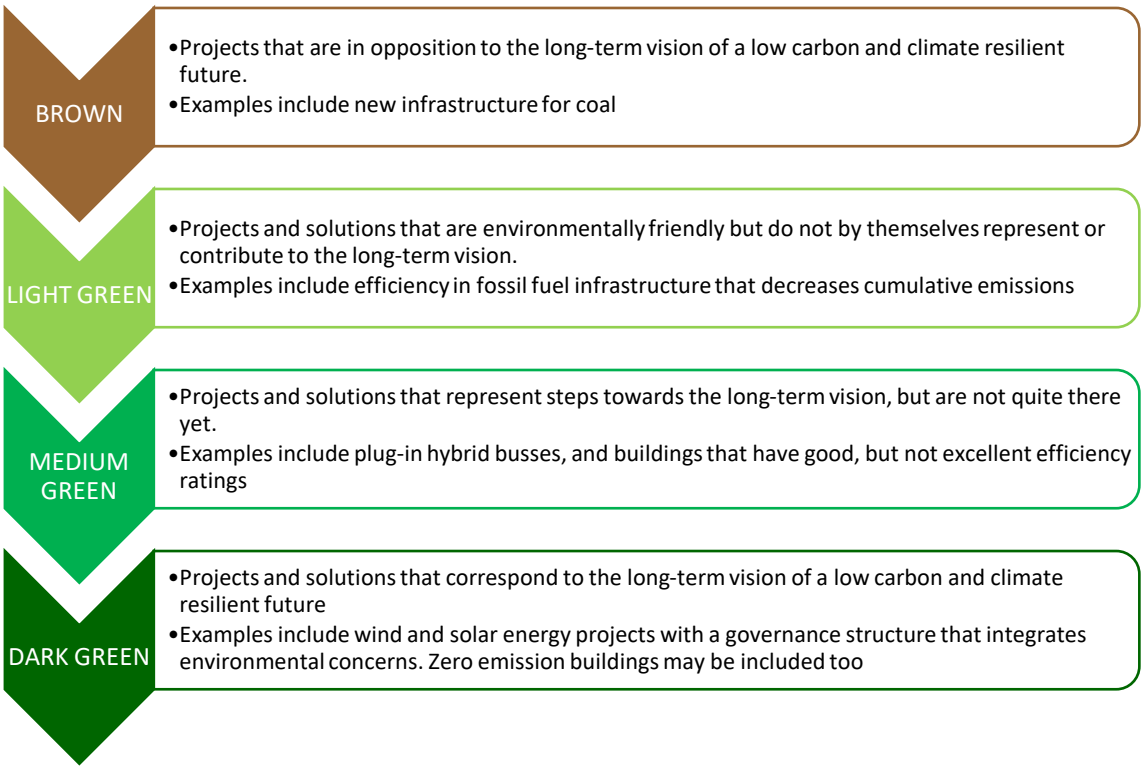



*Figure 10 - CICERO Shades of Green classification*
*Adapted from CICECO (2015) and CSS (2019)*

In South Africa there are two proxies, namely confirmed compliance to SANS 10400-XA or the IFC's EDGE certification, with the GBCSA's Net Zero Carbon certification approved as an eligible standard (Ecolution Consulting, 2019). These three represent progressively higher levels of emission reduction performance, and sustainability focussed investors may prefer higher levels of emission reduction performance above the minimum requirements of the building regulations (CSS, 2019; Walker, 2019). This is in line with the 'CICERO Shades of Green' methodology (Centre for International Climate Research), that provide second opinions on the "environmental quality" of green bonds. As per

[12] The CBI allows certification through a proxy method, selected from an approved set of green building certifications or national building standards. This option is only possible where representative energy consumption data is not available for creating a city baseline and portfolios using this approach are typically limited in bond term.

their classifications, bonds are rated from 'brown' up to 'dark green', as their long-term impact towards a low carbon future improves (CICERO, 2015). Figure 10 above provides details of the different levels. On this scale, SANS 10400-XA would likely rate as 'light green', EDGE certification as 'medium green', and Net Zero carbon certifications as 'dark green'.

## 3.3. Concluding summary

This chapter discussed both the mandatory and voluntary building efficiency tools and measures commonly utilised in South Africa. The South African National Energy Efficiency Strategy (NEES) represents the most detailed *mandatory* energy efficiency strategy that deals directly with residential energy consumption. Its focus areas include the progressive tightening of the building and household appliance efficiency standards, the issuance of energy performance certificates for residential buildings, financial incentives for improving the thermal performance of building envelopes, and public educational programmes on energy efficiency. The focus areas align well with international efforts on building energy efficiency as discussed in detail in subsections of section 2.4, and if implemented would represent a comprehensive push towards lowered residential energy intensity. A detailed analysis of the potential impact of the NEES is discussed in the final chapter, but swift implementation is urgently required.

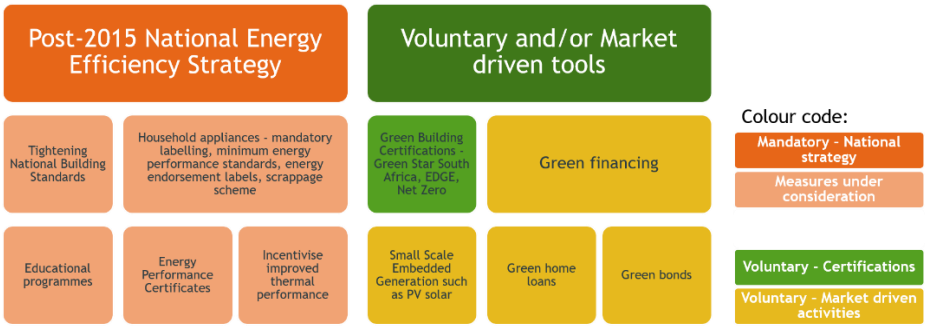



*Figure 11 - Chapter outline, split into mandatory and voluntary building efficiency measures*
*Source: Author's own diagram*

*Voluntary* or market-driven energy efficiency tools can be seen as complementary to the mandatory tools, but also as the vanguard of new ideas and improved standards. Green building certifications, while often limited to upmarket developments, are becoming

more common and have the potential to showcase the positive impact of and business case for green developments. Green financing supports these certifications as well as standalone energy efficiency improvements by alleviating some of the burden of the additional upfront building and certification costs. While green home loans are still nascent in South Africa's residential market, the recent ABSA and Balwin Properties collaboration on a 16 000 unit residential development, may raise the market profile of both green building certifications and green home loans. With the pace of privately installed solar PV systems increasing, it too is becoming a more mainstream addition to homes and residential complexes, providing a buffer against rising electricity prices while encouraging municipalities to develop conducive SSEG policies.

# 4. SOUTH AFRICA'S RESIDENTIAL SECTOR PARIS COMMITMENTS AND GHG EMISSIONS

## 4.1. RSA's Nationally Determined Contributions

The Paris Agreement requires countries to submit their Nationally Determined Contributions (NDCs) to indicate their planned action towards climate change mitigation, as detailed in section 2.2 of the literature review. South Africa ratified the Agreement on 1 November 2016, having already provided its Intended NDC (INDC) by 25 September 2015. The main targets of the INDC (Government of South Africa, 2015) are that:

- emissions will range within 398 and 614 Mt $CO_2$-eq[13] between 2025 and 2030;
- the emission profile will peak between 2020 and 2025, plateau for a decade and then decline in absolute terms from there onwards; and
- targets apply to all sectors of the economy.

In 2018, South Africa released the draft Climate Change Bill for comment (DEA, 2018), which seeks to establish a legal framework by which a national emissions reduction trajectory is determined, and setting carbon budgets and sectoral emissions targets (DEA, 2019). While South Africa is one of the few countries that provided absolute targets in its INDC, the commitment is insufficient to place the country on a pathway that will limit warming to +2°C or less (Climate Action Tracker, 2019b). This is consistent with the findings in the report by the UNFCCC (United Nations Framework Convention on Climate Change), that stated that the aggregate effect of all the INDCs by countries worldwide is insufficient to meet the target warming level limit (UNFCCC, 2016, p. 13).

[13] Mt $CO_2$-eq denotes 'metric tons of carbon dioxide equivalent', which is used to quantify the global warming impact of emissions from different greenhouse gases, standardized to that of one unit mass of carbon dioxide.

Climate Action Tracker's analysis does however note that RSA's current policy projections show that it may be on track to meet the upper range of its target band for 2020 (Climate Action Tracker, 2019b). There is thus scope to provide more ambitious targets for 2030, in line with the Paris Agreement's five-year revision cycle of progressively more ambitious targets (Paris Agreement, 2015). A UNEP report (2018b) notes however, that RSA's current 2030 upper target would be reached only if the country's future energy mix decarbonises as per the 2019 Integrated Resource Plan (IRP 2019), which came into effect in October 2019. South Africa's INDC makes specific reference to the significant impact our energy sector plays in our current GHG emission levels and that substantial investment in transforming the sector away from coal is required. The energy sector and its future as per the Integrated Resource Plan of 2019 is discussed in detail in section 4.2 below.

Except for the recognition of the large impact of the energy sector and the need for a lower-carbon supply (section 4.2), no sector-specific targets or plans are provided in RSA's INDC. Similarly, RSA's three update reports to the UNFCC (BUR-1 to BUR-3) focussed on the emissions and mitigation actions in the industrial sector including energy production, mining, and manufacturing, with no specific focus on the building sector (DEA, 2019, p. 70). To investigate the potential emission impact of the building sector, section 4.3 examines the energy demand and carbon emissions of the South African residential sector, while section 4.4 details its makeup and current growth.

## 4.2. The carbon footprint of the RSA energy mix

South Africa has a very high carbon economy due to our heavy reliance on coal-generated energy (IPEEC, 2018), and RSA has the highest $CO_2$ emissions per GDP in Africa and the 5$^{th}$ highest in the world (Global Carbon Project (2018) citing (Boden, et al., 2017; BP, 2018; UNFCCC, 2018)). As per the 2019 South African Integrated Resource Plan (IRP 2019), coal-fired plants represented 72% of the total installed generation capacity in 2018, with an additional 7% being derived from gas or diesel peaking plants (DME, 2019). The IRP 2019 recognises in its introduction that South Africa's INDC has

committed to an emission profile that peaks, plateaus and declines from there onwards, and the shift in the energy generation mix is summarised in Figure 12 below (Government of South Africa, 2015). The emission profile shift is supported by the new higher efficiency coal power stations Medupi and Kusile being brought online in the next five years, and the decommissioning of 26%, by capacity, of end-of-life coal power stations by 2030. It also includes a fourfold increase in the current installed renewable energy capacity, while discounting any embedded generation through lowered demand assumptions.

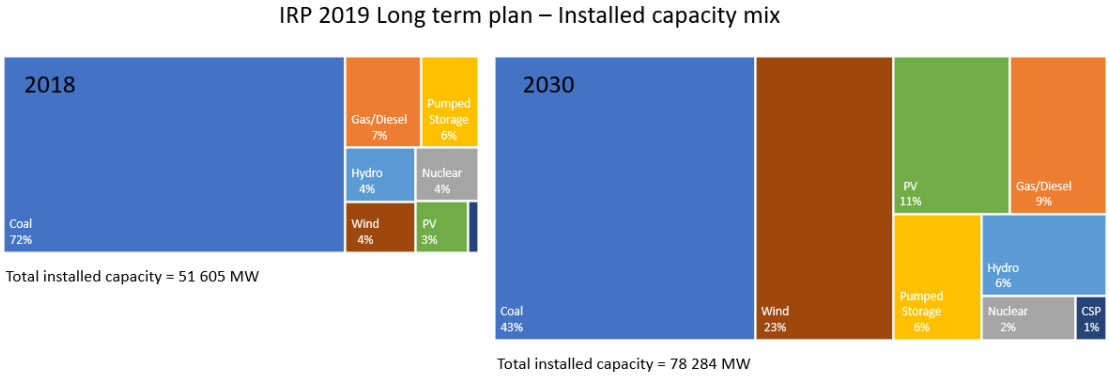



*Figure 12 - Comparison between the 2018 and planned RSA installed capacity mix for 2030 Calculated from DME (2019)*

Despite this, the share of coal will still constitute the bulk of the installed capacity by 2030 at 43%, with gas or diesel peaking plants contributing 9% of the mix. Fossil fuel based generation capacity will thus constitute more than half of the mix. On an annual energy contribution basis (% of MWh[14]), coal will contribute 59% and peaking plants 1% by 2030. In absolute terms, the installed coal plant capacity drops only 10% from 37 149 MW[15] in 2018 to 33 364 MW in 2030. Renewables will make up 46% of the capacity mix, up from 17% in 2018, providing 34% of the total energy in MWh by 2030 (DME, 2019, p. 44). It is thus clear that coal-generated power will remain dominant in South Africa in the short to medium term, although the construction of new coal power plants is likely to be muted due to funding limitations imposed by OECD countries (Organisation for

[14] MWh denotes a megawatt hour, which is a measure of total power generated over an amount of time
[15] MW denotes a megawatt, which is a measure of the electrical generating capacity of a plant at one point in time

Economic Cooperation and Development) on greenfield coal projects that are not highly efficient (OECD, 2015). Despite international pressure, several local banks continue to fund coal-fired power stations (Fin24, 2017), although several published updated thermal coal financing policies in 2019 and early 2020, increasing transparency in this regard (BusinessDay, 2020). Under ABSA's new sustainability policy they will continue to finance existing coal sector clients, but funding of new greenfield projects will only take place under "extenuating circumstances", and ABSA will consider the OECD guidelines as part of their due diligence processes (Engineering News, 2020b).

On a longer time frame, the decommissioning of an additional 24 100 MW coal plants capacity is proposed for between 2030 and 2050, leading to coal contributing less than 30% of energy by 2040 and 20% by 2050 (DME, 2019). Eskom has in the past experienced fierce opposition from labour unions at the suggestion of mothballing power plants (Njobeni, 2017), and it remains to be seen how this transition will be managed.

To stay within the limit of +2 degrees or below[16], the energy-carbon intensity of the world's building sector needs to be below 20 tonnes[17] $CO_2$ per terajoule[18] (TJ) before 2050 (IEA, 2017). Due to South Africa's heavy reliance on coal, its building-related emissions exceeded 150 tonnes $CO_2$ per terajoule in 2015 (Figure 13), thus currently placing it far from the targeted value of less than 20 tonnes $CO_2$ per terajoule.

[16] The Paris Agreement aims to hold "global average temperature to well below 2°C above pre-industrial levels" and to pursue "efforts to limit the temperature increase to 1.5°C above pre-industrial levels" (Paris Agreement, 2015, p. 29).
[17] Tonnes is a metric ton, which is equal to 1 000 kilograms.
[18] TJ denotes a terajoule, which is the SI-unit of measure for power utilised over an amount of time, where 3.6 terajoules (TJ) is equal to 1 000 megawatt hours (MWh).

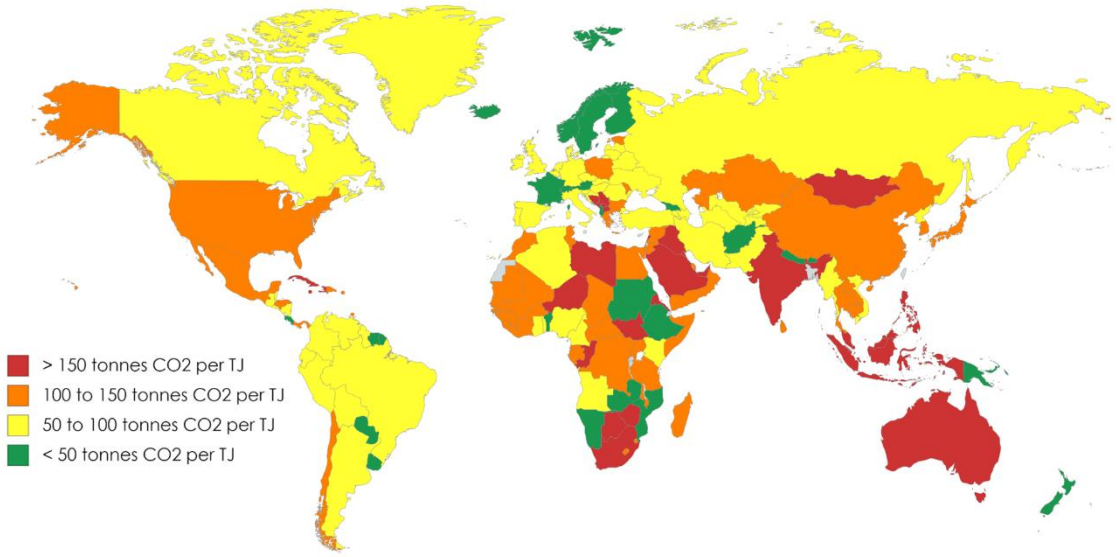



*Figure 13 - Carbon intensity of the building sector in 2015 (UNEP & IEA, 2017)*

## 4.3. Residential sector energy demand

South Africa's statistics on energy consumption per sector are limited, and estimates can vary, even in the same report, such as the Integrated Energy Plan 2016 (DoE, 2016). For example, estimates on the **energy consumption** of the residential sector as a percentage of the total, include:

| | |
|---|---|
| 19.3% | (DME, 2006) as quoted in (UNEP-SBCI, 2009, p. 25) |
| 9% | (DME, 2006) values adjusted by (UNEP-SBCI, 2009, p. 26) |
| 9% | (DEAT, 2007) as quoted in (UNEP-SBCI, 2009, p. 26) |
| 20% | (DoE, 2009b; DoE, 2016, p. 92), as quoted in (DEA, 2014, p. 108) |
| 17% | (DEA, 2014) |
| 14% | (DoE, 2016, p. 108) |
| 25% | (DEA, 2016) |

The estimates on **electricity consumption** appear to be more consistent amongst sources, with:

| | |
|---|---|
| 17% | ESKOM obtained values for 2006 quoted in (UNEP-SBCI, 2009, p. 28) |
| 18% | (DME, 2006) values adjusted by (UNEP-SBCI, 2009, p. 28) |
| 17% | (DoE, 2009a) as quoted in (DEA, 2014) |
| 20% | StatsSA 2013 data quoted in (Deloitte, 2017, p. 20) |

Estimates on **fuel types** used also vary considerably and are at times questionable, with the Integrated Energy Plan 2016 (IEP 2016) providing estimates for the use of wood as a residential fuel source of both ~20% and ~45%, and another report quoting 50% (DEA, 2014). Both these reports seem to be quoting the same source that also states that, in contradiction to the amount of wood reportedly used in the sector, electricity constitutes 73%, coal 29%, and petroleum products 7.4% of energy fuel use in the residential sector. The UNEP-SBCI (2009) report noted similar discrepancies and inflated values for coal and wood in (DME, 2006) data, specifically when compared to the Stats SA's 2007 General Household Survey's (HHS 2007) data on the dominant use of electricity in domestic cooking and heating.

My calculations, based on an analysis of this survey data for 2017 (Stats SA, 2017), show that electricity constitutes around 70% of the total energy consumption in the residential sector (as calculated in Table 3 below). This calculated value is in line with the energy consumption according to fuel used as reported in (UNEP-SBCI, 2009), which estimated a use of 69% electricity, 10% wood, 1% coal and 19% petroleum products.

*Table 3 – Calculating the percentage of residential energy sourced from electricity*

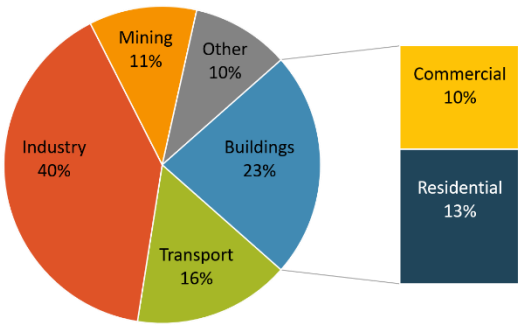
| | Lighting | Cooking | Space heating | Water heating | Other electrical appliances | Total | Source |
|---|---|---|---|---|---|---|---|
| % of people who use mains electricity as primary energy source for specific use | 87% | 80% | 38% | 81% | 100% | N/A | Q531a from HHS 2017 |
| Residential energy end-use split | 5% | 38% | 28% | 21% | 8% | 100% | IEP 2016 |
| Calculated % of electricity use by end use | 4% | 31% | 11% | 17% | 8% | **70%** | Own calculation |

*Data from Stats SA (2017) and DoE (2016)*

With the use of emissions coefficients, which estimate the greenhouse gas emissions per fuel type, the carbon emissions per sector is then determined in the UNEP-SBCI report (2009, p. 33), calculating the building sector's carbon emissions in 2006 as 23% of the total, with the **residential sector contributing 13% of the country's total emissions**, as per Table 4 below.

*Table 4 – The building sector and the residential market's carbon emissions in 2006*

| South African $CO_2$ emissions per sector in 2006 | % |
|---|---|
| Commercial | 10% |
| Residential | 13% |
| **Building sector subtotal** | **23%** |
| Transport | 16% |
| Industry | 40% |
| Mining | 11% |
| Other | 10% |
| **Total** | **100%** |




*Adapted from UNEP-SBCI (2009, p. 33)*

## 4.4. Residential building sector composition

South African Reserve Bank data shows that the annual growth in the building sector investment has remained relatively stable over the last decade, but is almost 50% higher than the three decades that preceded the building boom around the year 2000 (see Figure 14 below). It also indicates that in 2018 investments in the residential sector equalled that of the non-residential sector (Table 5 below), with private residential making up the largest portion of investments at 49% (South African Reserve Bank, 2018).

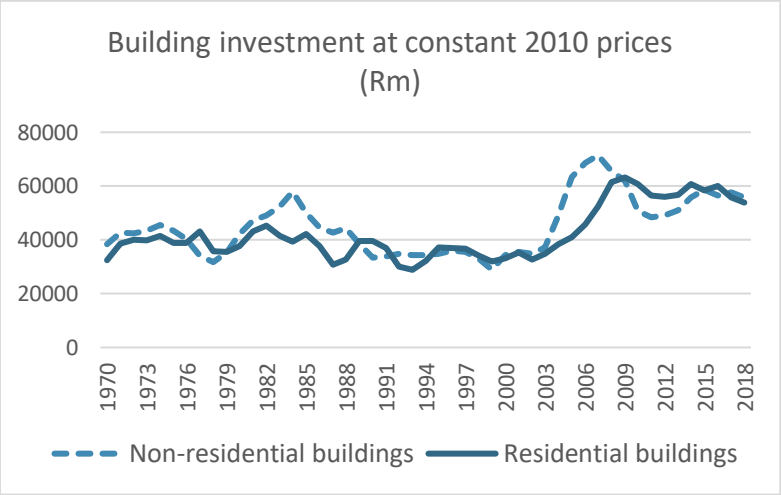
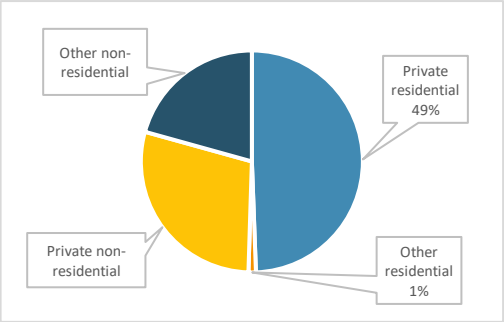



*Figure 14 - Building investment at constant 2010 prices in million Rands*
*Adapted from data series KBP6110 and KBP6114 from the South African Reserve Bank (2018)*

*Table 5 - Investment in the building sector in 2018*

| Investment in the building sector in 2018 | | | |
|---|---|---|---|
| **Sector** | | **R millions** | **%** |
| Residential | Government + Public | 1 850 | 1% |
| Residential | Private | 84 236 | 49% |
| Non-residential | Government + Public | 35 270 | 21% |
| Non-residential | Private | 49 118 | 29% |
| | | **170 474** | **100%** |




*Calculated from data series KBP6110 to KBP6117 from the South African Reserve Bank (2018)*

A survey of residential buildings reported as completed (after the submission of building plans to municipalities) show that for the different building types there has been little shift over the last decade in the relative percentage of number of units, areas, and

investment values, as per Table 6 below (Stats SA, 2018). It does not seem to indicate that there has been a shift towards flats or townhouses at the expense of individual dwellings in the last decade, despite what was suggested in earlier reports (UNEP-SBCI, 2009). **It does highlight that the bulk of the floor area growth and private investment lies in individual dwellings larger than 80m$^2$ and flats/townhouses, while dwellings smaller than 80m$^2$ has the largest increase in number of units.**

*Table 6 – Annual investment in residential buildings split per building type for 2007 and 2017*

| Residential building type | Units (Number) | | Area (m$^2$) | | Value (R'000) | |
|---|---|---|---|---|---|---|
| Year of completion | 2007 | 2017 | 2007 | 2017 | 2007 | 2017 |
| **Dwelling-houses < 80 m$^2$** | **56%** | **58%** | 24% | 25% | 11% | 13% |
| **Dwelling-houses >= 80 m$^2$** | 21% | 20% | **48%** | **48%** | **54%** | **52%** |
| Flats and townhouses | 23% | 22% | 27% | 23% | 32% | 29% |
| Other residential buildings (incl. tourism accommodation and casinos) | 1% | 0% | 2% | 4% | 3% | 6% |

*Calculated from data set P5041.3 of Stats SA (2018)*

Private sector investment as above does not capture the split between formal and informal dwellings in South Africa, which stood at over 16 million dwellings in 2018. Of this, 74% can be classified as formal and 26% as informal in 2018 (see Table 7 below), from a 57% formal, 43% informal split in 1993. On a year-on-year basis, formal housing has been increasing at an average of 3.1% per year since 1993, while informal housing has increased by only 0.1%. Overall, the number of dwellings has increased by an average of 2% per year (Quantec, 2018). The South African population growth rate was 1.4% for the period 2018-2019, with the rate showing an increasing trend, having been 1.0% for the period 2002-2003 (Stats SA, 2019). This shows that the **South African housing market is increasingly more formalised, at a rate that is higher than the average population growth.**

*Table 7 - Dwelling types in South Africa in 2018 split between formal and informal*

| Type of dwelling as of 2018 | Number of households | % of households | % in 2018 | % in 1993 |
|---|---|---|---|---|
| **Formal** | | | **74%** | **57%** |
| House or brick structure on a separate stand or yard | 10 357 930 | 65% | | |
| Flat in a block of flats | 811 446 | 5% | | |
| Town/cluster/semi-detached house (simplex, duplex or triplex) | 632 577 | 4% | | |
| **Informal** | | | **26%** | **43%** |
| Traditional dwelling/hut/structure made of traditional materials | 1 174 872 | 7% | | |
| House/flat/room, in backyard | 486 984 | 3% | | |
| Informal dwelling/shack, in backyard | 834 800 | 5% | | |
| Informal dwelling/shack, NOT in backyard, e.g. in an informal/squatter settlement | 1 466 344 | 9% | | |
| Room/flatlet not in backyard but on a shared property | 135 193 | 1% | | |
| Other/unspecified/NA | 143 832 | 1% | | |
| **Total** | **16 043 979** | **100%** | **100%** | **100%** |

*Adapted from Quantec (2018)*

## 4.5. Concluding summary

In summary, it has been shown that the residential sector is responsible for around 20% of South African's electricity and contributes around 13% of the country's total greenhouse gas (GHG) emissions. It also continues to become more formalised, and the number of dwellings is growing at a rate in excess of the South African population growth rate. If the number of households continues to rise, along with an increase in average household incomes (Deloitte, 2017), it is anticipated that the sector's electricity consumption will continue to rise. To limit this increase, and subsequently, the GHG emissions, both the residential energy intensity (energy consumed per household) and carbon intensity of the national energy supply must be reduced. South Africa's ability to effect this change, within the context of the current and proposed mandatory and voluntary tools are discussed in detail in the chapter that follows.

# 5. FINDINGS, ANALYSIS AND CONCLUSIONS

In order to decarbonise the building sector and stay within the +2°C limit[19], the Climate Bond Initiative (CBI) advocates a focus on '**total building emissions**', not just on improved energy efficiency. The International Energy Agency (IEA) states that only around a third of the required carbon reduction can be achieved through building efficiency alone (net zero buildings and deep renovations). The remaining two-thirds reduction requires a low carbon energy supply and the use of low carbon building materials (CBI, 2017).

## 5.1. Impact of individual building energy efficiency tools

The *mandatory* and *voluntary* building efficiency tools are discussed individually in the sections to follow, firstly to see which of the three '**total building emission**' reduction areas they align with, and then to detail their recency, target market and reach, and finally targeted savings and calculated achievable impact. A summary of the analysis is provided in section 5.1.9.

Projected savings and impacts are given as compared to 2015 as the reference year, as used in the post-2015 National Energy Efficiency Strategy (NEES). Thus, market growth is calculated from this date to determine reach, although efficiency improvements are set against those of the mandatory energy efficiency standards for the National Building Regulations (NBR), if applicable. EDGE also models its saving projections as a function of exceeding the NBR requirements.

[19] The Paris Agreement aims to hold "global average temperature to well below 2°C above pre-industrial levels" and to pursue "efforts to limit the temperature increase to 1.5°C above pre-industrial levels" (Paris Agreement, 2015, p. 29).

### 5.1.1. Impact of National Building Regulations and Standards

The table below provides an overview of the influence of the proposals in the post-2015 NEES in terms of the National Building Regulations and thermal retrofit incentives.

| Energy efficiency | Low carbon energy | Embodied energy | Last update | Residential Market | Income band | Target set | Reach | Achievable impact based on reach |
|---|---|---|---|---|---|---|---|---|
| **National Building Regulations and Standards** | | | | | | | | |
| Yes | Limited to water heating | No | September 2011<br><br>Significant update required by 2021 to meet NEES target | New builds and major renovations only<br><br>Applicable to both rental and bonded market | All housing that requires building plans must comply, but governmental subsidised housing has only been included since 2014 | 38% energy consumption reduction by 2030 from 2011 NBR - requires a 72% actual reduction in water and space heating from 2011 NBR | Applicable to all new builds, new stock built after 2015 assumed to be 20% of 2030 stock | **7.6% reduction** in the energy intensity of the 2030 residential building stock if ambitious targets are met |
| **Thermal retrofits incentives** | | | | | | | | |
| Yes | No | No | Only proposed in NEES as a supplement to EPCs | Existing | Different incentive types, from direct grants for low income to rebates for higher income | 15% energy intensity improvement for existing homes by 2030 through thermal retrofits – requires a 65% reduction in the electricity expended on space heating<br><br>10 to 15% improvement from multiple measures more typical | Applicable to all existing buildings, with those built before 2015 assumed to be 80% of 2030 stock.<br><br>1 to 2% annual refurbishment rate more likely, resulting in a maximum 30% of building stock refurbished by 2030 | 12% improvement of the energy intensity of the 2030 residential building stock if ambitious targets are met.<br><br>1% **reduction** in the energy intensity is considered a more achievable target |

*NBR - Focus area* – The National Building Regulations and Standards' primary focus is 'energy efficiency', as the 'Environmental Sustainability' portion (part X) of the national standards currently pertains only to 'Energy usage in buildings' (part XA), specifically the efficient use of energy. The embodied energy of the material used in construction is not

addressed, and the carbon intensity of the energy used is only considered as part of the hot water heating requirement. While the use of solar energy for water heating can be considered a low carbon energy source, other suggested technologies such as heat pumps are also energy efficiency measures.

*Reach* – The NBR requires that all new buildings or major refurbishments are designed and built so that their passive design (orientation, shading, services, and building envelope) ensure efficient use of energy, and that at least 50% of hot water generation (by volume) take place without the use of electric resistance heating[20], such as solar water heating (dti, 2011).

*Target* - To achieve its targets, the NEES (DEA, 2016) requires (1.) a 38% reduction in household energy consumption in new builds, through tightening of the current National Building Regulations (NBR) energy efficiency standards by 2030, with the assumption that (2.) at least 20% of all buildings in 2030 will be built after 2015 or the introduction of the new standard. If met, it could result in a total impact of 7.6% reduction of energy consumption per square metre of 2030 residential building stock (excluding plug loads).

It is important to note that raising the minimum standards of the NBR by the proposed 38% would not guarantee an equivalent energy consumption reduction in the new homes implementing the improved standard. This is because implementing the requirements of the standard would only ensure that the notional energy use of buildings is improved, but no measurements are required to confirm or prove savings expected.

(1.) To achieve an overall reduction of 38%, a significant tightening of the NBR is required, as it currently mandates only efficiency requirements for hot water

[20] The conventional approach to water heating for domestic use uses an electrical element inside a geyser to heat water ('electric resistance heating'). SANS 10400–XA Regulations require that all new buildings utilise other means of heating for at least 50% of the water, such as solar water heaters, heat pumps and gas geysers.

systems and the passive design (orientation, shading, services, and building envelope insulation). As water and space heating accounts for only 53% of the energy consumed in urban medium- and high-income households (UNEP-SBCI, 2009, p. 29), it would require an average efficiency improvement of 72% for these two systems to meet the 38% target.

(2.) Analysis of available data (Quantec, 2018) indicates that 26% of overall and 33% of formal households projected to have been built by 2030, will be built after 2015. The NBR is however applicable only to *formal* dwellings, and with medium- and high-income households responsible for 89% of total electricity consumption (UNEP-SBCI, 2009, p. 29), the homes built from 2016 will consume 23% and 30% of electricity respectively. As per the last column in Table 8 below, in order to achieve the requisite minimum 20% of formal new housing for the target, the NBR standards must be tightened by the proposed 38% by 2021 at the latest.

In January 2020 a draft of an updated version of the standard was released for public comment. While the maximum annual energy consumption of commercial buildings is set to be reduced significantly if the standard implemented in its current form, it is yet unclear to what extent the proposed update will influence the energy intensity of residential buildings (SANS 10400-XA (draft), 2020).

*Table 8 - Increase in housing between 2016 and 2030*

| Type of dwelling | Increase in households between date and 2030 | | Total households at the date | % of households in 2030 which was built from date | | % energy in 2030 from homes built after the date | |
|---|---|---|---|---|---|---|---|
| | **2016** | **2021 (projected)** | **2030 (projected)** | **2016** | **2021** | **2016** | **2021** |
| Overall | 5 517 645 | 3 818 889 | 20 980 686 | 26% | 18% | 23% | 16% |
| Formal | 5 628 117 [21] | 3 954 887 | 16 880 580 | 33% | 23% | 30% | 21% |

*Calculated from Quantec (2018)*

[21] The increase in number of formal households is larger than the increase in overall households as the absolute number of informal housing is falling.

*Thermal Retrofit Incentives - Focus area* – As an interim measure for buildings that are existing or built before the proposed NBR update, financial incentives are proposed to encourage the undertaking of thermal retrofits.

*Reach and target* - The NEES targets a 15% improvement for existing homes, which would amount to around 80% of the residential building stock in 2030.

*Achievable impact* - Globally, the typical renovation rates are about 1% to 2% of the building stock per year, with an overall energy intensity improvement of 10% to 15% from multiple improvement measures (GlobalABC & UNEP, 2016; IEA & UNEP, 2018). It is thus unlikely that the 15% improvement of the total existing stock would be achieved by 2030. If met, it would result in an overall impact of 12% reduction of energy consumption, which conflicts with a report cited in the NEES that states that the potential for energy intensity improvements from passive thermal design is limited to 5% (DEA, 2016, p. 12). In order to achieve the target of 15% improvement, it would require a 65% reduction in the electricity expended on space heating, as space heating accounts for only 23% of households' average electricity consumption (UNEP-SBCI, 2009).

Assuming an optimistic average renovation rate of 2% per year, with a 10% energy intensity improvement starting in 2020, a more realistic, if bullish, target for South Africa is a 1% improvement in the residential stock's energy intensity due to thermal retrofits.

### 5.1.2. Impact of Energy Performance Certificates

*Focus area* – Energy performance certificates (EPCs) report on the energy intensity of a property and serve as an informative tool for both owners and occupiers, on the energy efficiency of a building. Because EPCs have been shown to improve the sales and rental price of properties, they drive improvement in energy efficiency and alternative energy sources. An overview of the influence of EPCs, as proposed by the post-2015 NEES is provided in the table below.

| Energy efficiency | Low carbon energy | Embodied energy | Last update | Residential Market | Income band | Target set | Reach | Achievable impact based on reach |
|---|---|---|---|---|---|---|---|---|
| Yes | Yes – promotes solar in that it lowers the overall energy consumption and improves rating | No | Proposed by NEES | Newly constructed and existing | All formal housing that is rented or sold | No target is set, as EPC is supportive of energy efficiency renovations, but a range of 2 to 3% may be possible | May be mandatory on property transfer – property turnover may take between 10 and 20 years<br><br>May be mandatory for rentals – 46% of the market | The majority of properties could have EPC by 2030, although energy intensity improvements only seen later.<br><br>The national database of residential energy intensity, track the impact of building policies and implementation of minimum energy efficiency requirements |

*Reach and target* - The NEES envisions the use of EPCs for both newly constructed and existing residential stock, with different strategies for owners and renters. As per the 2017 Household Survey (Stats SA, 2017), 56% of households own the dwellings they occupy, while 30% rent and 14% occupy rent-free. For owners, the NEES may explore the use of incentives such as rebates on Transfer Duty if made voluntary, or making EPCs mandatory upon transfer of a property. If South African tenure trends are similar to other countries (Moon & Miller, 2018; GBCSA, 2018), it takes between 10 and 20 years for properties to change hands, the point at which a mandatory EPC on transfer would be required. The majority of properties could thus feasibly have an EPC by 2030, although the energy intensity impact may only be felt later as the market matures its response to EPC ratings (DEA, 2016). EPCs may be made mandatory for rentals (up to 44% of the market), due to the split incentive that exists, as the tenant receives the benefits from lower utility bills, instead of the owner.

*Achievable impact* - International studies show a broad band of possible impacts of implementing EPCs, with the most conservative in the range of 2% to 3% energy consumption reduction (Wong & Kruger, 2017). The NEES provides no targeted energy intensity improvement as a result of EPC implementation, and this may be due to the

difficulty in separating the impact due to policies and standards, or wholly due to the market incentive created by the EPCs. As EPCs serve as a national source of information on the energy intensity of properties, they can also be a tool used to track the impact of building policies and the implementation of minimum energy efficiency requirements (BPIE, 2014)

### 5.1.3. Impact of Appliance Minimum Energy Performance Standards

The table below provides an overview of the influence of the post-2015 NEES proposal of successively tightened minimum energy performance standards (MEPS), a scrappage scheme for old inefficient appliance, mandatory labelling, and energy endorsement labels.

| Energy efficiency | Low carbon energy | Embodied energy | Last update | Residential Market | Income band | Target set | Reach | Achievable impact based on reach |
|---|---|---|---|---|---|---|---|---|
| Yes | No | No | November 2014<br><br>NEES target requires two successive tightening of MEPS before 2030 | All | Middle to upper<br><br>Lower may decide on second hand – incentive to scrap | All new appliances purchased by 2030 consume on average 33% less energy relative to a 2015 baseline | 75% of current appliances will be replaced at least once by 2030.<br><br>No further efficiency gains from the current standard, thus tightening of MEPS are required.<br><br>54% of equipment in households by 2030 will be more efficient if MEPS updated by 2021 | 15% MEPS tightening by 2021 would result in a **4 to 6% reduction** in residential energy intensity by 2030. |

*Focus area* – Energy efficiency only, thus measure does not seek to address any of the other focus area

*Reach and target* - Minimum Energy Performance Standards (MEPS), combined with energy labels, have been shown to be an effective method to encourage appliance energy efficiency (Götz, et al., 2016). Up to 77% of electricity is consumed by lighting and appliances used for water heating, cooking, cold storage, and laundry in urban high-medium income households in South Africa (UNEP-SBCI, 2009). It is this large segment that is being targeted by the MEPS and energy labels (Figure 15), with the NEES targeting

an overall 33% reduction in average specific energy consumption of new household appliances purchased by 2030 (DEA, 2016).

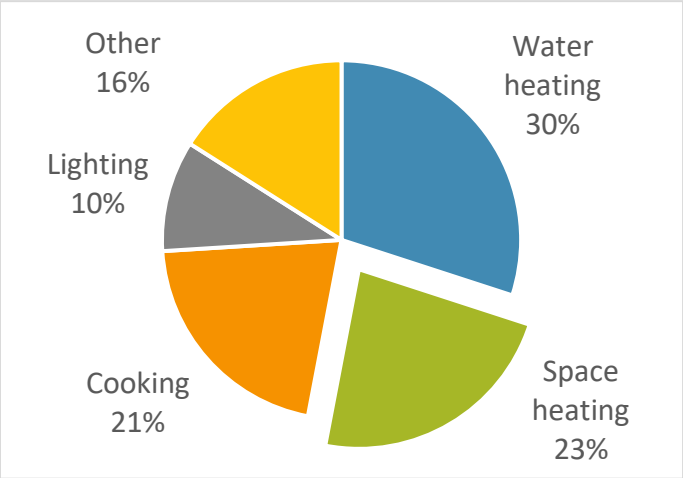



*Figure 15 - Urban high-medium income household electricity consumption patterns*
*Adapted from UNEP-SBCI (2009)*

*Achievable impact* - As appliances typically have a lifespan of between 7 and 20 years (CBI, 2017), short-lived appliances only have one or two upgrade cycles between now and 2030. Recently purchased appliances with long lifespans may not be replaced by 2030 at all. To reach the 33% NEES target, it proposes that two successive tightening of the MEPS take place before 2030. Assuming a uniform distribution of appliance lifespans and purchase dates, 75% of current appliances will be replaced at least once by 2030. A study by Götz, Tholen, Adisorn and Covary (2016) on the impact of the South African MEPS that came into effect in 2015, showed that the majority of appliances already met the minimum standard by 2014, indicating that no further efficiency gains can be expected unless the current standard (2015 MEPS) is raised.

On the assumption that a 15% MEPS tightening takes place by 2021, 54% of equipment in households by 2030 will be based on the new MEPS, resulting in an average specific energy consumption reduction for appliances of 8%. Given that 77% of total household energy consumption is from appliances in Urban High-Medium Income homes, the improved MEPS could result in a 6% reduction in residential energy intensity by 2030. With 30% of energy consumption in these homes due to water heating (UNEP-SBCI, 2009), there may be an overlap and double accounting of the savings targeted under the

improved MEPS and the improved NBR discussed in section 5.1.1. Discounting any improvements in the water heating category to account for possible overlap in savings, would then provide a potential 4% reduction in residential energy intensity by 2030 due to improved MEPS.

### 5.1.4. Impact of public energy efficiency educational programs

In the 2017 General Household Survey (Stats SA, 2017), when asked what the top three priorities of the Department of Energy should be, households placed energy security as the top priority. The International Energy Agency defines 'energy security' as "the uninterrupted availability of energy sources at an affordable price" (IEA, 2019). This is captured in the top responses, which dealt with the cost of electricity, the provision of free electricity to poor households, and avoiding load shedding (in order of priority). Providing information on how to save electricity was rated 4$^{th}$ on the list of priorities.

| Energy efficiency | Low carbon energy | Embodied energy | Last update | Residential Market | Income band | Target set | Reach | Achievable impact based on reach |
|---|---|---|---|---|---|---|---|---|
| **Yes** | Yes | No | Ongoing programmes | Existing | Middle to upper, but suggestion to provide information specifically tailored to low-income groups | None | | None quantified |

The NEES states that campaigns to provide energy conservation and sustainable energy information should continue, so that consumers can positively respond to market signals, such as the labelling of energy-efficient appliances. It does, however, recognise that these programmes are often aimed at middle- and upper-income groups, and suggest that municipalities develop programmes specifically aimed at low-income groups. These groups often spend a disproportionate amount of household income on

energy and suffer from the health consequences associated with using biomass for cooking and heating (DEA, 2016; SEA, 2017).

It is often impossible to separate the energy improvement due to behavioural changes from equipment replacement (Lopes, et al., 2012) and the NEES does not set an energy intensity reduction target based on this proposed measure.

### 5.1.5. Impact of Small-Scale Embedded Generation

The table below provides an overview of the potential influence of the SSEG in the South African residential market, followed by a detailed discussion of its content.

| Energy efficiency | Low carbon energy | Embodied energy | Last update | Residential Market | Income band | Target set | Reach | Achievable impact based on reach |
|---|---|---|---|---|---|---|---|---|
| No – typically encouraged to reduce costs of PV install | Yes | No | No government incentives for residential solar, although local municipalities' SSEG tariffs are under development | All<br><br>More typical in owner-occupied, unless property manager does on-selling of generated PV electricity | Middle to upper for private purchase – long payback periods<br><br>May be installed in residential complexes, then gap market and up | IRP 2015 caps maximum to 500 MW new capacity per annum | Maximum 15% residential penetration in mature markets | Up to **1% reduction** in residential energy intensity by 2030. |

*Focus area* – While the installation of solar PV or other alternative energy sources does not equate to improved energy efficiency, energy efficiency improvements are often promoted as the first step before progressing to solar energy. Lower energy consumption due to energy efficiency improvements reduces the size and cost of the alternative energy system required (Vieira, 2006; Matt Power for Green Builder Media, 2016; SEA, 2017; GBCSA, 2019b; D'Agostino & Mazzarella, 2019).

*Reach* - Solar PV has a much better business case in commercial applications than residential applications, due to a mismatch between residential peak electricity demand

and peak solar power generation, with some local suppliers advising against a solar system if it is not grid-tied (Green Energy Solutions, 2019). Solar PV is also more common with owner-occupied properties than rental properties as the benefit primarily accrues to the occupant. Some commercial property developers and managers in both the residential and non-residential sector do however install PV solar on their properties for on-selling the solar energy to the tenant, and to improve the 'green' characteristics and marketability of the property. The property developers and managers who have previously installed such systems include Similan Properties, International Housing Solutions, Balwin Properties, Johannesburg Housing Company, Attacq and Atterbury (Harms, 2020).

*Achievable impact* - Depending on the system size and tariff structure, residential solar PV projects can have a typical payback period from 12 to over 20 years. Commercial projects typically have a payback period of 10 years or less, giving PV projects in this sector a more reasonable business case. Due to these factors, residential SSEG market penetration tends to be low, with world leader Australia having achieved a penetration rate of 15% by 2015, while Belgium has a rate of 7% (SEA, 2017).

While Section 12B of the Income Tax Act allows companies to accelerated capital depreciation of renewable energy assets, there are currently no tax incentives aimed at the homeowner in the residential market. A potential residential SSEG consumer can either be incentivised or discouraged through the SSEG tariff structure that municipalities develop, but a cost-reflective SSEG does not pose a significant threat to a municipality's financial sustainability, even at penetration rates as high as 20% (SEA, 2017).

The IRP 2019 currently places a cap of 500 MW additional SSEG capacity per year (DME, 2019) and the market is expected to grow to this saturation point from the current rate of around 200 MW of new systems per year (GreenCape, 2019). If this point is reached in the next five years, the overall installed SSEG capacity will by around 5 GW in 2030, equating to 6% of the total installed generating capacity in the country. Assuming the

residential sector remains at 15% of the installed systems (GreenCape, 2019), it would represent a 1% reduction in the energy intensity of the sector by 2030.

### 5.1.6. Impact of EDGE certification

The table below provides an overview of the potential influence of EDGE certification in the South African residential market, followed by a detailed discussion of its content.

| Energy efficiency | Low carbon energy | Embodied energy | Last update | Residential Market | Income band | Target set | Reach | Achievable impact based on reach |
|---|---|---|---|---|---|---|---|---|
| Yes | Not required, but encourage to achieve EDGE Zero Carbon | Yes<br><br>Refurbishes get recognised for material reuse | Savings are measured against NBR, thus tightening requires an update of NBR | New and major refurbishments<br><br>Currently seen in rentals supported by developmental funds | From affordable housing and up.<br><br>Local market dominated with multi-unit residentials in the affordable sector | Min 20% reduction in each of the categories – electricity, water, embodied energy | Up to 10% of new build formal market.<br><br>New formal stock built after 2017 assumed to be 32% of 2030 stock | Up to **0.5% reduction** in the energy intensity of the sector by 2030. |

*Focus area* – To pursue certification, the EDGE standard of 20% less energy use, 20% less water use, and 20% less embodied energy in materials compared to a base case building[22] must be achieved, which is then independently verified and certified. This makes EDGE one of the only green building certification schemes that explicitly address the embodied energy or 'upfront carbon' of constructing buildings. In 2019, additional levels of certification became available in the form of EDGE Advanced and EDGE Zero Carbon, which require 40% less energy use and 100% carbon neutral, respectively. Low carbon energy sources are not required for the standard EDGE certification, although achieving EDGE Zero Carbon would involve either renewable energy sources or carbon offsets.

[22] EDGE models its saving projections as a function of exceeding the consumption of a base case building with the same overall dimensions, which in South Africa would be a building that meets the National Building Regulation requirements.

*Reach and achievable impact* – Many local residential EDGE certifications locally are being pursued by developers in the affordable or gap housing market, primarily due to the social co-benefits that have attracted funding by Development Finance Institutions, but also for market differentiation. The International Housing Solutions Fund II has enabled the development of 5 000 EDGE certified residential units, of the nearly 10 000 certified units between 2017 and 2019 (CSS, 2019). With between 40 000 and 50 000 residential buildings being completed annually, EDGE certified units could represent up to 10% of all new homes being constructed annually.

By 2030, 32% of the formal housing would have been built after 2030 (Quantec, 2018), meaning that up to 3% of the total housing stock could be EDGE certified. As EDGE certification requires buildings to be at least 20% more efficient than the local building codes, it could equate to a 0.5% reduction in the energy intensity of the sector by 2030.

### 5.1.7. Impact of Net Zero certification

The table below provides an overview of the potential influence of Net Zero certification in the South African residential market, followed by a detailed discussion of its content.

| Energy efficiency | Low carbon energy | Embodied energy | Last update | Residential Market | Income band | Target set | Reach | Achievable impact based on reach |
|---|---|---|---|---|---|---|---|---|
| Yes | Yes | Not current certification focus, but will be included in future versions | No mandatory requirement | New and major refurbishments<br><br>Potentially in rentals supported by developmental funds | High income if self-funded.<br><br>Potentially in gap market rentals if supported by developmental funds | Net Zero requires zero emissions | Up to 0.75% of new build formal market.<br><br>New formal stock built after 2015 assumed to be 33% of 2030 stock | Up to **0.25% reduction** in the energy intensity of the sector by 2030. |

*Focus area* – Energy efficiency and low carbon energy are generally required for Net Zero certifications, which will typically set a minimum level of energy efficiency. Only once this level is reached can the remainder of the energy needs be produced from low carbon energy sources, such as PV solar, or by purchasing carbon offsets. Embodied energy is not currently included as a focus area in most Net Zero certifications, although it may be included in future versions (WorldGBC, 2019d).

*Reach and achievable impact* - To meet the 2-degree goals[23] provided by the IPCCC, net zero emissions for all sectors must be reached by 2050 or earlier. In support of this, several organisations are calling for net zero buildings, with typical targets set as 2030 for all new builds and 2050 for existing buildings (GlobalABC & UNEP, 2016; WorldGBC, 2018a). Currently, net zero new builds make up less than 5% in most markets (IEA & UNEP, 2018). While the South African National Development Plan Vision 2030 set the objective of creating a zero-emission building standard by 2030, the post-2015 NEES only targets a 38% energy consumption reduction due to improved NBR requirements. Municipal bylaws that mandate net zero buildings are currently in development, but in the absence of current specific government-mandated net zero requirements for the residential market, it is assumed that South African new builds will not currently exceed the typical 5% penetration rate. As PV solar is typically key to generating the energy in net zero building, it is assumed that the residential vs non-residential split in net zero buildings will be similar to that of the PV spread in South Africa, where only 15% is due to the residential market.

Thus, a residential penetration of net zero is assumed as reaching a maximum of 0.75% of the market. Analysis of Quantec data (2018) indicates that 33% of formal households projected to have been built by 2030, will be built after 2015, meaning up to 0.25% of all formal houses could be net zero in 2030. As Net Zero certification requires a building

[23] The Paris Agreement aims to hold "global average temperature to well below 2°C above pre-industrial levels" and to pursue "efforts to limit the temperature increase to 1.5°C above pre-industrial levels" (Paris Agreement, 2015, p. 29).

to produce as much emission-free energy as it consumes, it could equate in a 0.25% reduction in the energy intensity of the sector by 2030.

### 5.1.8. Impact of Green financing

Internationally, there is a robust appetite for green bonds which is evident in the scale of oversubscription and other benefits when they are issued (CBI, 2017; CSS, 2019; Walker, 2019). These bonds are accessed by aggregators, including residential property investors and home loan providers, such as banks and home loan companies (CSS, 2019). Green home loans and green bonds facilitate the investment into technologies that reduce energy intensity, whether through energy efficiency, renewable energy, or thermal envelope upgrades. Some have argued that in the absence of a global carbon pricing scheme, green bonds are key to financial climate change mitigation projects (Blanding, 2019). Still, questions have been raised as to whether those projects would not have taken place, despite the availability of green bonds (Walker, 2019). The impact of green financing is thus poorly defined, and no energy intensity reduction is quantified based on this measure, as per the summary table below.

| Energy efficiency | Low carbon energy | Embodied energy | Last update | Residential Market | Income band | Target set | Reach | Achievable impact based on reach |
|---|---|---|---|---|---|---|---|---|
| **Green home loans** | | | | | | | | |
| **Yes** | Yes | No | Market-driven | New and existing bonded homes | Middle to upper-income homeowners | Improve the building efficiency renovation rate | Still a small market even internationally | Facilitates the investment into technologies that reduce the sector's energy intensity, impact not quantified |
| **Green Bonds** | | | | | | | | |
| **Yes** | Yes | Yes | Market-driven | Utilised by residential property investors and home loan providers | From affordable housing and up | Improved access and reduced cost for green financing | Green bonds constitute 1% of bond markets, 28% of this allocated to green buildings | Facilitates the investment into technologies that reduce the sector's energy intensity, impact not quantified |

## 5.1.9. Summary table of the impact of common residential building efficiency tools in South Africa

| Tool (paragraph) | Energy efficiency | Low carbon energy source | Embodied energy | Last update | Residential Market | Income band | Target set | Reach | Achievable impact based on reach |
|---|---|---|---|---|---|---|---|---|---|
| **NBR (5.1.1)** | Yes | Limited to water heating | No | September 2011<br><br>Significant update required by 2021 to meet NEES target | New builds and major renovations only<br><br>Applicable to both rental and bonded market | All housing that requires building plans must comply, but governmental subsidised housing has only been included since 2014 | 38% energy consumption reduction by 2030 from 2011 NBR - requires a 72% actual reduction in water and space heating from 2011 NBR | Applicable to all new builds, new stock built after 2015 assumed to be 20% of 2030 stock | **7.6% reduction** in the energy intensity of the 2030 residential building stock if ambitious targets are met |
| **Thermal retrofits incentives (5.1.1)** | Yes | No | No | Only proposed in NEES as a supplement to EPC's | Existing | Different incentive types, from direct grants for low income to rebates for higher income | 15% energy intensity improvement for existing homes by 2030 through thermal retrofits – required a 65% reduction in the electricity expended on space heating<br><br>10 to 15% improvement from multiple measures more typical | Applicable to all existing buildings, with those built before 2015 assumed to be 80% of 2030 stock.<br><br>1 to 2% annual refurbishment rate more likely, resulting in a maximum 30% of building stock refurbished by 2030 | 12% improvement of the energy intensity of the 2030 residential building stock if ambitious targets are met.<br><br>1% **reduction** in the energy intensity is considered a more achievable target |

| Tool (paragraph) | Energy efficiency | Low carbon energy source | Embodied energy | Last update | Residential Market | Income band | Target set | Reach | Achievable impact based on reach |
|---|---|---|---|---|---|---|---|---|---|
| **EPC (5.1.2)** | Yes | Yes – promotes solar in that it lowers the overall energy consumption and improves rating | No | Only proposed for residential by NEES | Newly constructed and existing | All formal housing that is rented or sold | No target is set, as EPC is supportive of energy efficiency renovations, but a range of 2 to 3% may be possible | May be mandatory on property transfer – property turnover may take between 10 and 20 years<br><br>May be mandatory for rentals – 46% of the market | The majority of properties could have EPC by 2030, although energy intensity improvements only seen later.<br><br>A national database of residential energy intensity, track the impact of building policies and implementation of minimum energy efficiency requirements |
| **Appliance MEPS (0)** | Yes | No | No | November 2014<br><br>NEES target requires two successive tightening of MEPS before 2030 | All | Middle to upper<br><br>Lower may decide on second hand – incentive to scrap | All new appliances purchased by 2030 consume on average 33% less energy relative to a 2015 baseline | 75% of current appliances will be replaced at least once by 2030.<br><br>No further efficiency gains from the current standard, thus tightening of MEPS are required.<br><br>54% of equipment in households by 2030 will be more efficient if MEPS updated by 2021 | 15% MEPS tightening by 2021 would result in a **4% to 6% reduction** in residential energy intensity by 2030. |

| Tool (paragraph) | Energy efficiency | Low carbon energy source | Embodied energy | Last update | Residential Market | Income band | Target set | Reach | Achievable impact based on reach |
|---|---|---|---|---|---|---|---|---|---|
| **Education (0)** | Yes | Yes | No | Ongoing programmes | Existing | Middle to upper, but suggestion to provide information specifically tailored to low-income groups | None | | None quantified |
| **Solar PV (5.1.5)** | No – typically encouraged to reduce costs of PV install | Yes | No | No government incentives for residential solar, although local municipalities' SSEG tariffs are under development | All<br><br>More typical in owner-occupied, unless property manager does on-selling of generated PV electricity | Middle to upper for private purchase – long payback periods<br><br>May be installed in residential complexes, then gap market and up | IRP 2015 caps maximum to 500 MW new capacity per annum | Maximum 15% residential penetration in mature markets | Up to **1% reduction** in residential energy intensity by 2030. |
| **EDGE certification (0)** | Yes | Not required, but encourage to achieve EDGE Advanced or EDGE Zero | Yes<br><br>Refurbishes get recognised for material reuse | Savings are measured against NBR; thus tightening requires an update of NBR | New and major refurbishments<br><br>Currently seen in rentals supported by developmental funds | From affordable housing and up.<br><br>Local market dominated with multi-unit residentials in the affordable sector | Min 20% reduction in each of the categories – electricity, water, embodied energy | Up to 10% of new build formal market.<br><br>New formal stock built after 2017 assumed to be 32% of 2030 stock | Up to **0.5% reduction** in the energy intensity of the sector by 2030. |

| Tool (paragraph) | Energy efficiency | Low carbon energy source | Embodied energy | Last update | Residential Market | Income band | Target set | Reach | Achievable impact based on reach |
|---|---|---|---|---|---|---|---|---|---|
| **Net Zero certification (5.1.7)** | Yes | Yes | Not current certification focus, but will be included in future versions | No mandatory requirement | New and major refurbishments<br><br>Potentially in rentals supported by developmental funds | High income if self-funded.<br><br>Potentially in gap market rentals if supported by developmental funds | Net Zero requires zero emissions | Up to 0.75% of new build formal market.<br><br>New formal stock built after 2015 assumed to be 33% of 2030 stock | Up to **0.25% reduction** in the energy intensity of the sector by 2030. |
| **Green home loans (5.1.8)** | Yes | Yes | No | Market-driven | New and existing bonded homes | Middle to upper-income homeowners | Improve the building efficiency renovation rate | Still a small market even internationally | Facilitates the investment into technologies that reduce the sector's energy intensity, impact not quantified |
| **Green Bonds (5.1.8)** | Yes | Yes | Yes | Market-driven | Utilised by residential property investors and home loan providers | From affordable housing and up | Improved access and reduced cost for green financing | Green bonds constitute 1% of bond markets, 28% of this allocated to green buildings | Facilitates the investment into technologies that reduce the sector's energy intensity, impact not quantified |

## 5.2. Conclusion - Overall climate mitigation contribution

This section concludes the research report by summarising the key findings of the analysis conducted on the common residential building efficiency tools in South Africa and my interpretation of their impact within the context of the provided background.

Given the analysis of the current proposed energy efficiency improvements as per the post-2015 NEES and commonly used voluntary tools in the residential market, it is possible that **by 2030 there could be up to a 16% reduction in the energy intensity of the residential sector**.

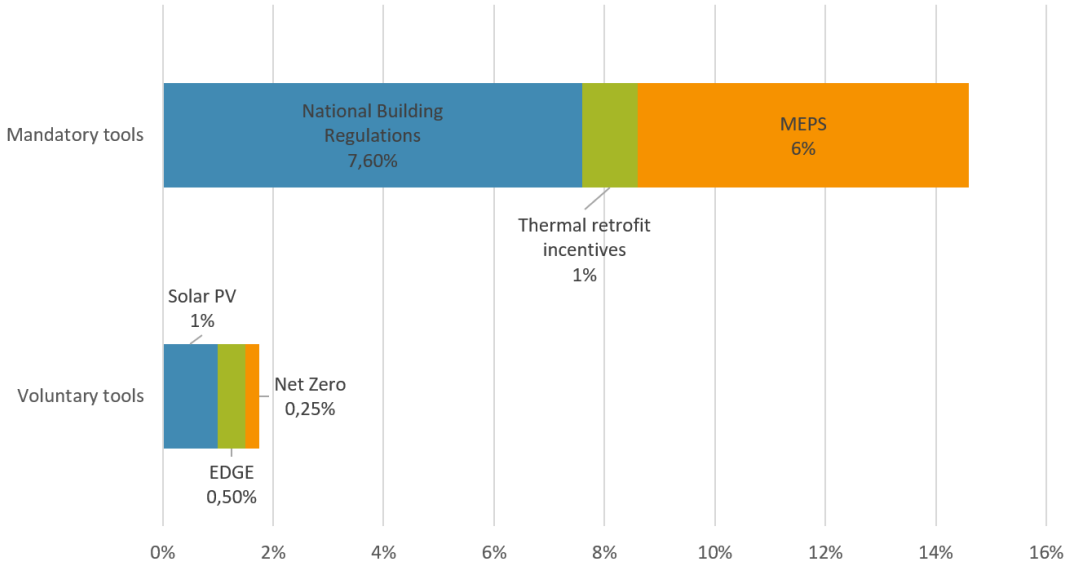



*Figure 16 - Energy intensity reduction potential of different building efficiently tools commonly used in South Africa*

If the South African residential market continues to grow at its current pace of around 2% per year, the housing market will be nearly 40% larger in 2030 than it was in 2015. This means that the projected 16% reduction in the energy intensity (measured as energy consumed per square metre) will be more than offset by the increased building floor area. This shows that the current targets are **insufficient to meet the peak, plateau and decline trajectory of our INDC** as they relate to building emissions specifically, and that more ambitious targets must be set and implemented within a reasonable time frame.

The projected massive growth in the South African housing market over the next decade and beyond, shows that **tools focussed on the new residential market are critical**. Over 80% of the total potential for energy intensity reduction can be derived from the *mandatory tools* that focus on the new build sector, namely the National Building Regulations and minimum performance standards for appliances.

The dominance of the potential impact by *mandatory* tools seems to confirm what others have stated, in that *voluntary* green building certifications do not directly contribute to a significant change in the residential sector's emissions, although they are becoming more common and demonstrate the tangible feasibility of low or zero carbon buildings (IEA & UNEP, 2018, p. 36)**. Mandatory regulations must thus continue to be updated timeously with standards (based on scientifically obtained targets) being tightened , and enforcement of it strengthened.** These areas are often sorely lacking in the South African sphere, where draft documents can linger in limbo while their potential impact fade, and they are no longer able to provide the desired positive impact.

While the projected energy reduction due to small scale embedded solar is relatively small in the medium term, the **impact of a decarbonized electricity grid is significant**. If the IRP 2019 is followed, coal-generated electricity will contribute 60% of the energy mix in 2030, down from the current level of 90%. This could result in a 35% reduction in the carbon emissions of the residential sector due to fuel switching alone.

Finally, despite providing a third of the carbon reduction potential, the **embodied energy of materials remains a poorly understood and a largely ignored** improvement area, only featuring in two of the voluntary tools and not in any of the mandatory tools. Within this context, in late 2019 the World Green Building Council launched a "Bringing Embodied Carbon Upfront" campaign to create a conversation around embodied energy and to further stimulate embodied carbon reductions. This is an area that deserves additional focus by all, given its large untapped potential.

Further research should be done on the potential impact of the updated energy efficiency standard of the South African National Building Regulations that was publish for comment in early 2020. This should include both the extent to which the new standard is able to reduce the energy consumption of the residential sector, and the ability of the sector to meet these requirements. Similar research could also be conducted on the net zero carbon building policies and municipal bylaws currently in development by the C40 cities and planned for implementation end 2020.

- END -

# REFERENCE LIST


Akerman, J. & Hojer, M., 2006. How much transport can the climate stand?—Sweden on a sustainable path in 2050. *Energy Policy,* Volume 34, p. 1944–1957.

ASAQS, GBCSA & UP, 2019. *Green building in South Africa guide to costs and trends,* Pretoria: Association of South African Quantity Surveyors, Green Building Council South Africa and the University of Pretoria.

ASHRAE SA Chapter & SEA, 2020. *GETTING TO ZERO: A Guide To Developing Net Zero Carbon Buildings In South Africa,* s.l.: C40 Cities - C40 South Africa Buildings Programme.

Bagnoli, M. & Watts, S. G., 2019. On the corporate use of green bonds. *Journal of Economics & Management Strategy,* pp. 1-23.

Bai, Y. et al., 2019. How does urbanization affect residential CO2 emissions? An analysis on urban agglomerations of China. *Journal of Cleaner Production,* Volume 209, pp. 876-885.

Balwin Properties, 2020. *The Reid.* [Online]
Available at: https://www.balwin.co.za/developments/the-reid/
[Accessed 19 March 2020].

Bhushan, C., 2019. *After 25 years of failure, we should abandon the UNFCCC.* [Online]
Available at: https://www.climatechangenews.com/2019/03/27/25-years-failure-abandon-unfccc/
[Accessed 9 October 2019].

Bir, B., 2020. *Anadola Agency, Qatar: 'Climate change issue demands COVID-19 like measures'.* [Online]
Available at: https://www.aa.com.tr/en/environment/qatar-climate-change-issue-demands-covid-19-like-measures-/1809519#
[Accessed 19 April 2020].

Blanding, M., 2019. *Harvard Business School Working Knowledge. 'Green Bonds' May Be Our Best Bet for Environmental Damage Control.* [Online]
Available at: https://hbswk.hbs.edu/item/green-bonds-may-be-our-best-bet-for-environmental-damage-control
[Accessed 30 November 2019].

Boden, T., Marland, G. & Andres, R., 2017. *Global, Regional, and National Fossil-Fuel CO2 Emissions, Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory,*

*U.S. Department of Energy.* [Online]
Available at: http://cdiac.ess-dive.lbl.gov/trends/emis/meth_reg.html
[Accessed 20 November 2019].

BP, 2018. *Statistical Review of World Energy.* [Online]
Available at: http://www.bp.com/en/global/corporate/energy-economics.html
[Accessed 20 November 2019].

BPIE, 2014. *Energy Performance Certificates across the EU. A mapping of national approaches,* Brussels: Buildings Performance Institute Europe.

Bruni, J., 2017. *The Economics of Green Building: The Green Rental Premium in Johannesburg, Unpublished Research Report,* Johannesburg: Faculty of Engineering and the Built Environment, University of the Witwatersrand.

Buildings Performance Institute Europe, 2014. *Energy Performance Certificates across the EU,* Brussels: Buildings Performance Institute Europe (BPIE).

BusinessDay, 2020. *Absa publishes coal-funding policy.* [Online]
Available at: https://www.businesslive.co.za/bd/companies/financial-services/2020-04-16-absa-publishes-coal-funding-policy/
[Accessed 20 April 2020].

BusinessTech, 2018. *The cost of living in a luxury vs middle-class vs low income area in South Africa right now.* [Online]
Available at: https://businesstech.co.za/news/property/263893/the-cost-of-living-in-a-luxury-vs-middle-class-vs-low-income-area-in-south-africa-right-now/
[Accessed 19 March 2020].

Caceres, A. G., 2018. Shortcomings and Suggestions to the EPC Recommendation List of Measures: In-Depth Interviews in Six Countries. *Energies,* 11(10), p. 2516.

CBI, 2017. *Climate Bonds Initiative. Aligning Buildings with the Paris Climate Agreement: Insights and Developments from the Green Bond Market.* [Online]
Available at:
https://www.climatebonds.net/files/files/Low%20Carbon%20Buildings%20Criteria%20Background%20Paper.pdf
[Accessed 9 January 2019].

CICERO, 2015. *CICERO Shades of Green.* [Online]
Available at: https://www.cicero.oslo.no/en/posts/single/cicero-shades-of-green
[Accessed 26 November 2019].

Ciplet, D. & Roberts, J. T., 2017. Climate change and the transition to neoliberal environmental governance. *Global Environmental Change,* Volume 46, pp. 148-156.

City of Cape Town, 2018. *Save Electricity - Driven by the City of Cape Town.* [Online] Available at: https://savingelectricity.org.za/resources/ [Accessed 20 November 2019].

Clar, C., Prutsch, A. & Steurer, R., 2013. Barriers and guidelines for public policies on climate change adaptation: A missed opportunity of scientific knowledge-brokerage. *Natural Resources Forum,* 37(1), pp. 1-18.

Climate Action Tracker, 2019a. *Effect of the US withdrawal from the Paris Agreement.* [Online] Available at: https://climateactiontracker.org/press/effect-of-the-us-withdrawal-from-the-paris-agreement/ [Accessed 24 February 2020].

Climate Action Tracker, 2019b. *South Africa Country Summary.* [Online] Available at: https://climateactiontracker.org/countries/south-africa/ [Accessed 16 November 2019].

Climate Action, 2018. *European banks launch green mortgage pilot scheme.* [Online] Available at: http://www.climateaction.org/news/european-banks-launch-green-mortgage-pilot-scheme [Accessed 24 February 2020].

Climate Focus, 2015. *The Paris Agreement Summary, Climate Focus Client Brief on the Paris Agreement III.* [Online] Available at: https://climatefocus.com/sites/default/files/20151228%20COP%2021%20briefing%20FIN.pdf [Accessed 24 October 2019].

CSS, 2019. *Consulting for Sustainable Solutions. South African Scoping Study: Assessing the Potential for Green Bonds Financing Green Buildings,* s.l.: ALCB Fund.

D'Agostino, D. & Mazzarella, L., 2019. What is a Nearly zero energy building? Overview, implementation and comparison of definitions. *Journal of Building Engineering,* Volume 21, pp. 200-212.

DEA, 2014. *GHG Inventory Report, South Africa, 2000 - 2010,* Pretoria: Department of Environmental Affairs.

DEA, 2016. *Draft v1.1 Post-2015 National Energy Efficiency Strategy, published for public comment (In Government Gazette 40515; Notice 948 of 2016),* Pretoria: Department of Environmental Affairs.

DEA, 2018. *Draft Climate Change Bill, published for public comment (In Government Gazette 41689; Notice 580 of 8 June 2018),* Pretoria: Department of Environmental Affairs.

DEA, 2019. *South Africa's 3rd Biennial Update Report to the United Nations Framework Convention on Climate Change,* Pretoria: Department of Environmental Affairs.

DEAT, 2007. *Energy Research Centre, Long Term Mitigation Scenarios: Technical Appendix,* s.l.: Department of Environment Affairs and Tourism.

Deloitte, 2017. *An overview of electricity consumption and pricing in South Africa. An analysis of the historical trends and policies, key issues and outlook in 2017. Report prepared for Eskom Holdings SOC Ltd,* s.l.: Deloitte Consulting.

DHS, 2014. *Enhancements to the national norms and standards for the construction of stand alone residential dwellings and engineering services and adjustment of the housing subsidy quantum,* Cape Town: Department of Human Settlements.

DME, 2006. *Department of Minerals and Energy, Aggregate Energy Balances for South Africa.* [Online]
Available at: http://www.dme.gov.za/energy/documents.stm
[Accessed - referenced in a 2009 report].

DME, 2019. *Integrated Resource Plan 2019, published for implementation (In Government Gazette 42784; Notice 652 of 18 October 2019),* Pretoria: Department of Mineral Resources and Energy.

DoE, 2009a. *Digest of South African Energy Statistics,* Pretoria: Department of Energy.

DoE, 2009b. *Electrification statistics,* Pretoria: Department of Energy, Electricfication Policy Development and Management Directorate.

DoE, 2016. *Integrated Energy Plan 2016,* s.l.: Department of Energy.

DPW, 2018. *Public Works Green Building Policy,* s.l.: Department of Public Works.

dti, 2011. *National Building Regulations and Building Standards Act, 1177 (Act 103 of 1177), Introduction of amendments to the National Building Regulations to introduce requirements for energy usage in buildings. (In Government Gazette 34586, Notice 711),* Pretoria: Department of Trade and Industry.

dti, 2014. *Compulsory Specification for Energy Efficiency and labeling of electrical and electronic apparatus (VC 9008). National Regulator for Compulsory Specifications Act*

*(Act 5 of 2008). (In Government Gazette 38232, Notice 944 of 28),* Pretoria: Department of Trade and Industry.

Ecolution Consulting, 2019. *South African Study: Reviewing the methodologies for certifying buildings under the CBI's Low Carbon Building criteria,* s.l.: ALCB Fund.

Engineering News, 2020a. *Balwin, Absa partner to launch South Africa's first green home loan.* [Online] Available at: https://www.engineeringnews.co.za/article/balwin-absa-partner-to-launch-south-africas-first-green-home-loan-2020-03-12/rep_id:4136 [Accessed 13 March 2020].

Engineering News, 2020b. *Absa imposes strict new coal project financing criteria.* [Online] Available at: https://www.engineeringnews.co.za/article/absa-imposes-strict-new-coal-project-financing-criteria-2020-04-16 [Accessed 20 April 2020].

European Commission, 2010. *EUROPE 2020 - A strategy for smart, sustainable and inclusive growth,* Brussels: European Commission.

European Commission, 2018. *Smarter, greener, more inclusive? Indicators to Support the Europe 2020 Strategy, 2018 edition,* Luxembourg: Publications Office of the European Union.

European Environment Agency, 2017. *Trends and projections in Europe 2017, Tracking progress towards Europe's climate and energy targets,* Luxembourg: Publications Office of the European Union.

Fawcett, A. A. et al., 2015. Can Paris pledges avert severe climate change?. *Science,* 350(6265), pp. 1168-1169.

Fin24, 2017. *SA banks slated for dirty energy investments.* [Online] Available at: https://www.fin24.com/Companies/Financial-Services/sa-banks-slated-for-dirty-energy-investments-20170615 [Accessed 20 April 2020].

GBCSA & WorldGBC, 2018. *Advancing Net Zero Snapshot: South Africa,* London: WorldGBC.

GBCSA, 2014. *Green Building Council South Africa. My Green Home.* [Online] Available at: http://mygreenhome.org.za/about-us/ [Accessed 21 August 2018].

GBCSA, 2017. *Green Building Council South Africa. EDGE - Residential.* [Online]
Available at: https://gbcsa.org.za/certify/edge/edge/
[Accessed 21 August 2018].

GBCSA, 2018. *Integrated Annual Report 2018,* Cape Town: Green Building Council South Africa.

GBCSA, 2019a. *Green Building Council South Africa. Green policies slowly help market growth.* [Online]
Available at: https://gbcsa.org.za/green-policies-slowly-help-market-growth/
[Accessed 23 November 2019].

GBCSA, 2019b. *Net Zero / Net Positive Certification Scheme Technical Manual V1.0,* s.l.: Green Building Council South Africa.

Global Carbon Project, 2018. *Global Carbon Atlas.* [Online]
Available at: http://www.globalcarbonatlas.org/en/CO2-emissions
[Accessed 20 November 2019].

GlobalABC & UNEP, 2016. *Roadmap for transition towards low-GHG and resilient buildings,* Kenya: Global Alliance for Building and Construction with UN Environment Programme.

Götz, T., Tholen, L., Adisorn, T. & Covary, T., 2016. *The New South African Standards and Labelling Programme for Residential Appliances – A First-Hand Evaluation Case Study.* Amsterdam, International Energy Policies & Programmes Evaluation Conference.

Government of South Africa, 2012. *National Development Plan 2030,* Pretoria: Government of South Africa.

Government of South Africa, 2015. *Nationally Determined Contribution (NDC).* [Online]
Available at: https://www4.unfccc.int/sites/submissions/indc/Submission%20Pages/submissions.aspx
[Accessed 15 November 2019].

Graham, P. & Rawal, R., 2019. Achieving the 2 degrees C goal: the potential of India's building sector. *Building Research and Information,* 47(1), pp. 108-122.

Gray, W. & Covary, T., 2015. *Proposal for a revision and extension of Table 2 of SANS 204:2011 / Table 3 of SANS 10400 XA (Maximum Annual Consumption per Building Classification for Each Climatic Zone),* Johannesburg: Solid Green.

Green Energy Solutions, 2019. *Standard solar power systems.* [Online]
Available at: https://www.greenenergysolutions.co.za/standard-solar-power-systems/
[Accessed 28 November 2019].

GreenCape, 2019. *Energy Services: Market Intelligence Report 2019,* Cape Town: GreenCape.

Harms, A., 2020. *Personal communication, Director, Ecolution Consulting* [Interview] (22 February 2020).

Hawken, P., 2017. *Drawdown: The Most Comprehensive Plan Ever Proposed to Reverse Global Warming.* New York: Penguin Books.

Hoffman, D., 2016. Green building costs in South Africa. *INNOVATE*, Volume 11, pp. 53-54.

Holm, D., Johannsen, A. & Harris, H., 2007. *Report OR-13554, Energy efficient homes and buildings: performance criteria for energy efficient naturally ventilated buildings in South Africa,* Pretoria: Department of Minerals and Energy.

IEA & UNEP, 2018. *2018 Global Status Report: towards a zero-emission, efficient and resilient buildings and construction sector,* s.l.: International Energy Agency and the United Nations Environment Programme.

IEA, 2014. *International Energy Agency. Capturing the Multiple Benefits of Energy Efficiency,* France: OECD/IEA.

IEA, 2017. *Energy Technology Perspectives 2017,* Paris: International Energy Agency/OECD.

IEA, 2019. *International Energy Agency. What is energy security?.* [Online]
Available at: https://www.iea.org/topics/energysecurity/whatisenergysecurity/
[Accessed 28 November 2019].

IFC, 2017. *Website of EDGE operated by the International Finance Corporation.* [Online]
Available at: https://www.edgebuildings.com/wp-content/uploads/2017/08/2017-07-27-English-version-EDGE-Brochure-HR.pdf
[Accessed 21 August 2018].

IFC, 2018a. *Methodology | EDGE Methodology Report.* [Online]
Available at: https://www.edgebuildings.com/technical/methodology/
[Accessed 24 February 2020].

IFC, 2018b. *Software | EDGE Buildings - Website of EDGE operated by the International Finance Corporation.* [Online]
Available at: https://www.edgebuildings.com/software/
[Accessed 21 August 2018].

IPCC, 2007. *Climate Change 2007: Synthesis Report,* Geneva, Switzerland: Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)].

IPCC, 2019. *IPCC Special Report, Global warming of 1.5C, Summary for Policy Makers,* Geneva, Switzerland: Intergovernmental Panel on Climate Change.

IPEEC, 2018. *International Partnership. South Africa's Appliance Energy Efficiency Label: How we are increasing consumer awareness.* [Online]
Available at: https://ipeec.org/bulletin/78-south-africas-appliance-energy-efficiency-label-how-we-are-increasing-consumer-awareness.html
[Accessed 23 November 2019].

Khosla, R. & Janda, K. B., 2019. India's building stock: towards energy and climate change solutions. *Building Research & Information,* 47(1), pp. 1-7.

Li, K. & Lin, B., 2015 . Impacts of urbanization and industrialization on energy consumption/CO2 emissions: Does the level of development matter?. *Renewable & Sustainable Energy Reviews ,* Volume 52, pp. 1107-1122.

Lopes, M., Antunes, C. & Martins, N., 2012. Energy behaviours as promoters of energy efficiency: A 21st century review. *Renewable and Sustainable Energy Reviews,* Volume 12, p. 4095– 4104.

Matt Power for Green Builder Media, 2016. *Green Building Pyramid Clarifies Construction Priorities for Your Clients.* [Online]
Available at: https://codewatcher.us/better-than-code/green-building-pyramid-clarifies-building-priorities-for-your-clients/
[Accessed 21 August 2018].

Moon, C. & Miller, M., 2018. *How Long Do Homeowners Stay in Their Homes? - ValuePenguin.* [Online]
Available at: https://www.valuepenguin.com/how-long-homeowners-stay-in-their-homes
[Accessed 28 November 2019].

MSCI, 2018. *Extracts from: Insights for Performance – IPD SA Annual Green Property Index – July 2018,* Cape Town: MSCI.

Nedbank Limited, 2017. *Nedbank funding makes green affordable housing a reality.* [Online]
Available at: https://nedbank.co.za/content/nedbank/desktop/gt/en/aboutus.html
[Accessed 21 August 2018].

Nedbank Limited, 2017. *Nedbank Smart Living Guide, 2nd Edition.* [Online]
Available at:
https://www.nedbank.co.za/content/nedbank/desktop/gt/en/aboutus/green-and-caring/Publications/nedbank-smart-living-guide.html
[Accessed 22 August 2018].

Nedbank Limited, 2019. *Smart Living Solutions.* [Online]
Available at:
https://www.nedbank.co.za/content/nedbank/desktop/gt/en/info/campaigns/home-loans-smart-living-solutions.html
[Accessed 19 November 2019].

Njobeni, S., 2017. *Business Report. Eskom wants to mothball five plants.* [Online]
Available at: https://www.iol.co.za/business-report/energy/eskom-wants-to-mothball-five-plants-8180946
[Accessed 25 February 2020].

OECD, 2015. *Sector Understanding on Export Credits for Coal-Fired Electricity Generation Projects.* [Online]
Available at:
https://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=TAD/PG(2015)9/FINAL&docLanguage=En
[Accessed 24 November 2019].

Paris Agreement, 2015. [Online]
Available at: https://treaties.un.org/doc/Treaties/2016/02/20160215%2006-03%20PM/Ch_XXVII-7-d.pdf
[Accessed 22 November 2019].

Parliamentary Monitoring Group, 2018a. *ATC181127: Report of the Portfolio Committee on Energy on the Draft Integrated Resource Plan 2018 (IRP2018) Public Hearings, dated 27 November 2018.* [Online]
Available at: https://pmg.org.za/tabled-committee-report/3488/
[Accessed 25 November 2019].

Parliamentary Monitoring Group, 2018b. *Regulations for the Mandatory Display and Submission of Energy Performance Certificates Buildings - Draft.* [Online]
Available at: https://pmg.org.za/call-for-comment/701/
[Accessed 2 April 2019].

Parliamentary Monitoring Group, 2019. *Audit outcomes: AGSA briefing; DMR, DoE & MHSC 2018/19 Annual Reports, with Minister.* [Online]
Available at: https://pmg.org.za/committee-meeting/28983/
[Accessed 22 November 2019].

Pasichnyia, O. et al., 2019. Energy performance certificates — New opportunities for data-enabled urban energy policy instruments?. *Energy Policy,* Volume 127, p. 486–499.

Quantec, 2018. *RSA Standardised Regional Development Indicators - Households' Facilities.* [Online]
Available at: https://www.easydata.co.za/dataset/RHHF/
[Accessed 13 November 2019].

SAGEN, 2019. *South African-German Energy Programme. Invitation To Apply For Support: Municipal Support for Small-scale Embedded Generation (SSEG) and Municipal Electricity Business Models.* [Online]
Available at: https://www.sagen.org.za/support-for-municipalities/sseg-support-for-municipalities
[Accessed 25 November 2019].

SANS 10400-XA (draft), 2020. *South African National Standard,* Pretoria: The application of the National Building Regulations. Part XA: Energy usage in buildings. Edition 2.

SANS 10400-XA, 2011. *South African National Standard,* Pretoria: The application of the National Building Regulations. Part XA: Energy usage in buildings. Edition 1.

SANS 1544, 2014. *South African National Standard. Energy Performance Certificates for Buildings,* s.l.: SABS Standards Division.

SANS 204-1, 2008. *South African National Standard. Energy efficiency in buildings, Part 1: General requirements,* s.l.: SABS Standards Division.

SAPVIA, 2019. *South African Photovoltaic Industry Association. SAPVIA welcomes licencing of SSEG projects.* [Online]
Available at: https://www.sapvia.co.za/sapvia-welcomes-licencing-of-sseg-projects/
[Accessed 22 November 2019].

Scholes, B., Scholes, M. & Lucas, M., 2015. Introduction. In: *Climate Change: Briefings from Southern Africa.* Johannesburg: Wits University Press, pp. 51-52.

SEA, 2017. *Sustainable energy solutions for South African local government: a practical guide,* Cape Town: Sustainable Energy Africa.

SEIA, 2020. *Solar Energy Industries Association, Solar Accounts for 40% of U.S. Electric Generating Capacity Additions in 2019, Adds 13.3 GW.* [Online]
Available at: https://www.seia.org/news/solar-accounts-40-us-electric-generating-capacity-additions-2019-adds-133-gw
[Accessed 19 March 2020].

South African Reserve Bank, 2018. *Online statistical query (historical macroeconomic timeseries information).* [Online]
Available at: https://www.resbank.co.za/Research/Statistics/Pages/OnlineDownloadFacility.aspx
[Accessed 12 November 2019].

Statista, 2020. *South Africa: Urbanization from 2008 to 2018.* [Online]
Available at: https://www.statista.com/statistics/455931/urbanization-in-south-africa/
[Accessed 24 February 2020].

Stats SA, 2017. *Statistics South Africa. Easy Data by Quantec - General Household Survey 2017.* [Online]
Available at: https://surveys.easydata.co.za/ReportFolders/reportFolders.aspx
[Accessed 14 November 2019].

Stats SA, 2018. *Statistics South Africa. Easy Data by Quantec - P5041.3 & Report-50-11-01: Building statistics.* [Online]
Available at: https://www.easydata.co.za/service/construction-macroeconomic-service-rsa-economic-data-stats-sa/
[Accessed 12 November 2019].

Stats SA, 2019. *P0302 - Mid-year population estimates.* [Online]
Available at: http://www.statssa.gov.za/?page_id=1854&PPN=P0302&SCH=7668
[Accessed 2019 November 2019].

Szokolay, S. V., 2014. *Introduction to Architectural Science : The Basis of Sustainable Design.* Abingdon, Oxon: Routledge.

Terblanche, R., 2019. Achieving net zero status in South Africa. *IOP Conference Series: Earth and Environmental Science,* Volume 323, p. 012182.

Thunberg, G., 2018. *The disarming case to act right now on climate change [Video file].* [Online]
Available at: https://www.ted.com/talks/greta_thunberg_the_disarming_case_to_act_right_now_

on_climate

[Accessed 3 October 2019].

UNEP & IEA, 2017. *UN Environment and International Energy Agency. Towards a zero-emission, efficient, and resilient buildings and construction sector. Global Status Report 2017,* s.l.: s.n.

UNEP, 2011. *Towards a Green Economy Pathways to Sustainable Development and Poverty Eradication, PART II: Investing in energy and resource efficiency, Building,* s.l.: United Nations Environment Programme.

UNEP, 2018a. *A Guide for Incorporating Buildings Actions in NDC, Job No: DTI/2225/PA,* s.l.: United Nations Environment Programme.

UNEP, 2018b. *The Emissions Gap Report 2018,* Nairobi: United Nations Environment Programme.

UNEP-SBCI, 2009. *Greenhouse Gas Emission Baselines and Reduction Potentials from Buildings in South Africa,* s.l.: United Nations Environment Programme, Sustainable Building and Climate Initiative.

UNFCCC, 2016. *Aggregate effect of the intended nationally determined contributions: an update, FCCC/CP/2016/2,* s.l.: United Nations Framework Convention on Climate Change.

UNFCCC, 2018. *National Inventory Submissions 2018. United Nations Framework Convention on Climate Change.* [Online]
Available at: http://unfccc.int/process/transparency-and-reporting/reporting-and-review-under-the-convention/greenhouse-gas-inventories-annex-i-parties/national-inventory-submissions-2018
[Accessed June 2018].

UNFCCC, 2019. *United Nations Framework Convention on Climate Change. The Paris Agreement and NDCs.* [Online]
Available at: https://unfccc.int/process-and-meetings/the-paris-agreement/nationally-determined-contributions-ndcs
[Accessed 25 October 2019].

UN-Habitat, 2011. *Cities and Climate Change: Global Report on Human Settlements,* London: Earthscan.

UN-Habitat, 2016. *Urbanization and Development. Emerging Futures. State of World Cities Report 2016,* Nairobi: UN-Habitat.

United Kingdom , 2019. *GOV.UK. Press release. Homeowners could cut mortgage rates, bills and emissions with new green mortgages.* [Online]
Available at: https://www.gov.uk/government/news/homeowners-could-cut-mortgage-rates-bills-and-emissions-with-new-green-mortgages
[Accessed 25 November 2019].

United Nations Treaty Collection, n.d. *Paris Agreement.* [Online]
Available at: https://treaties.un.org/pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XXVII-7-d&chapter=27&clang=_en
[Accessed 25 October 2019].

Vieira, R., 2006. The Energy Policy Pyramid - A Hierarchal Tool For Decision Makers. In: *Fifteenth Symposium on Improving Building Systems in Hot and Humid Climates, July 24-26.* Orlando, FL: s.n.

Walker, D., 2019. *INTHEBLACK. How green are green bonds?.* [Online]
Available at: https://www.intheblack.com/articles/2019/09/01/how-green-are-green-bonds
[Accessed 19 November 2019].

WHO, 2015. *World Health Organization, WHO calls for urgent action to protect health from climate change – Sign the call.* [Online]
Available at: https://www.who.int/globalchange/global-campaign/cop21/en/
[Accessed 19 April 2020].

Wong, I. L. & Kruger, E., 2017. Comparing energy efficiency labelling systems in the EU and Brazil: Implications, challenges, barriers and opportunities. *ENERGY POLICY,* Volume 109, pp. 310-323.

WorldGBC, 2013. *The Business Case for Green Building,* s.l.: World Green Building Council.

WorldGBC, 2017a. *World Green Building Council. From Thousands to Billions - Coordinated Action towards 100% Net Zero Carbon Buildings By 2050.* [Online]
Available at: https://www.worldgbc.org/news-media/thousands-billions-coordinated-action-towards-100-net-zero-carbon-buildings-2050
[Accessed 26 November 2019].

WorldGBC, 2017b. *World Green Building Council. What are green mortgages & how will they revolutionise home energy efficiency?.* [Online]
Available at: https://www.worldgbc.org/news-media/what-are-green-mortgages-how-

will-they-revolutionise-home-energy-efficiency
[Accessed 25 November 2019].

WorldGBC, 2018a. *World Green Building Council. Infographic: The Pathways to Net Zero Carbon Buildings.* [Online]
Available at: https://www.worldgbc.org/news-media/infographic-pathways-net-zero-carbon-buildings
[Accessed 26 November 2019].

WorldGBC, 2018b. *World Green Building Council. Major European banks launch new green mortgage scheme.* [Online]
Available at: https://www.worldgbc.org/news-media/major-european-banks-launch-new-green-mortgage-scheme
[Accessed 2019 November 2019].

WorldGBC, 2019a. *Advancing Net Zero - Status Report May 2019,* London: World Green Building Council.

WorldGBC, 2019b. *World Green Building Council.* [Online]
Available at: https://www.worldgbc.org/
[Accessed 30 October 2019].

WorldGBC, 2019c. *World Green Building Council. Commitment Signatories.* [Online]
Available at: https://www.worldgbc.org/commitment-signatories
[Accessed 31 October 2019].

WorldGBC, 2019d. *World Green Building Council, Bringing Embodied Carbon Upfront.* [Online]
Available at: https://www.worldgbc.org/embodied-carbon
[Accessed 24 February 2020].

WorldGBC, 2019e. *World Green Building Council. What is Net Zero?.* [Online]
Available at: https://www.worldgbc.org/advancing-net-zero/what-net-zero
[Accessed 26 November 2019].

WRI, 2016. *World Resource Institute. Accelerating Building Efficiency: Eight Actions for Urban Leaders.* [Online]
Available at: http://www.wrirosscities.org/sites/default/files/16_REP_Accelerating_Building_Efficiency.pdf
[Accessed 23 April 2019].

Yigit, K. & Acarkan, B., 2016. Assessment of energy performance certifcate systems: a case study for residential buildings in Turkey. *Turkish Journal of Electrical Engineering & Computer Sciences,* Volume 24, pp. 4839-4848.

Zhang, N., Yu, K. & Chen, Z., 2017. How does urbanization affect carbon dioxide emissions? A cross-country panel data analysis. *Energy Policy ,* Volume 107, pp. 678-687.

Zhang, Y.-X., Chao, Q.-C., Zheng, Q.-H. & Lei Huang, 2017. The withdrawal of the U.S. from the Paris Agreement and its impact on global climate change governance. *Advances in Climate Change Research,* 8(4), pp. 213-219.