Title

Under 2C Living Laboratories

Authors

Streiff, Lara

Ramanathan, Veerabhadran

Publication Date

2017

Under 2^0C Living Laboratories

Lara G. Streiff[1] and Veerabhadran Ramanathan[2]

[1,2]Scripps Institution of Oceanography, University of California San Diego

Corresponding author: Veerabhadran Ramanathan (vram@ucsd.edu)

Abstract

Fifty-two cities, sixty-three businesses, and several universities have become living laboratories for ambitious climate mitigation programs. By 2050, the total annual emissions for the fifty-two cities will reduce by 407 MMTCO2e (million metric tons), compared with their base period (ranging from 1990 to 2013) emissions, which is equivalent to making the entire state of California, the sixth largest world economy, nearly carbon neutral. Case studies reveal that between 2000 and 2014, California and Sweden grew their Gross Domestic Products (GDPs) by nearly 30% while their CO2e emissions declined by 5% and 24% respectively. Such reductions employ a multitude of action plans, which we place in the context of the Ten Solutions for Carbon Neutrality and Climate Stability published by the University of California. The technologies deployed by the living laboratories include: improving end-use efficiencies; conversion to renewably generated electricity; solving intermittency of solar and wind power with batteries, fuel cells, and hydrogen; developing micro-grids for distributed power generation; expanding use of electric vehicles; recycling reform; capturing agricultural/landfill emissions for conversion to gas; and food waste reduction. The living laboratories have demonstrated that scalable technologies are available now to drastically reduce world-wide carbon emissions. However, doing so requires fundamental behavioral changes.

Keywords: Urban Carbon Neutrality, Living Laboratories, Climate Change Mitigation

1. Introduction

As illustrated by the historic Paris Agreement, there is a consensus among climate scientists, policy makers, and national leaders alike to limit the rise of global temperatures to well below

2^0C (Rockstrom et al, 2016). Thus far, only one nation, Bhutan, actually absorbs more carbon dioxide than it releases, primarily due to its large forest cover (Climate Action Tracker, 2015). Only few other small countries (with populations under 10 million) have committed to national-scale carbon neutrality; these include Costa Rica, the Maldives, Iceland, Sweden, Norway, and New Zealand. For larger nations, this requires daunting large-scale changes that can be more effectively implemented at sub-national levels. In all jurisdictions, the convergence of science and policy is fundamental to setting and achieving ambitious targets. Limiting warming well below 2^0C requires that we achieve zero net emissions of CO_2 (Carbon Neutrality) by mid-century (IPCC, 2014; Ramanathan et al, 2015; Rockstrom et al, 2016) and maximum possible reductions of four short-lived climate pollutants: methane, black carbon, Hydrofluorocarbons (HFCs) and tropospheric ozone (Ramanathan and Xu, 2010; Shindell et al, 2012) by 2030. This in turn requires widespread investments, commitment by local to national governments, and immediate action from all stakeholders across the globe. The Paris agreement and its mechanism of Intended Nationally Determined Contributions (INDCs) have already put us on a pathway of emissions well below the business as usual (BAU) trajectory. Nevertheless, the committed Nationally Determined Contributions (NDCs) have to be augmented significantly to limit the warming to well below 2^0C.

The fundamental issue is how and where we start on this historic journey of carbon neutrality and climate stability. For the fifty-two cities and the sixty-three businesses included in this study, that journey has already begun. Cities produce 70% of global CO_2 emissions, and hence are the ideal test cases for the present Living Laboratory study. As of 2011, the global CO_2 emission is 38 Gt CO_2Yr^{-1} for all sources including fossil fuels, cement production, and land use changes (including deforestation) [IPCC, 2014]. For emission mitigation of CO_2 and all other greenhouse gases (GHGs), the data is shown in terms of equivalent CO_2 (CO_2e), and the global emission of GHGs (including CO_2) is 48 Gt CO_2eYr^{-1} (IPCC, 2014). The mitigation data we gathered for the cities and other jurisdictions are in some cases for CO_2 emissions and for others in terms of equivalent CO_2 emissions, CO_2e. In what follows, we have adopted a uniform convention of citing and grouping the data for emission mitigation as CO_2e, since in instances when the emission mitigation targets are just for CO_2, CO_2e and CO_2 mitigation have the same value.

The primary objective of this study is to capture the approaches and techniques of these living laboratories. The expectation is that an illustration of these living laboratories can energize and motivate the rest of the world to innovate solutions for carbon neutrality. The solutions adopted by these living laboratories can in turn help transform society, from its current unsustainable consumption of fossil fuels, to a sustainable growth pattern that preserves natural resources for future generations. There is precedence for making such a claim. The University of California (UC) System of 10 campuses with a combined population of 500,000 has decided to go carbon neutral by 2025. As we report later, this carbon neutrality initiative (CNI) has created a number of innovations within each campus to cut carbon emissions. The initiative prompted 50 faculty members from the 10 campuses, representing multiple disciplines including the social and natural sciences, engineering, and religious studies, to band together under the umbrella of the CNI Carbon Neutrality Initiative and release a report “Bending the Curve” (BtC) (Ramanathan et al, 2015). The BtC report identified 10 broad solutions covering the various interlinked dimensions which need to be addressed by any climate solutions effort. These 10 solutions also serve as an important analysis tool for evaluating the case studies presented here. We follow the description of cities and industries, with two case studies involving the state of California and the country of Sweden, and conclude with lessons learned.

Several pollutants contribute to warming of the climate system. These include the long-lived greenhouse gases, GHGs, (CO_2, N_2O and halocarbons such as CFCs) and the four short-lived climate pollutants (SLCPs), three of which are gases (CH_4; tropospheric Ozone; Hydro-fluoro-carbons or HFCs) and the fourth being black carbon (BC), which is a particle. The Paris climate agreement includes the long-lived GHGs and two of the SLCPs (CH4 and HFCs), but does not explicitly include tropospheric ozone or black carbon. It is also likely that switching to renewables to achieve carbon neutrality will eliminate certain (but not all) sources of SLCPs such as black carbon from diesel vehicles and fugitive emissions of methane from production and transport of fossil fuels. Another complicating factor is that air pollution laws regulating emissions of particulates (so-called PM laws) usually target black carbon emissions from diesel vehicles and open burning; and laws regulating ozone may regulate methane emissions. Until these distinctions and linkages between climate mitigation and air pollution mitigation are explicitly recognized in climate mitigation policies, it is preferable to keep track of CO_2 mitigation actions and SLCP mitigation actions separately as is done by the Climate and Clean Air Coalition of the United Nations Environment Program (www.ccacoalition.org) and we follow this precautionary practice in the present paper.

2. Living Laboratories: Cities

Cities currently cover only 2% of the earth's surface, yet produce more than 70% of the world's CO_2. It is also predicted that by 2050, two thirds of the world population will be urban dwellers. [UN Habitat, 2016]. With respect to climate change, cities face triple threats: Global warming, the urban heat island effect, and air pollution. These threats are bound to worsen as urban areas become more densely populated. If low carbon urban development strategies were to be adopted and implemented by 2020, required mitigation actions could reduce GHGs cumulatively by 3.7 Gt by 2030 [New Climate Economy Report, 2015]. The C40 organization has currently enrolled 86 affiliated cities, while the Compact of Mayors currently contains commitments, at various stages of implementation, from 428 cities. Using these two organizations as references, fifty-two cities were selected based on three criteria: first, they were already on a pathway of emissions reductions; second, they had a published climate action plan; finally, the third criteria we adopted was to include only those cities that committed to greater than 25% total GHG reductions by 2050. Reductions are generally based on so-called Scope 1&2 emissions sources, which encompass all emissions from sources within the city boundary, as well as those occurring from use of grid-supplied electricity, heat, steam, and or cooling. Most city climate action plans do not include Scope 3 emissions; those which occur outside of a city boundary but as a result of city activity. These emissions are not included, primarily because they are very difficult to track and control, but may include significant emissions sources such as those concerning waste. Reductions of such scope 3 emissions require nationally mandated plans or cooperative agreements between city governments, especially among neighbors.

The total sum of the emissions (CO_2e) from the fifty-two cities is 657 $MMTCO_2e$ for 1990 and 618 $MMTCO_2e$ for 2015. The emission targets adopted by the fifty-two cities are shown in

Figure 1, where they are grouped together by continent, and in the supplemental material Table S1.

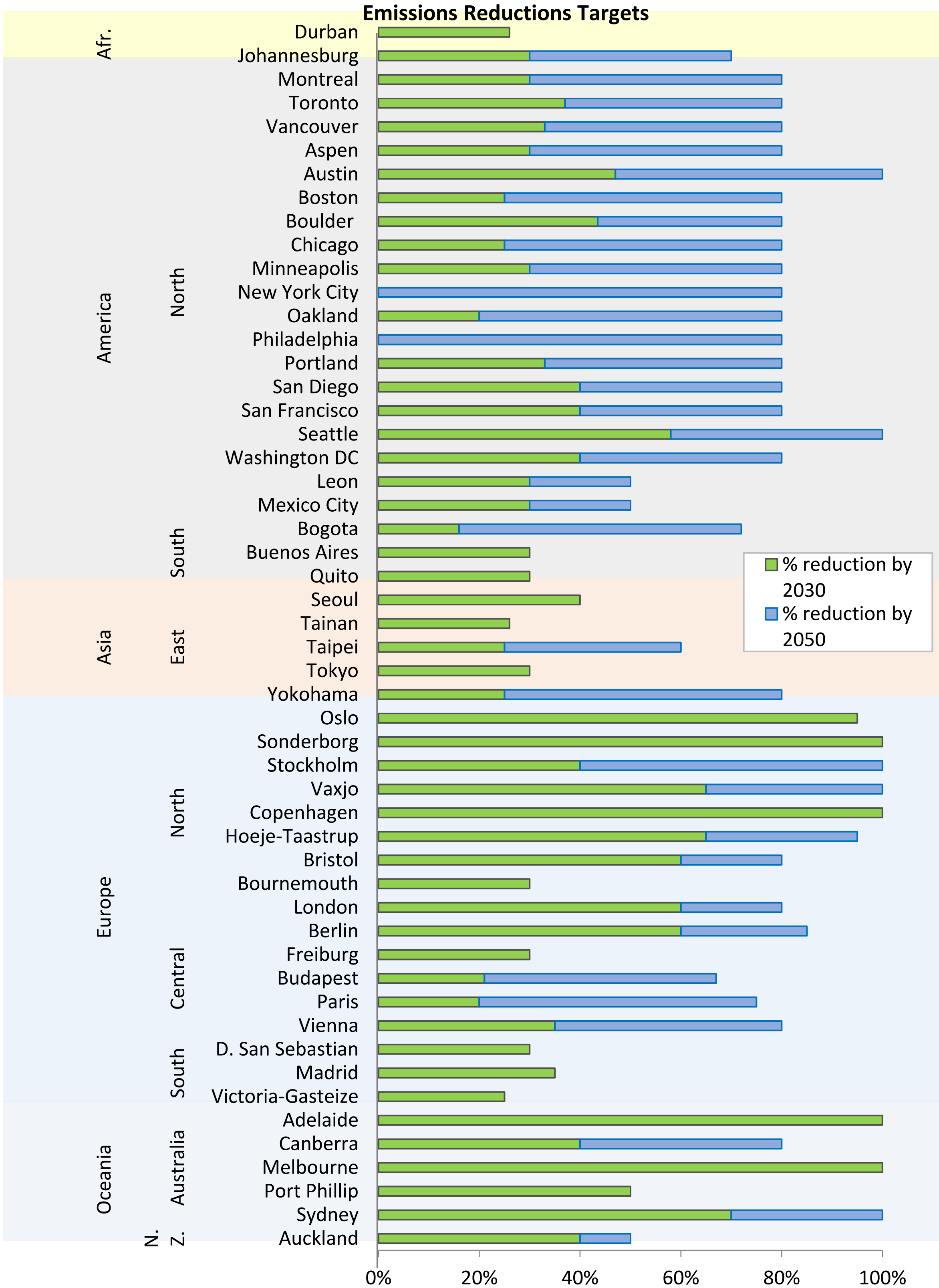

Figure 1: Targets for GHG emissions reductions by region for 2030 [2020-2040] and 2050 [2040-2060] from a baseline year (ranging from 1990-present). The baseline year is not the same for each city. It varies from 1990 to 2012 (see Table S1 in Supplements). In addition, the target year for the first period centered around 2030, varies from 2020 to 2040 depending on the city; and for the second period it varies from 2040 to 2060. In order to present these data in a uniform way, we grouped target years that varied from 2020 to 2040 under the 2030 emissions; and target years from 2040 to 2060 under the year 2050 emissions. Some cities, target the year 2040 exactly; in such instances, the cities have a second target year that is either earlier or later than 2040. For those cities with a second target year earlier than 2040, we group the 2040 data under 2040 to 2060 period; for those with a second target year later than 2040, the 2040 data is grouped under the 2020 to 2040 period.

The fifty-two cities shown in Figure 1 include large metropolises and capital cities, which contribute significantly to their state, and national, emissions. Two such cities, Seoul and Tokyo, are designated megacities: populations exceeding 10 million. Initiatives, such as achieving 100% renewable energy, including power generation, or becoming fossil fuel free, are additionally adopted by many of these sampled cities. Examples include Copenhagen, which aims to be the first carbon neutral capital by 2025, or Melbourne, which is targeting carbon neutrality by 2020, making it the first among the fifty-two cities to do so [Kim Le Cerf, personal communication, City of Melbourne August 21, 2016]. Copenhagen and Melbourne both have energy efficiency initiatives and incentives to encourage sustainability, while their energy mixes differ greatly. Copenhagen has a district heating system, which will transition to biomass for fuel. On the other hand, Melbourne gets more than 50% of its electricity from coal, and is working to purchase more renewables, as well as offer increasing rebates for solar installations. Stockholm and Oslo are two cities which have vowed to eliminate the use of fossil fuels entirely by 2040 and 2050 respectively, especially targeting their transportation sectors via biogas and electric public transportation, as well as implementing highly efficient heating and cooling energy systems. A handful of others are on track toward becoming 100% renewable, including Vancouver, Copenhagen, San Francisco, and San Diego. Vancouver has plans to transition neighborhoods to centralized heating systems and use bio-methane and biofuels to replace fossil fuels. San

Francisco and San Diego both plan to expand their current mix of solar, wind, and wave energies (Jacobson, 2016).

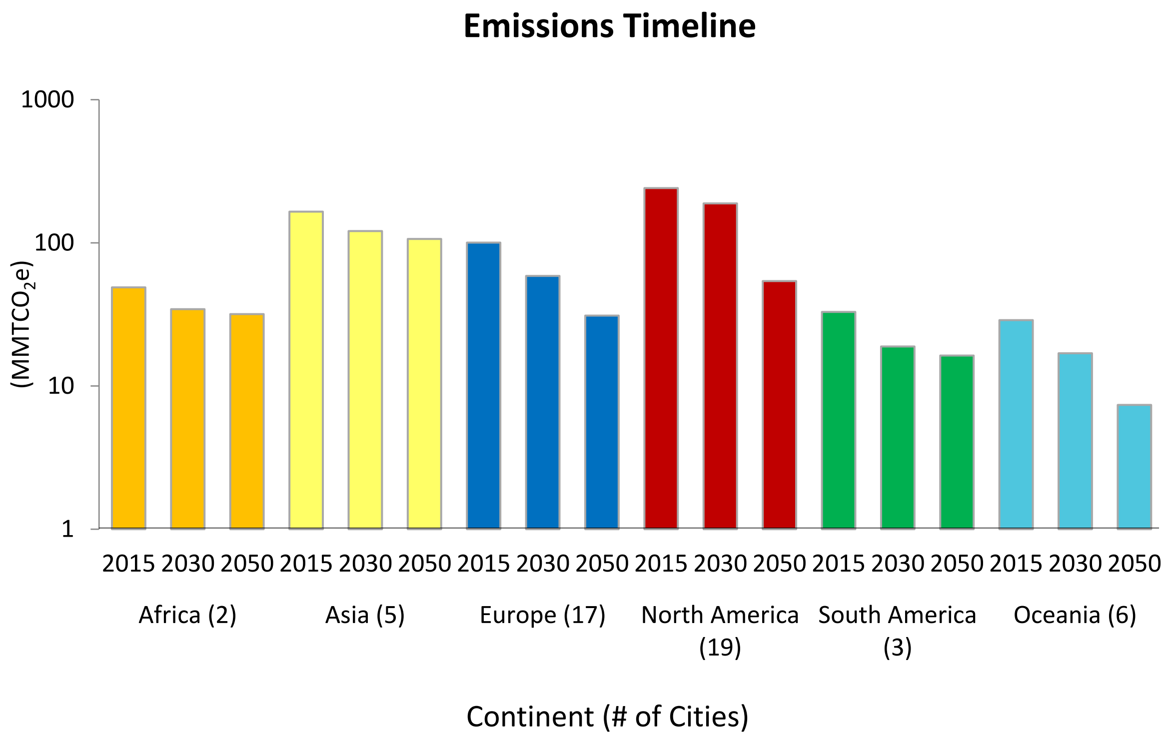

Figure 2: Current (2015) emissions and projected emissions for 2030 and 2050 for the 52 cities grouped by continent. Units: MMTCO$_2$e (million megatons carbon dioxide equivalent). The total emissions for the 52 cities are: 618 MMTCO$_2$e for 2015; 442 MMTCO$_2$e for 2030; 251 MMTCO$_2$e for 2050.

Figure 2 shows the emissions for 2015 along with the projected emissions for 2030 and 2050, for the fifty-two cities grouped by continent. The data shown in Fig. 2 were estimated as follows: For the year 2015, we estimate the emissions based on the data provided for the year closest to 2015, which range from 2006 to 2015. We then apply the percent reduction data from Figure 1 to the baseline emission to obtain the emissions for 2030 or 2050. The total emissions reduction for the fifty-two cities for the year 2050, when compared with the baseline emissions, is 407 MMTCO$_2$e. Compared with the global CO_2 emissions of 38 Gt CO_2Yr^{-1} (for 2011 from IPCC-AR5) the reduction in emissions for the fifty-two cities is about 1%; about 0.8% of the 48 Gt CO_2e Yr^{-1} (for 2011 from IPCC-AR5) for the emissions of all anthropogenic greenhouse gases. In order to provide another perspective of the magnitude of the mitigation efforts by the fifty-two cities, let us compare with California, the sixth largest economy in the world. The 2014 emission of greenhouse gases by California is 441.5 MMT CO2e, and thus the 407 MMTCO$_2$e mitigation by the fifty-two cities is equivalent to making the entire state of California nearly carbon neutral.

The stringent search criteria employed in this study limited the number of cities from Asia, Africa, and South America to just 10. Despite this, we see that the emissions from the 5 Asian cities are comparable to the high emission levels of North America and Europe.

3. Case Studies

3.1 California and Sweden

California: California currently has the world's sixth largest economy, the United States' most prominent agricultural and IT industry, and has historically proven to be a leader in mitigation of air pollution, as well as in climate change mitigation actions through aggressive command and control policy and technological innovations. Three cities in California are among the 10 most populated cities in the United States. The state's vulnerabilities to the projected impacts of climate change include longer and more intense heat waves which amplify the urban heat island effect; coastal erosion due to sea level rise; intense storms and associated floods and landslides; severe droughts caused by the early melting of the snowpack and the increased evaporation of moisture from the warmer surface, both of which exacerbate the drought caused by variability in precipitation. California's total GHG emission for 1990 was 427 $MMTCO_2e$, and has risen slightly to 441.5 MMT in 2014. California's Assembly Bill 32 (AB 32) mandates the state to reduce its 2020 emissions to 1990 levels. Additional legislation, Senate Bill 32 (SB 32) signed into law last year by the state's governor, sets the goal for reducing GHGs emissions (CO2e) by 40% (from 1990 level) by the year 2030. In addition, it has set strict mandates targeting SLCPs (Short-Lived Climate Pollutants) which are commonly overlooked [SB1383-Air Resources Board, 2016].

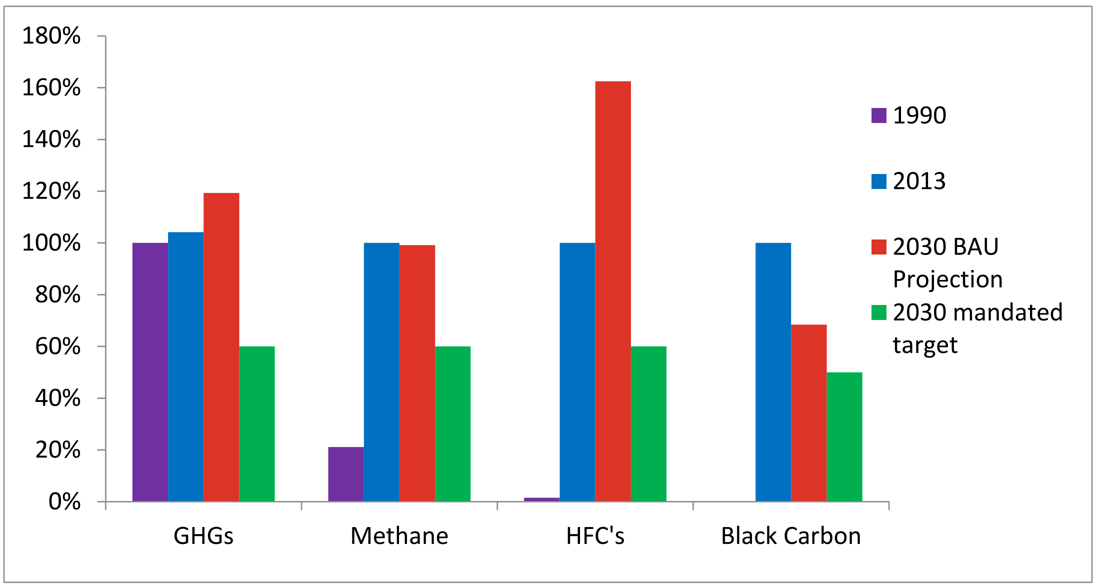

Figure 3: California's mitigation targets. For GHGs, California's AB32 law mandates the reductions. This law passed in 2006, uses GHG emissions of 1990 as baseline levels. For Carbon dioxide there is no specific 2030 mandated target or BAU projection; instead goals for CO_2 are encompassed within the mandated 40% total GHG emissions reduction measured in CO_2e. The mandates for the short-lived climate pollutants were set only in 2016 (SB1383) with a baseline year of 2013. Accordingly, the 100% emission in the figure for GHGs is the 1990 emission levels (426.6 MMT CO_2e), whereas for SLCPs, it is 2013 emission levels which are: Methane: 118 $MMTCO_2e$, HFCs: 40 $MMTCO_2e$, Black Carbon: 38 $MMTCO_2e$. In reporting black carbon emissions as equivalent CO_2e emissions, we are simply citing the numbers from the CA government website. Conversion of black carbon emissions to equivalent CO_2 emissions is subject to numerous uncertainties. However, such uncertainties do not impact the conclusion

we draw from the numbers in Figure 3, which is that black carbon emissions will be reduced by 50% from its 2013 levels by 2030. One reason for choosing 2013 as the baseline (instead of 1990) for SLCPs is that black carbon emissions for 1990 are not known.

The 40% reductions in GHGs emissions (as in SB32) in principle include the GHGs methane and HFCs, which are also included under SLCPs in SB1383. By targeting methane and HFCs under SB-1383 (the SLCPs emissions), SB 32 can therefore largely focus on CO_2 emissions. The state has also created an *Under2 MOU* (Memorandum of Understanding) for an international partnership with jurisdictions (cities; states; nations) which have agreed to the significant emissions reductions mandated by California. A total of 170 jurisdictions representing 33 countries and six continents have signed or endorsed the Under2 MOU. In addition, a five climate-change- pillars strategy to achieve the 2030 emissions targets has been established. The five pillars include attaining 50% renewable energy, a 50% cut in petroleum use in vehicles, doubling energy efficiency savings in existing buildings, incorporating and managing carbon sequestration from natural and working lands, and reducing SLCPs. A sixth pillar, "safeguard California" was also added to incorporate adaptation of the state to present, and future, unavoidable impacts resultant of pollution and climate change [Air Resources Board, 2015].

Interim mandates for statewide renewable electricity sources are to reach 20% by 2017, and 33% by 2020, ensuring that the state remains on track to reach its 50% goal by 2030 [Rechtschaffen, 2016]. The current energy mix includes a large range from hydroelectric, natural gas, solar, petroleum, wind, nuclear, biomass, and 20% of the world's geothermal electrical power. The advancement of clean cars and zero-emissions vehicles (ZEVs), and a low-carbon fuel standard, make up valuable components of California's past and current efforts to reduce vehicle petroleum use and mitigate specific super pollutants, such as black carbon. Such energy efficiency standards and zero net emissions (ZNE) targets for vehicles, accompanied by required increases in fuel economy and a ZEV mandate of 1.5 million vehicles by 2025, contribute significantly to emissions reductions in the transportation sector. Transportation currently makes up 36% of the state's emissions, making it the largest source, 70% of which is due to light duty vehicles [Air Resources Board, 2016]. With further developments of hydrogen fuel cell technology, which strips the electrons to produce current, the hydrogen currently produced from natural gas could fuel all vehicles in the state. 68 Hydrogen stations are currently in existence to support a solid hydrogen fueling infrastructure [Samuelsen, 2016]. Another mandated strategy includes diesel engine controls to limit black carbon emissions, which has been adopted worldwide; Methane cap and trade offsets and landfill regulations, as well as HFC limitations were nationally adopted for refrigerants and air conditioning as well, following California's initiatives. These aggressive steps illustrate that technologies to reduce emissions by 40% are already on hand or can be innovated soon.

However, one prerequisite for gaining public confidence is good governance and a history for mandating such aggressive goals; more importantly, a history of success in implementing the goals. California's history with climate change mitigation legislation is shown in Table 1, spanning from the late '90's to today. In the past, the aggressive policies targeting air pollution have resulted in visible improvements in the air quality, especially impacting the infamous Los Angeles smog, bettering public perception of policy and science's cooperative effectiveness. For example, monitoring networks have shown that black carbon concentrations have come down by 90% since the 1960s (Ramanathan et al, 2013; Report to CARB). These bills and initiatives build on one another over the years and demonstrate the commitment and diligence required to achieve success. The state is now attempting the same outcome for reducing the super-pollutants known as short-lived climate pollutants [SLCPs] with the most stringent restrictions in the country. The SLCPs bill, SB 1383, if implemented globally, would reduce warming by about 0.6^0C by 2050, equivalent to reducing projected warming by as much as 50% (Ramanathan and Xu, 2010; Shindell et al, 2012).

The state also relies on aggressive measures adopted by its major cities which are described below.

San Francisco The city of San Francisco has a 1990 emissions baseline of 6.2 $MMTCO_2e$. It has set targets for reducing to 3.72 $MMTCO_2e$ by 2025, on the path toward a 2050 goal of 1.24 $MMTCO_2e$ (an 80% total reduction from the 1990 level) [San Francisco Department of Environment, 2013]. San Francisco's first Climate Action Plan was published in 2004, and set a target for a 20% reduction from the then current emissions levels by the year 2012. It was updated once the city had surpassed its goal, to the current level of a 40% reduction by 2025. Public support is evident in the near 100% compliance rate for actions such as the 2007 Food waste Reduction act, successfully resulting in reduced food service pollution, the creation of a market for recyclable food-ware, the ban of Styrofoam and polystyrene foams as well as non-compostable bags, and reduced packaging and consumption of carbon-intensive products. The city also plans to expand the tree canopy from 13% to 25% cover, in order to moderate the urban heat island effect through natural vegetation.

The entire state of California, and especially the San Francisco Bay Area, additionally benefit from the technology hub in Silicon Valley. Many of the Valley's biggest companies are also leaders within their respective industries, which set examples for the execution of sustainable business practices. Apple Inc., which aims for 100% renewable energy sourcing, has been able to cut its scope 1 and 2 emissions in the past 5 years by 65%; Facebook, which has a 50% renewable goal by 2018 with a 100% goal following thereafter; provide two such examples. Apple is largely investing in solar panels and is sustainably sourcing purchases of materials, such as purchasing aluminum for the iPhone casings which was smelted using hydroelectricity. Facebook already has two of their seven data centers powered entirely by wind energy [Facebook, 2015; Apple Inc., 2016].

San Diego Despite the geographic as well as ideological differences throughout the state, southern California's policies and approaches for addressing climate change often mirror the attitudes of their northern neighbors. Significantly larger than San Francisco in land and population size, San Diego's 1990 baseline emissions were 12.98 $MMTCO_2e$. Its climate action plans call for a 2030 emissions goal of 7.79 $MMTCO_2e$, and a 2050 goal of 2.6 $MMTCO_2e$ (40% and 80% respectively reductions from 1990 levels) [City of San Diego, 2016].

Southern California, with its semi-arid climate and high levels of sunshine, is an ideal location for photovoltaics (PV) and advanced solar energy projects. One of the nation's largest solar installations and still expanding; Borrego Springs (70 km east of San Diego) houses a solar powered micro grid which not only powers its entire community, but allows for power continuity during maintenance periods of some of San Diego County's other electricity sources, while contributing to growing wind and solar markets. San Diego Gas and Electric (SDG&E), a subsidiary of Sempra Energy, has been named the number one utility in America for renewable energy sales, and is the first investor-owned utility in California to transition to new private solar program after meeting previous program limits. In 2011, SDG&E produced 42% of its electricity from carbon-free sources, a mixture of renewables and nuclear. Additionally, its support of Community Choice Aggregation (CCA) demonstrates the consumer driven shift in demand toward renewable energy sources occurring in the region.

Sweden: Scandinavia experiences some of the most extreme temperature disparities with seasonal change, and as a result presents some of the highest per capita energy demand in the world. Environmental concerns for Sweden specifically include increased and more severe floods, landslides and coastal erosion given expected sea level rise, as well as negative impacts on water quality in lakes which could affect drinking water supply, and heat waves which result in numerous negative health impacts. According to the Swedish Energy Agency [2015], Sweden's GHG emissions have already been significantly reduced from the 1990 level, from 71.9 $MMTCO_2e$, to the 2014 level of 54.3 $MMTCO_2e$, almost 24% reduction. Also, published on the national website, Sweden.se, a study by the Swedish National Institute of Economic Research is reported to have assessed that Sweden can meet its 40% reduction goal for the year 2020, and the ultimate goal of neutrality for the whole country by 2050, with some additional measures to those already in place [Sweden.se, 2016].

Historically, Sweden was the first country in the world to establish an Environmental Protection Agency (EPA) in 1967, and hosted the first UN conference on the environment which led to the establishment of the United Nations Environmental Programme (UNEP). As part of the European Union (EU), Sweden takes part in the EU's Emissions trading system (ETS), the only such system in the world larger than that in the state of California [Brown et. al 2012]. The current electricity mix in Sweden consists of 83% electricity that is nuclear and hydroelectric, 10% combined heat and power (CHP), and 7% wind. Additionally, 52% of energy production is renewable (95% of which comes from hydropower). Sweden has had a joint social democrat and green party government since 2014; however, tax reliefs to power intensive industries for taking steps to reduce energy have already been offered since 2005. There has been a carbon tax on oils and natural gas since 1995, and supports for early stage start-ups are available from the Swedish Energy Agency. Furthermore, two of Sweden's most recognizable businesses, Volvo and IKEA, are among the Swedish industries taking steps toward sustainability and corporate responsibility. Volvo has committed to the delivery of at least one million electric vehicles, as well as entirely climate neutral operations, by the year 2025. Concurrently, the IKEA group became a founding partner of the RE100 campaign, a campaign from The Climate Group and Carbon Disclosure Project (CDP) for businesses committed to achieving 100% renewable electricity from a mix of sources and technologies.

Stockholm: Sweden's capital city hosts a combination of climate change mitigation strategies emphasizing energy efficiency, public transportation, waste management, and community involvement. Stockholm has been able to reduce its carbon emissions by 25% per resident since 1990, and aims to be effectively fossil fuel free by 2040. Stockholm's first Climate Action Plan was adopted in 1998, and the city is now in its fourth installment. Heating solutions are responsible for the largest proportion of the city's GHG reductions thus far. Stockholm switched to centralized heating and cooling for apartment blocks so that the central plant can more easily be advanced to cleaner forms of fuel and power and heat co-generation. These steps have saved around 500,000 $MMTCO_2e$ as a result. Additional switches from oil heating to heat pumps saved another 300,000 $MMTCO_2e$. The city also has more unique projects like the "passive heating" and geothermal systems at its Central Station, which capture body heat from commuters during the day, and through a heat regulator and water system, pump that heat into the nearby office building [Sweden.se, 2016]. The successes of these measures lie in the complete integration or replacement in the city infrastructure which is in place. Other significant emissions reductions have resulted from increased "green" cars, saving about 80,000 $MMTCO_2e$, and transitioning diesel buses to renewable forms of public transportation, saving around 10,000 $MMTCO_2e$. Within Stockholm there are even smaller scale neighborhoods providing examples of smart, sustainable urban planning; Hammarby Sjöstad, a former industrial area, now houses smart electric grids, civic design for public transportation and bicycles, and a highly efficient waste management system.

3.2 Universities

University of California System The University of California is one of the largest public research university systems in the world attempting to reach carbon neutrality. Even before reaching this goal for 2025, each of the ten individual campuses in the state is additionally striving to reduce their individual GHG emissions to the 1990 baselines before the year 2020. These campuses now serve as living laboratories for new and innovative solutions for reducing emissions and subsequently combating climate change. The San Diego campus operates the largest micro-grid for a university, meeting 95% of their power needs. Creative projects extend beyond testing technologies and green building measures, to studies and analysis tools, like the Climate and Energy Study from UC Santa Cruz, which incorporated a climate centric techno-economic analysis tool designed to analyze various scenarios for development, project implementation, technology application, and policy updates. By sharing tools like these, the universities can identify practical but efficient methods for achieving carbon neutrality by 2025, as well as manage compliance costs. Scientists across the UC campuses came together as a working group, coined "the UC50", for collaborating on a report titled: "Bending the Curve Report: 10 Scalable Solutions for Carbon Neutrality and Climate Stability" (Ramanathan et al, 2015). This report outlined generalized solutions for climate mitigation.

The UC-wide 1990 baseline emissions are calculated to have been 1.25 $MMTCO_2e$, while the 2014 levels were 1.56 $MMTCO_2e$. As such, the goal for 2020 is to return to the 1990 baseline and continue toward the 2025 goal of carbon neutrality (for emissions scopes 1 and 2) [University of California Annual Report on Sustainable Practices. (2015); Janicka Mcfeely, personal communication, UC Office of the President, August 11, and 16, 2016; Lifang Chiang, personal communication, UC Office of the President, July 24, 2016]. This would result in final emissions levels remaining around .4 $MMTCO_2e$ (scope 3) for the entire UC system. Previous, and current projects, are detailed in Table 2, including LEED (Leadership in Energy and Environmental Design) certifications per campus. There are many such examples in the world and these illustrate that universities can provide creativity, collaboration, commitment, and innovation, for seeing solutions to the climate change problem.

Swedish Universities Individually, a number of Swedish Universities have contributed to the efforts to mitigate the national carbon footprint. The Chalmers University of Technology (among other international universities such as the Massachusetts Institute of Technology (MIT), ETH

Zurich, and the University of Tokyo) has initiated substantial research and development on environmental science and sustainability measures. The Royal Institute of Technology (KTH) also boasts significant investments in sustainable development, while the University of Gothenburg has previously been recognized by the International Sustainable Campus Network (ISCN) with awards for its campus and building designs, and is in the process of developing their climate action plan for the coming three years. [Eddi Omrcen, personal communication, University of Gothenburg, August 11, 2016]. These Swedish universities do not currently have set goals for achieving carbon neutrality, but continue to make progress towards lowering emissions and sustainable development.

3.3 Businesses

Despite some efforts for regulation, businesses often contribute significantly to city and global emissions. Corporations expanding to keep up with population growth and the 20th century consumer culture have become increasingly high emitters and provide an opportunity for significant mitigation. Many businesses are rising to the challenge, as is shown in Figure 4.

Like cities, most businesses only have rough estimates, if any, for their scope 3 emissions. In their case, scope 3 refers to emissions indirectly caused by their activities, such as through transportation, production of purchased materials and fuels, etc. However, scope 1&2 encompass all direct GHG emissions, and indirect emissions which come from the consumption of electricity, heat, or steam, and are generally well accounted for and reported. Regardless of industry, the quandary today lies in satisfying increasing demand while reducing impact. All sixty-three businesses we examined have pledged to reduce emissions or increase their renewable energy sources, while some are even intending on climate neutrality by reducing emissions and completely offsetting the remaining. Ten of our sixty-three businesses are already carbon neutral (scope 1&2) due to the balance of efficiency, renewables, and offsets. Another seven have committed to future carbon neutrality (scope 1&2) by 2050. Cox Enterprises is the eighteenth business which has pledged future carbon neutrality, however does not release their emissions data to the public, so they are not included in our calculated estimates of impact. The seventeen businesses which do release their data have combined current emissions (using levels from 2014-2016) of 51.37 $MMTCO_2e$, which will be further reduced and offset, ranging from 5% in the next year, to 100% as soon as 2020. Adidas is also not included because, as of yet, their target date for neutrality is unspecified. Our choice of companies attempted to find a range of business sectors from across the globe with comprehensive documentation of future targets and action plans.

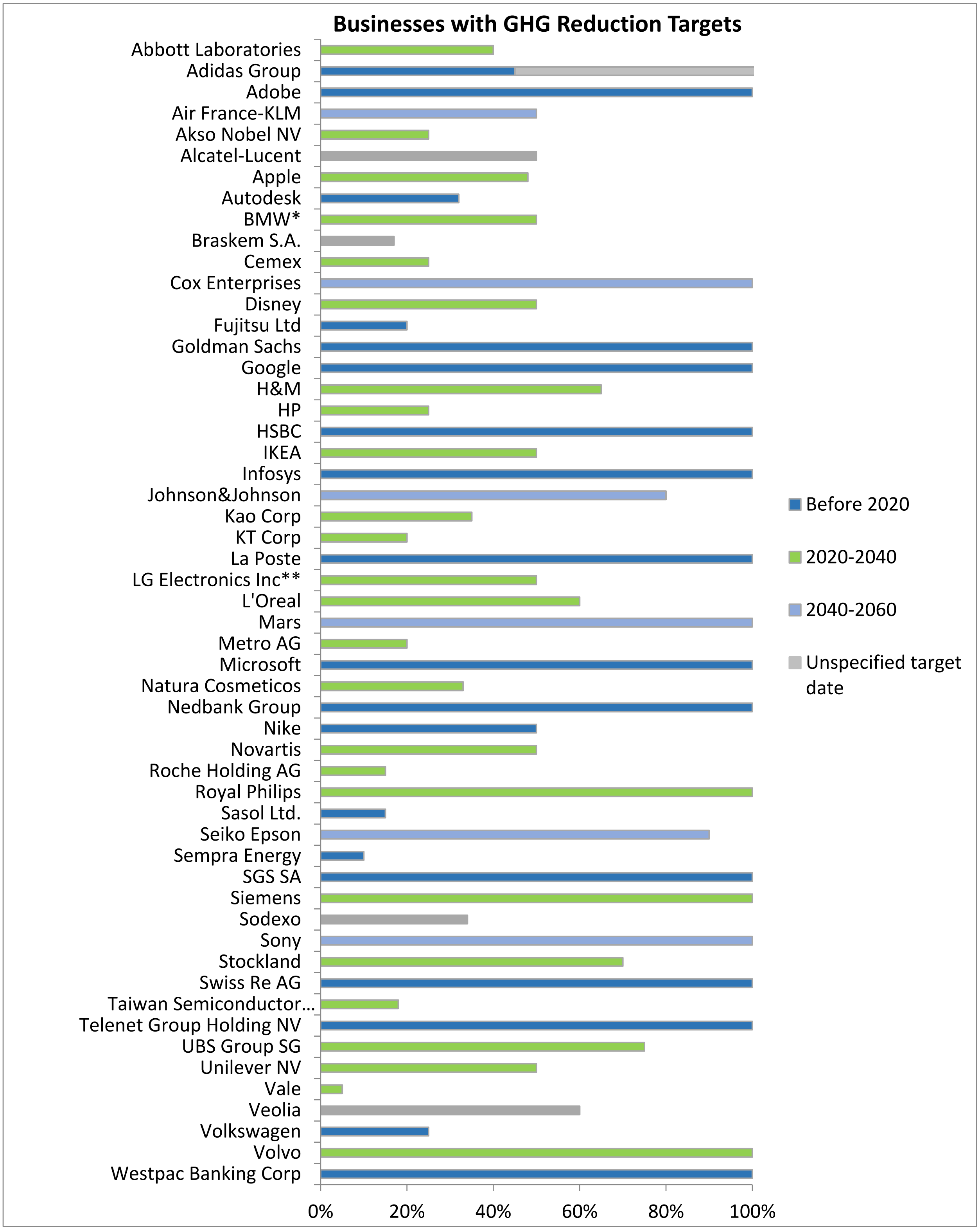

Figure 4: The sixty-three businesses with reported GHG mitigation goals. *BMW reductions reference vehicle emissions only, not facilities **LG Electronics reductions are for United States divisions only.

Nike, Inc., Headquartered in Oregon, USA, is one of a handful of businesses which has expressed a carbon neutrality goal. However, it changed its position around the same time its goals were to be met- 2012/13. Instead of achieving carbon neutrality through the purchase of offsets, which is controversial, Nike has since focused on reducing its supply chain emissions (scope 3) [Nike Inc., 2016]. It is their stance that sustainability and business growth will complement one another as the world shifts toward a low-carbon economy.

La Poste is a French postal delivery company for which all products and services of mail, parcels, and service, have been carbon neutral since 2012. They strictly monitor their emissions levels, especially in transportation, and purchase offsets accordingly, both in France and in developing countries [La Poste, 2016]. They market their carbon neutrality to consumers directly, which indicates that motivations may have been, in part, consumer driven.

The automotive industry is obviously a large source of pollution, both through the use and production of their vehicles. Germany's BMW has goals of cutting its vehicle emissions by 50%, and converting their facilities to 100% renewable energy by 2020. The heating of the Styr/AT plant already has 50% of its heat coming from a carbon neutral method of wood chip combustion [BMW Group, 2016]. Sweden's Volvo has an ambitious plan to achieve carbon neutrality in all of its manufacturing operations, as well as producing one million electric vehicles by 2025. Their current energy mix comes from natural gas, liquefied petroleum gas, diesel oil, and petrol; however, they are working to shift all of the liquid petroleum gas usage to biogas or natural gas. Volvo is also investing in and purchasing a multitude of renewable energies from solar, wind, biomass/biogas, geothermal, hydropower, heat pumps, and waste heat. Their reports state that sustainability and corporate responsibility are considered prerequisites to a successful business. [Volvo Car Groupe, 2015].

Infosys, Google, Microsoft, Adobe, and Telenet Group Holding, are all businesses in the IT sector which are close to, or have already achieved, carbon neutrality. Google was the first to do so, since 2007, by renovating their data centers and campus to be energy efficient, recycling 100% of their electronic equipment, and offering biodiesel shuttles to employees to cut transportation emissions. Google is currently the largest non-utility purchaser of renewable energy in the world; 2.5 Gigawatts. Their Mountain View, California headquarters also house a 1.9 MW solar panel installation [Google, 2016]. Like La Poste, they actively promote their environmentally conscious platform to consumers. Offsetting projects have also included landfill gas projects in North Carolina and New York, as well as animal-waste management systems in Mexico and Brazil. New Mexico based Microsoft became carbon neutral in 2012 by implementing an internal carbon fee to both incentivize and support green power innovation. The energy cost savings have amounted to over $10 million per year, and are used to purchase renewable power, increasingly wind, hydropower, and solar. Microsoft is also working on its own innovative projects, such as developing fuel cell technologies, and investing in biomass, geothermal, hydropower, landfill gas, and wind energy to offset emissions [Microsoft, 2015]. The company is looking to be a leader in sustainability and even provide a guide for other businesses to customize their internal carbon fee model. San Jose's Adobe reached neutrality the following year, through power purchasing agreements, because they believe in a ripple effect of benefits from climate through the economy and human health [Adobe, 2015]. Outside of the United states, Belgium's Telenet Group Holding is the most recent to achieve carbon neutrality in 2015, by pairing emissions reductions with solar panels, improved efficiency, and offsetting the remaining, primarily through forest replantation. They believe in a global shift in the economy and consumer expectations will reflect the need to preserve the planet and its increasingly sparse resources [Telenet, 2014]. Lastly, India's Infosys is aiming for carbon neutrality in 2018. They will achieve 100% renewable energy both by purchasing off grid and on-site technology, particularly solar including a 50 MW solar park. Additionally, the IT Company invests in projects such as smoke-free kitchens fueled by biogas, and is working to achieve zero waste to landfills, as well as biogas organic waste converters [Infosys, 2016].

In financial services, banking, and insurance, five of our selected businesses have already achieved carbon neutrality: Swiss Re, HSBC, Nedbank, Westpac Banking, and Goldman Sachs. Based in Zurich, Switzerland, Swiss Re achieved carbon neutrality in 2003 by cutting emission by 49% per employee and offsetting the remaining through purchase of emission reduction certificates. They state environmental conscientiousness is an inherent part of being a responsible business, and as insurance requires the management of risks and damages, it is a natural part of their work. Swiss Re has conducted studies on the economics of climate change adaptation. It is working to expand protections from natural catastrophes, and has implemented COyou2; a program which subsidizes emission cutting investments of its employees, such as the purchase of efficient household appliances, alternate and public transportation, and solar panel installation. Currently 87% of its energy is renewable, from wind farms, solar, and biogas digesters [Swiss Re, 2016]. In 2005, the British bank HSBC also became carbon neutral, stating that climate change is the single largest environmental threat, and that financial institutions play an important role in the shift to cleaner energy, thus they hope to inspire others to follow their lead. It was the first carbon neutral bank, and has reduced emissions through efficient building design, in addition to wind and solar installations, while offsetting the remaining in wind farms, methane capture to produce energy from waste, composting projects, and biomass cogeneration [HSBC, 2015]. In 2010, Nedbank became the first bank in South Africa, as well as the continent, to go carbon neutral. Its location was the push driving their efforts, as Africa stands to be greatly affected by climate change. Aside from minimizing emissions and waste, and installing renewable energy, their offsetting projects include forest rehabilitation, composting, water filtration, and recycling initiatives [Nedbank Group, 2014]. Many of these businesses, including Australia's Westpac banking, have echoed the sentiment that climate change will inevitably impact their clients, and thus their businesses, and as such they should be addressed. Westpac, which went carbon neutral in 2013, says it did so to better their reputation and relationships in the community, with $6 billion of investments in Green Tech and the environmental services sector [Westpac Group, 2015]. Lastly, Goldman Sachs, based in New York, achieved neutrality in 2015, and has invested $60 billion in clean energy since 2006 [Goldman Sachs, 2016]. They believe the key role of the financial sector is to infuse capital into low-carbon solutions, such as renewables.

4. Scaling up Living Laboratories: A Proposal

The analyses thus far reveal that technologies as well as policy instruments adopted by the living laboratories can be scaled to the rest of the world. This claim is based on the fact that the scales of the living laboratories range from individual universities, small cities or industries, mega cities to mega industries, extending all the way to an entire state (California) and an entire nation (Sweden). However, it is simply not a question of just scaling the technology through a top-down command and control policy. Support from the public willing to uphold the policies and to change behavior is paramount. In addition, it requires market mechanisms and other agents of change, as described in the Bending the Curve report (Ramanathan et al, 2015) mentioned earlier. This report proposed Ten Solutions (Figure 5) under 6 broad clusters of action topics: Science (solutions 1), Societal Transformation (solutions 2, 3), Governance (solution 4), Market Incentives and regulations (solutions 5, 6), Technology measures (solutions 7, 8, 9), and Natural and Managed Ecosystems (solution 10).

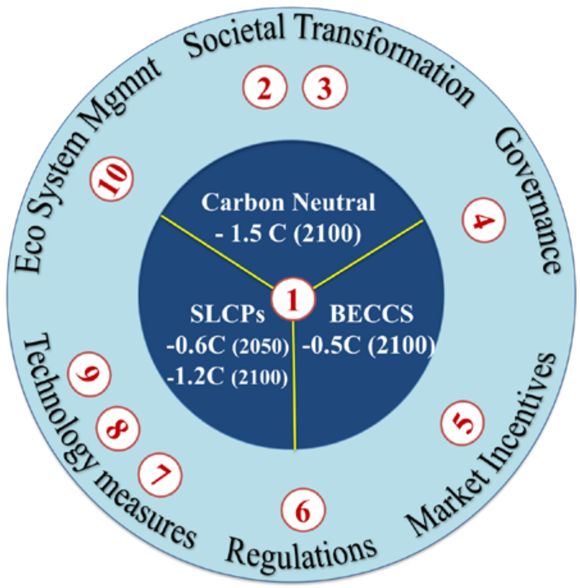

Figure 5: Ten Solutions to Bend the Curve and Limit Warming to under 2^0C; Adapted from Ramanathan et al, 2016.

<u>10 Solutions</u>

In what follows, we describe a summary of the 10 solutions.

1. Bend the warming curve immediately and sustainably, by reducing SLCPs and by replacing current fossil-fueled energy systems with carbon neutral technologies.
2. Foster a global culture of climate action through coordinated public communication and education at local to global scales. Combine technology and policy solutions with innovative approaches to changing social attitudes and behavior.
3. Deepen the global culture of climate collaboration by designing venues where stakeholders, community and religious leaders converge around concrete problems with researchers and scholars from all academic disciplines, with the overall goal of initiating collaborative actions to mitigate climate disruption.

4. Scale up subnational models of governance and collaboration around the world to embolden and energize national and international action.

5. Adopt market-based instruments to create efficient incentives for businesses and individuals to reduce CO_2 emissions. These can include cap and trade or carbon pricing and should employ mechanisms to contain costs.

6. Narrowly target direct regulatory measures — such as rebates and efficiency and renewable energy portfolio standards — at high emissions sectors not covered by market-based policies.

7. Promote immediate widespread use of mature technologies such as photovoltaics, wind turbines, battery and hydrogen fuel cell electric light-duty vehicles, and more efficient end-use devices, especially in lighting, air conditioning, appliances and industrial processes**.**

8. Aggressively support and promote innovations to accelerate the complete electrification of energy and transportation systems and improve building efficiency**.**

9. Immediately make maximum use of available technologies, combined with regulations, to reduce methane emissions by 50% and black carbon emissions by 90%. The required technology measures are listed in Table 3. Additionally, phase out hydrofluorocarbons (HFCs) by 2030 by amending the Montreal Protocol.

10. Regenerate damaged and natural ecosystems and restore soil organic carbon to sequester atmospheric CO_2 and reduce CO_2 emissions from deforestation and open burning.

These categories all intersect in a municipality through the interactions of its citizens with the government, environment, and one another. In the next three sub-sections, we use the two case studies (California and Sweden) to show how, the *under 2^0C living laboratories* action plans can be organized under the ten solutions. Examples of the ten solutions from California and Sweden have been compiled in Table 4.

4.1 Science and Technology (1, 7, 8, 9)

There are renewable energy and other green technologies being employed across a number of sectors in both Sweden and California, as listed in Table 5 Many of these have been implemented for some time, while others are still in development or continuing to evolve. These can provide possible solutions for other cities and states to emulate or apply themselves.

In addition to the strategies targeting CO_2, there are also increasingly more attempts to address and mitigate short-lived climate pollutants (Table 3). One of California's five pillars of focus in their environmental strategy is the targeting of SLCPs through stringent regulations. The state's bill SB-1383 targets drastic reductions in methane, black carbon, and HFCs. SB-1383 targets 40% reduction in methane emissions and HFCs by 2030 along with a 50% reduction in black carbon. Through SB-1383, California has set the highest restrictions on SLCPs within the United States. If the same restrictions were adopted worldwide, the projected warming from now until

2050 can reduce by 0.6C, equal to a 50% reduction in the projected warming (Ramanathan et. l, 2015). California has an allocation of $3.9 billion for the California Environmental Protection Agency (CalEPA) to invest in its pillar strategies, while Sweden allocates 3.3% of its GDP for research and development into sustainable solutions. Independent research institutions, such as the Stockholm Environmental Institute, are also actively exploring green technologies; specifically, biofuels, smart grids, and carbon capture and storage.

Solar and Wind: Conversion to electrification of many of the energy demand systems has the potential to vastly further improve efficiency, as electricity is significantly more efficient than internal combustion. Renewable electricity sources like solar and wind are also becoming increasingly more efficient and cost competitive over time, making them more economically appealing. Existing policies for California will increase renewable-based electricity to 33 percent by 2020. The shutdown of California's San Onofre Nuclear Generating Station in 2012 and the continuing decline in hydropower due to drought has now been offset by increases in wind, solar, and natural gas. Solar generation doubled in the state in 2013-2014, and rooftop PV increased by 39%. The greatest critique of solar and wind power generation stems from their intermittency, which can be addressed through the incorporation of advances in energy storage and infrastructure, as well as smart energy grids. As Sweden's renewable energy portfolio continues to grow toward their ultimate 100% goal, the Swedish Energy Agency continues to fund research into expanding solar and the potential for offshore wind.

Electric Vehicles: Another example of the interplay of industry and governance can be seen in the regulations and standards for fuel efficiency and electric vehicles. California specifically focuses on hybrids and fuel cell technologies, as well as light-weight, high-strength materials, and turbo-chargers for gas powered vehicles. There are several businesses and organizations in the state currently working on improving transportation emissions, including Institutes of Transportation Studies within the University of California System. California also benefits from the aerospace, engineering, and technology companies in Silicon Valley, such as Intel's contributions to the advancement of electric and hybrid vehicles through the improvement of semiconductors [Peak et al. 2004].

4.2 Societal Transformation (2, 3)

Top-down influences play a vital role in structuring changes to societal behaviors and way of life; however, bottom-up actions provide real movements and shifts. In Sweden, each municipality has an energy advisor (290 advisors nation-wide) providing assistance to homeowners seeking to reduce their impacts and energy usage. Some districts or neighborhoods are building smart consumption monitoring systems so that residents can track and monitor their own environmental impact, or implementing Echolog terminals which directly display their electricity, heat, and water consumption. Increasing numbers of individuals are also taking up private beekeeping, while urban farming in community plots has grown into an organization of over 25,000 members. In California, urban gardening is also being promoted, while land-use planning and carbon sequestration is garnering more attention.

Public Transportation: California's current policies focus on zero and near-zero technologies for freight, expanding high-speed rail, and developing Sustainable Community Strategies (SCSs). SCSs link land-use, transportation, and climate policy with the aim of reducing GHGs and subsequently improving air quality, broadening transportation and investment specifically in disadvantaged communities, and reducing negative health effects from polluted air. The entire subway system in California is planned to go carbon-free. The Swedish government-owned train operator, SJ Trains, already currently runs on 100% renewable electricity (specifically hydropower and wind). Sweden has also had great success in the promotion of multimodal public transportation, especially by incorporating bike friendly infrastructure into city planning. Public transportation is well organized to link regional and local transit, and subsidized, while providing an example of social and cultural influences on means of transportation and lifestyle.

Educating Climate Warriors: The UC system has started an effort to teach Climate Solutions for undergraduate students using living laboratories to energize the younger generations to take up climate solutions. The climate solutions course is being developed such that it can be scaled up to students from around the world with the ultimate goal of creating one million climate warriors. This concept should be extended to K-12 education to instill a respect for nature in children from the beginning.

Forming Alliance with inter-faith religious leaders: Inaction to limit climate change has caused the problem to become a huge moral and ethical issue; disproportionately affecting billions of poor and vulnerable, as well as future generations. In order to get massive public support for actions to limit climate change, scientists and policy makers should align with faith leaders to bring up climate change and the need to take drastic actions to protect the poor and the unborn. Pope Francis' (2015) climate change encyclical titled Laudato Si (Our Common Home) is an excellent example of yet another living laboratory involving faith leaders.

4.3 Governance, Market Incentives & Regulations (4, 5, 6)

At the heart of all the climate actions reported in this paper are commitments or agreements through international pacts and organizations. These partnerships were developed to hold one another accountable, to unite against a common cause, and to provide pathways for sharing methodologies and successes. Programs such as the Compact of Mayors and the C40 Alliance have allowed municipalities to come together to share their expertise, their burdens, and their responsibility. World leaders continue to meet at conferences like COP21 in Paris, and create alliances like the under2 MOU because motivation comes where there is partnership.

Within their respective regions, regulations for energy efficiency, ZEVs and low-carbon fuels, as well as percentages of renewable energies, play on the interconnectivity of government and industry. Tough regulations can push and advance technologies to catch up, and vice versa; each holding the other to progressively higher standards. Where industry is incorporated, so too are economies and markets, in which government can intervene through carbon taxes or cap and trade emissions trading systems; these compensate for the costly externalities arising from fossil fuel consumption, thus allowing the natural market forces to reduce fossil fuel demand [European Union, 2013]. Both Sweden and California take part in such systems, while Sweden additionally has an Electricity Certificate System in place: a market-based support system aiming to increase production of renewable electricity and make the cost more efficient. Sweden's carbon tax is among the highest in the world, at $150/ ton, however, it only covers about 50% of total emissions (CTC, 2015). California, on the other hand, has created a GHG reduction Fund with some of the proceeds from their cap and trade system assigned to reducing environmental injustice. AB 32 requires disadvantaged communities to receive 10% of the funds from the Cap and Trade permit auctions since individuals with lower socioeconomic status are disproportionately affected by the negative impacts of climate disruption [Rechtschaffen, 2016]. California's Cap and Trade system is currently linked to Quebec's, and based on the Under2MOU, has collaborative agreements with Shenzhen, China to aid in their ETS development [ARB, 2013]. Shenzhen's current carbon price is relatively low, at $5.46/ton. [ICAP, 2016].

Other regions which have instituted carbon price market mechanisms are New Zealand, Finland, Ireland, and British Colombia. Their carbon taxes range from just over $10 per ton to about $20, increasing over time (CTC, 2015).

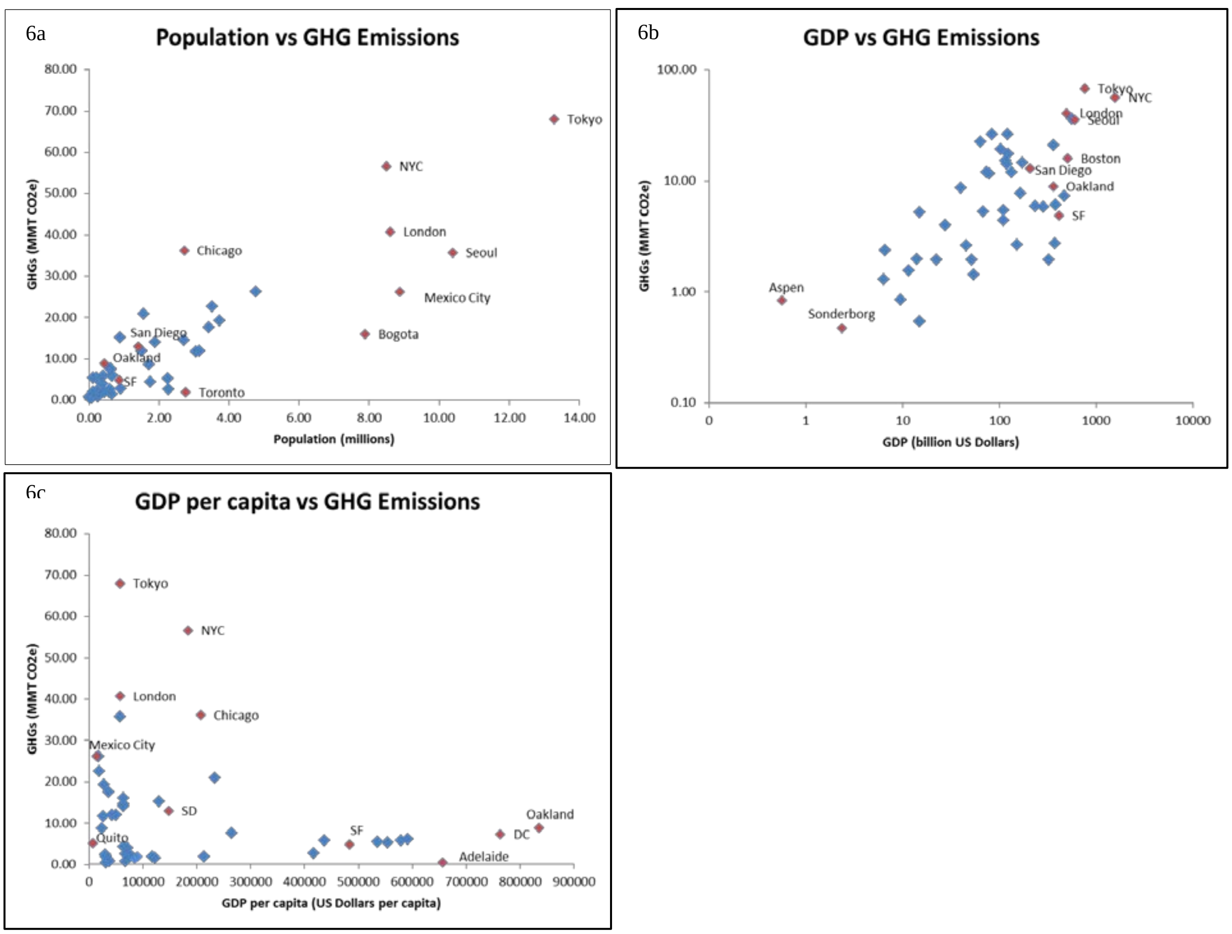

Figure 6: Dependence of GHG emissions on population (Fig. 6a), GDP (Fig. 6b), and GDP per capita (Fig. 6c). Figure 6b is plotted in logarithmic scale. The plots contain data for the most recent years (2014-2016) for 49 of the 52 selected cities, which allow for public access to the data.

Economic and demographic factors can play a critical role in designing solution strategies. The wide spread nature of the economics and demographics of the cities included in this study are illustrated in Figs 6a, 6b and 6c. According to the self-reported data provided by these cities, GHG emissions depend almost linearly on the population size (Fig. 6a). On the other hand GHG emissions displayed a power law dependence on GDP and hence in Fig. 6b, we plot the GHG emissions against the log (natural log) of GDP. There is considerable scatter of the data in both Figs 6a and 6b, which is also expected since the GHG emissions depend on socio-economic factors and the nature of the sectors dominating the economy (e.g., agriculture or manufacturing or high-tech industries). In order to bend the curve and achieve carbon neutrality, we have to decouple emissions of GHGs from population size or the GDP. Indeed, as shown next, this decoupling is already happening in some jurisdictions due to aggressive mitigation polices. Fig 6c, illustrates an interesting characteristic. There are two clusters: For GDP/Capita less than $300,000/Capita, the GHG emissions range from one to 70 MMTCO2e /year while for GDP/Capita greater than 300,000/Capita the emissions do not exceed 10 MMTCO2e /year. Most likely this is due to the fact that cities with larger per capita have less of the polluting sectors such as manufacturing, power generation and more of sectors such as banking and internet-technologies, among others. An additional graph of GDP per capita versus GHG per capita is shown in the supplementary Graph 6d.

Economists often express concern that investment in climate change mitigation or sustainable technologies will have a negative effect on the national and global economies. There is evidence to the contrary in California and Sweden. Sweden has accomplished what they call a complete decoupling of GHG emissions and economic growth, measured either by gross national income (GNI) or gross domestic product (GDP). Between 1990 and 2013 Sweden's emissions have fallen 22% while GDP has grown 58%, in part due to its high carbon tax [Sweden.se, 2016]. California's Under2 MOU appendix submitted in 2015 also reports GDP rising by 5% over the preceding five years while emissions fell [California Overview, 2015]. The growth trends over the years 2000 through 2014 of California's and Sweden's GDPs, alongside their reductions in CO_2e, can be seen in Figure 7.

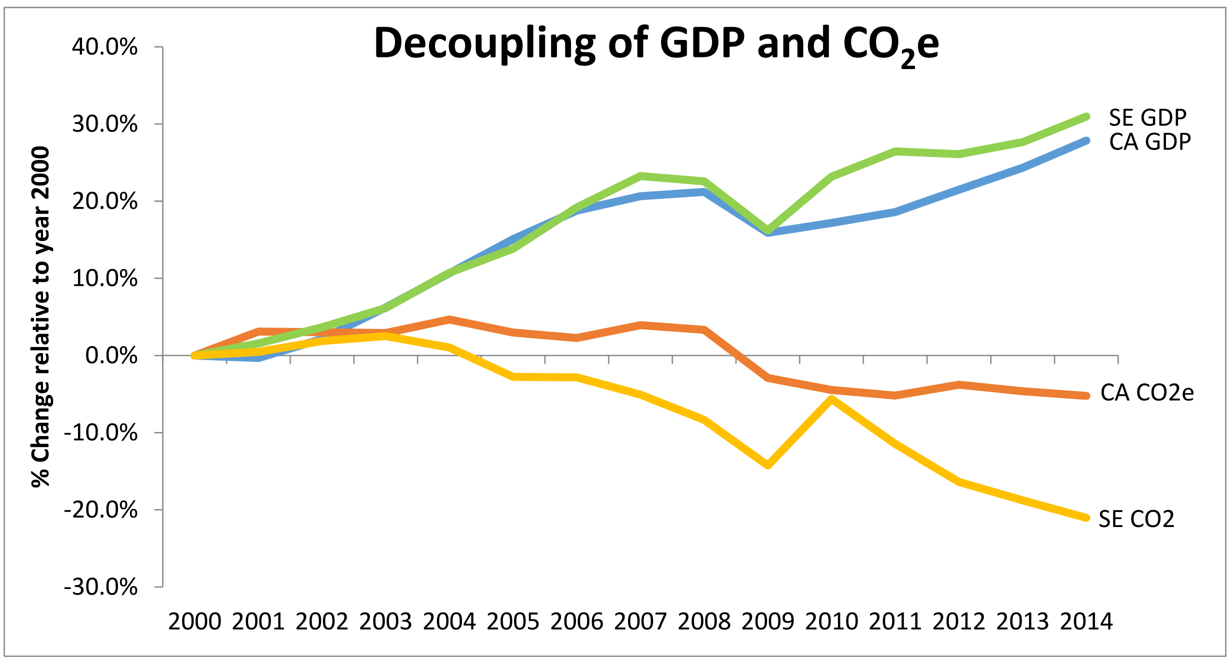

Figure 7: The graph displays the trends of GDP and CO_2e emissions relative to the year 2000 for both Sweden and California. Data from the California Air Resources Board, Statistics Sweden, and Swedish Environmental Protection Agency [Anny Huang, personal communication, California Air Resources

Board, September 29, 2016; Thomas Sundqvist, personal communication, Swedish Environmental Protection Agency, October 20, 2016]

As seen in the supplementary business data, (Tables S2 and S3) businesses and industries can also contribute significantly to emissions output and reductions. In the stock market, the Dow Jones additionally releases a Sustainability Index (DJSI) with annually identified industry leaders, aiding investors looking to place capital in environmentally conscious businesses.

4.4 Ecosystem Management (10)

Ultimately, we may have to extract the CO_2 that is already in the air to limit warming to well below 2^0C (IPCC-AR5, 2014). We can drastically reduce the 7 billion tons of annual emissions resulting from land use practices (e.g. deforestation); In addition, as much as 10 billion tons of CO_2 per year can be drawn down with afforestation, agro-urban forestry, soil carbon management, bio-char and other practices (IPCC-AR5; Ramanathan et al, 2015).

The newly developing California Forest plan and Scoping plan have objectives which include increased protection of land to preserve carbon sequestration and furthered urban greening [Air Resources Board, 2016]. Local actions such as these are crucial all around the world, generally more cost-efficient, more effective, and ultimately provide more co-benefits.

Waste: The case studies of Sweden and California described here provide examples of effective waste management. San Francisco attained an 80% waste diversion rate in 2010, the highest of any city in North America, aiding in the reduction of GHGs from landfills by nearly 50% with respect to 1990 levels. The city’s reuse, recycle, and compost campaign additionally contributes to the zero waste to landfills goal by the year 2020, largely through a mandatory recycling and composting ordinance passed in 2009. A future project to further advance the city is a zero-waste facility which utilizes anaerobic digestion of food-rich material to produce biogas for fueling waste collection fleets and buildings. The city of Växjö in Sweden also proves how tight local cycling of resources can benefit a community’s energy usage, with 90% of their energy and almost half of their electricity being derived from the scraps and saw dust from local timber industry. Stockholm has implemented such a concept, in which its collection of about 993,000kg food waste per month is then turned into 115,000m^3 of biogas for their buses and taxis.

As estimated by UN’s Food and Agriculture Organization (FAO, 2013), approximately one third of all the food that is produced is thrown away. The global carbon footprint of the food produced and not eaten is about 3.3 Gt CO_2e Yr^{-1} [FAO, 2013] which is about 7% of the global CO_2e emissions of 48 Gt CO_2e Yr^{-1}. This carbon footprint of 3.3 Gt CO_2e Yr^{-1} is the CO_2, N_2O and methane emitted in the production, transport, and distribution of the food, but does not include the methane released when the wasted food is discarded to the landfill. Sweden and California both boast high recycling rates, with Sweden reporting only 1% of household waste going to a landfill dump. Recycling stations are no more than 300m from residential areas throughout the country. The Västra hamnen (west harbor) neighborhood in the city of Malmö has even executed a vacuum suction system which transports waste directly underground from buildings and residences which is then converted to fuel/biogas.

5. Conclusions

We analyzed the mitigation goals and strategies of fifty-two cities, ranging from populations of under 100,000 to over 13 million, and sixty-three businesses, five of which are energy or utility companies, nineteen of which are in the technology industry, and thirty-eight of which are in manufacturing, pharmaceuticals, and consumer goods and services. Of the businesses examined, fifty-five have set emission reduction or carbon neutrality goals, and all but one have calculated and released estimates of their emissions inventories. Four mega IT companies have already achieved neutrality, at least eighteen businesses will be carbon neutral by 2050, and twelve additional businesses will reduce their emissions by at least 50%. California and Sweden have also proven that emissions reductions do not have negative impacts on economic growth. In fact, both jurisdictions show rising GDP alongside declining CO_2 e emissions. Between 2000 and 2014, both GDPs grew by nearly 30% while Sweden's emission declined by about 30% and California's by about 5%. In addition, California is the only jurisdiction that has mandated reductions of both CO_2 and short-lived climate pollutants.

As previously stated, the fifty-two cities in this study provide the potential for over 400 MMT CO_2e emissions reductions per year by 2050. Their annual baseline emission of 657 MMTCO_2e (for the period ranging from 1990 to 2005) will be reduced by 62% to 250 MMTCO_2e per year (Values in Table S1 in supplementary material).

Current national commitments under the Paris agreement are a start, but they are insufficient to limit global warming below potentially dangerous levels. Cities, businesses, and universities such as those analyzed in this paper, provide the living laboratories and testing grounds for creative new solutions. The examples described here clearly demonstrate that scalable technologies and measures are available now for reductions of about 40% to 50%. The full carbon neutrality goals, however, require new innovations. The eco-system of cities, industries and universities striving for carbon neutrality by 2050 will be the testing grounds for incubating such innovations. Scaling-up also requires solutions beyond the technological, and we have adopted 10 solutions (from published literature) including 3 devoted to technological solutions. Community and policy actions, as well as technologies deployed at the level of a city or a business can serve as beacons for national to global scale actions. Cumulatively the actions and efforts of these city-level initiatives and businesses categorized under the 10 solutions will create the shift/movement necessary for restoring the balance of the Earth system, limiting projected warming to *well below* 2^0C.

Acknowledgments: This study grew out of a class project for the 2016 Climate Solutions course piloted at the San Diego campus of the University of California. We benefited from support from the University of California office of the President. We thank Lifang Chang, Matt St Clair,

Byron Washom, Scott Samuelsen, Jack Miles, Bart Croes and Cliff Rechstaffen who gave lectures for the living laboratories portion of the course.

Acknowledgments, Samples, and Data

- This study grew out of a class project for the 2016 Climate Solutions course piloted at the San Diego campus of the University of California. We benefited from support from the University of California office of the President. We thank Lifang Chang, Matt St Clair, Byron Washom, Scott Samuelsen, Jack Miles, Bart Croes and Cliff Rechstaffen who taught the living laboratories portion of the course.
- The authors declare no affiliations or financial conflicts of interests
- Data for city and business commitments come from individual sources in references as well as the Compact of Mayors https://www.compactofmayors.org/cities/ , the CDP http://www.cdp.net/ , the World Resources Institute CAIT Climate Data Explorer: Paris Contributions http://cait.wri.org/indc/#/, and personal communication with the Cities of Philadelphia [Rich Freeh, Mayor’s Office of Sustainability, August 17th, 2016], Sydney [Hanya Gartner, C40 Cities, October 12th, 2016],Bournemouth [David Lawrence, Energy Engineer - Bournemouth Borough Council, August 23, 2016], Seattle [Tracy Morgenstern, Climate Policy Advisor at City of Seattle, September 13, 2016], Oslo [Guri Tajet, Oslo Kommune, October 25, 2016],Stockholm [Jonas Tolf, Head of Energy&Climate Unit, Environment and Health Administration, City of Stockholm, August 8, 2016], and Vaxjo [Henrik Johansson, Vaxjo Kommune, August 17, 2016]. City data is visible in supplement 1, and businesses in supplement 2

References

Abbott (2016) Abbot Global Citizenship Report 2015. http://prod3.dam.abbott.com/global/documents/pdfs/abbott-citizenship/global-reports/2015_Global_Citizenship_Report_061416.pdf

Abengoa (2015) Annual Report http://www.abengoa.com/export/sites/abengoa_corp/resources/pdf/en/gobierno_corporativo/informes_anuales/2015/Tomo1/2015_Volume1_AR.pdf

Adelaide City Council (2015) Carbon Neutral Strategy 2015-2025 Adelaide, South Australia http://www.bbhub.io/mayors/sites/14/2015/06/Adelaide-CarbonNeutralStrategy.pdf

Adidas Group (2015) How we create Responsibility: Adidas Group Sustainability Progress Report. http://www.adidas-group.com/media/filer_public/9c/f3/9cf3db44-b703-4cd0-98c5-28413f272aac/2015_sustainability_progress_report.pdf

Adobe (2015) Adobe Corporate Responsibility Report 2015. http://wwwimages.adobe.com/content/dam/acom/en/corporate-responsibility/pdfs/adobe-cr-report-2015.pdf

Agencia d'Ecologia Urbana de Barcelona (2010) Vitoria-Gasteiz against Climate Change 2010-2020 Executive Summary. https://www.vitoria-gasteiz.org/wb021/http/contenidosEstaticos/adjuntos/es/40/65/34065.pdf

Air France-KLM (2014) Corporate Social Responsibility Report. http://www.airfranceklm.com/sites/default/files/publications/afklm_radd_2014_uk_dp.pdf

Air Resources Board. (2015) California's 2030 Climate Commitment: Renewable Resources for half of the State's Electricity by 2030. https://www.arb.ca.gov/html/fact_sheets/2030_renewables.pdf

Air Resources Board. (2016) 2016 Edition California GHG Emission Inventory. California Greenhouse Gas Emissions for 2000 to 2014-Trends of Emissions and Other Indicators. Jun 17, 2016. https://www.arb.ca.gov/cc/inventory/pubs/reports/2000_2014/ghg_inventory_trends_00-14_20160617.pdf

Air Resources Board. (2016) 2030 Target Scoping Plan Update. Concept Paper. Jun17, 2016. https://www.arb.ca.gov/cc/scopingplan/document/2030_sp_concept_paper2016.pdf

Air Resources Board (2013) Memorandum of Understanding to Enhance Cooperation on Emissions Trading Systems between the Government of Shenzhen Municipality of the People's Republic of China and the Government of the State of California of the United States of America. June 18, 2013. https://www.arb.ca.gov/newsrel/2013/shenzhen_and_ca_mou.pdf

Akzo Nobel (2015) Note 5: Resource Efficiency http://report.akzonobel.com/2015/ar/sustainability/value-chain-management/note-5-resource-efficiency.html

Alcatel Lucent (2015) Sustainability Report https://www.unglobalcompact.org/system/attachments/cop_2016/285061/original/alu_2015_sustainability_report.pdf?1463416888

Apple Inc. (2016) Environmental Responsibility Report https://www.apple.com/environment/pdf/Apple_Environmental_Responsibility_Report_2016.pdf

Auckland Council (2015) Auckland's Greenhouse Gas Inventory for 2013. Technical Report. http://www.aucklandcouncil.govt.nz/SiteCollectionDocuments/aboutcouncil/planspoliciespublications/technicalpublications/tr2015031aucklandsgreenhousegasinventoryfor2013.pdf

Auckland Council (2014) Low Carbon Auckland Auckland's Energy Resilience and Low Carbon Action Plan. http://www.aucklandcouncil.govt.nz/EN/planspoliciesprojects/plansstrategies/theaucklandplan/Documents/lowcarbonauckactionplanfullversion.pdf

Austrian Energy Agency (2016) Findings of the Progress Report https://www.wien.gv.at/umwelt/klimaschutz/pdf/klip-folder2015-kurz-en.pdf

Autodesk (2015) Sustainability in Action: From Epic Challenges to Integrated Solutions https://www.unglobalcompact.org/system/attachments/cop_2015/173201/original/autodesk_sus

Brown, L.M., A Hanafi, A. Petsonk (2012) The EU Emissions Trading System: Results and Lessons Learned. Executive Summary. Environmental Defense Fund. Washington DC.

BMW Group (2015) Sustainable Value Report: Acting Sustainably Achieving Objectives. https://www.unglobalcompact.org/system/attachments/cop_2016/277121/original/BMW_SVR_2015

Braskem (2014) Annual Report. https://www.unglobalcompact.org/system/attachments/cop_2015/181691/original/Braskem_2014

Bureau of Economic Analysis, US Department of Commerce. (2015) Economic Growth widespread across Metropolitan Areas in 2013. Advance 2014 and revised 2001-2013. Retrieved Dec 11, 2017.

Bureau Veritas (2015) Verification Statement Greenhouse Gas Emissions and Renewable Energy Goldman Sachs http://www.goldmansachs.com/citizenship/environmental-stewardship-and-sustainability/operational-impact/carbon-emissions-verification.pdf

C2ES. (2015) California Cap and Trade. Center for Climate and Energy Solutions. http://www.c2es.org/us-states-regions/key-legislation/california-cap-trade

C40. (2016) Durban (eThekwini) Oct. 25 2016 http://www.c40.org/cities/durban-ethekwini

CAIT Paris Contributions Map. (2016) World Resources Institute. http://cait.wri.org/indc/
State of California. (2016) California Climate Change Legislation.
http://www.climatechange.ca.gov/state/legislation.html

California Overview. 2015. Under2 MOU Appendix http://under2mou.org/wp-content/uploads/2015/05/California-appendix-English.pdf

Canary Initiative. (2007) City of Aspen Canary Initiative Climate Action Plan http://aspenpitkin.com/Portals/0/docs/City/GreenInitiatives/Canary/CAP-final%20without%20dates.pdf

Carbon Neutral Cities Alliance. (2015) Framework for Long-Term Deep Carbon Reduction Planning. Executive Summary. http://usdn.org/uploads/cms/documents/cnca-executive-sum_web.pdf

Carbonn (2015) Adaptation and Mitigation to Climate Change Plan for Bogota. http://carbonn.org/uploads/tx_carbonndata/Brief%20%5bIngles%5d%20-%20Plan%20Distrital%20de%20Adaptaci%C3%B3n%20y%20Mitigaci%C3%B3n%20al%20Cambio%20Clim%C3%A1tico%2019.10.pdf

Carbonn Greenhouse Gas Emissions Inventory For the City of Johannesburg http://carbonn.org/uploads/tx_carbonndata/GPC%20Report%20for%20the%20City%20of%20Johannesburg_01.pdf

Carbonn (2016) Carbon Climate Registry Report: Oslo Municipality Norway http://carbonn.org/index.php?id=312&tx_datareport_pi1%5Buid%5D=339

Cemex (2014) Building Resilient and Sustainable Urban Communities http://www.cemex.com/SustainableDevelopment/files/CemexSustainableDevelopmentReport2014_s.pdf

City of Austin (2012) Climate Protection Resolution No. 20070215-0232 2012 Update http://austintexas.gov/sites/default/files/files/Sustainability/2012%20Resolution%20Matrix.pdf

City of Boston (2014) Greenovate Boston 2014 Climate Action Plan Update https://www.cityofboston.gov/eeos/pdfs/Greenovate%20Boston%202014%20CAP%20Update_Full.pdf

City of Boulder (2015) BOULDER'S CLIMATE COMMITMENT City of Boulder, Colorado October 2015 Rising to the climate challenge, powering a vibrant future. Draft 2015. https://www-static.bouldercolorado.gov/docs/11-24-15_Climate_Commitment_PRINT_READY-1-201605231619.pdf

City of Boulder, Colorado (2016) Boulder's. Community Greenhouse Inventory. https://bouldercolorado.gov/climate/boulders-community-greenhouse-gas-inventory

City of Budapest (2015) Budapest, Appendix "Under2 MOU" http://under2mou.org/wp-content/uploads/2015/05/Budapest-appendix-English.pdf

City of Canberra (2015) In Focus Report CDP
https://www.cdp.net/Documents/cities/2016/Canberra-2015-InFocus-Report.pdf

City of Chicago (2015) Chicago Climate Action Plan
http://www.chicagoclimateaction.org/filebin/pdf/finalreport/CCAPREPORTFINALv2.pdf

City of Copenhagen. The Technical and Environmental Administration. Copenhagen Climate Neutral by 2025 Copenhagen Climate Plan
https://www.energycommunity.org/documents/copenhagen.pdf

City of Johannesburg (2015) In Focus Report CDP
https://www.cdp.net/Documents/cities/2015/johannesburg-in-focus.pdf

City of Johannesburg Metropolitan Municipality. Joburg 2040: Growth and Development Strategy http://www.joburg.org.za/gds2040/pdfs/joburg2040_gds.pdf

City of Leon (2015) Mitigation Climate Action Plan
http://www.bbhub.io/mayors/sites/14/2015/07/Mitigation-Climate-Action-Plan.pdf

City of Melbourne (2014) Zero Net Emissions by 2020. Update 2014
https://www.melbourne.vic.gov.au/SiteCollectionDocuments/zero-net-emissions-update-2014.pdf

City of Mexico City (2015) In Focus Report CDP
https://www.cdp.net/Documents/cities/2016/Mexico-City-2015-InFocus-Report.pdf

City of Minneapolis (2012) Greenhouse Gas Inventories
(http://www.minneapolismn.gov/www/groups/public/@citycoordinator/documents/webcontent/wcms1p-092812.pdf
City of Minneapolis (2014) Greenhouse Gas Emissions Climb in 2013
http://www.minneapolismn.gov/www/groups/public/@citycoordinator/documents/webcontent/wcms1p-138003.pdf

City of Minneapolis (2016) Sustainability Indicators August 24, 2016
http://www.minneapolismn.gov/sustainability/indicators/WCMS1P-087163

City of Montreal (2015) MONTRÉAL DURABLE 2016-2020 Ensemble pour une métropole durable.
http://ville.montreal.qc.ca/pls/portal/docs/PAGE/d_durable_fr/media/documents/plan_montreal_durable_2016_2020.pdf

City of New York, Inventory of New York City Greenhouse Gas Emissions, September 2011, by Jonathan Dickinson and

Andrea Tenorio. Mayor's Office of Long-Term Planning and Sustainability, New York, 2011.

City of Philadelphia (2015) Philadelphia Citywide Greenhouse Gas Inventory, 2012. Mayor's Office of Sustainability https://beta.phila.gov/media/20160429144916/2015-citywide-greenhouse-gas-emissions-inventory-for-2012.pdf

City of Port Phillip (2011) Greenhouse Plan Low Carbon City http://www.bbhub.io/mayors/sites/14/2015/11/ICL_GEN_004_Port_Phillip_Compact_Greenhouse_Plan_01-1.pdf

City of Port Phillip (2016) Welcome to City of Port Phillip Economic Profile . Demographic Resources. http://economy.id.com.au/port-phillip

City of Portland (2015) Climate Action Plan: Local Strategies to Address Climate Change. Multnomah County. http://www.bbhub.io/mayors/sites/14/2015/06/Portland-Action-Plan.pdf

City of San Diego Climate Action Plan. July 12, 2016. https://www.sandiego.gov/planning/genplan/cap

City of San Diego Cool California Case Study http://www.coolcalifornia.org/sites/coolcalifornia.org/files/case_study_file/San%20Diego%20City%20story.pdf

City of Sonderborg (2016) CDP Cities Response

City of Stockholm. (2009) City of Stockholm's Climate Initiatives http://carbonn.org/uploads/tx_carbonndata/Stockholm_Climate_Initiatives.pdf

City of Stockholm (2010) Stockholm Action Plan for Climate and Energy http://carbonn.org/uploads/tx_carbonndata/StockholmActionPlanForClimateAndEnergy2010-2020%5b1%5d.pdf

City of Sydney (2012) State of the Environment Report. http://www.cityofsydney.nsw.gov.au/__data/assets/pdf_file/0005/122387/StateOfEnvironmentReport201112Final.pdf
City of Sydney (2015) In Focus Report CDP https://www.cdp.net/Documents/cities/2015/sydney-in-focus.pdf

City of Tainan. Low Carbon City http://www.bbhub.io/mayors/sites/14/2015/11/Tainan-City-_2014-Low-Carbon-City-Promotion-Report1.pdf

City of Vancouver (2015) Greenest City 2020 Action Plan. http://vancouver.ca/files/cov/greenest-city-2020-action-plan-2015-2020.pdf

City of Vancouver (2016) Renewable City Strategy Summary http://vancouver.ca/files/cov/renewable-city-strategy-summary.pdf

City of Vienna (2014) Smart City Wien Framework Strategy. https://smartcity.wien.gv.at/site/files/2014/09/SmartCityWien_FrameworkStrategy_english_onepage.pdf

City of Yokohama . Overviews of Yokohama City Section Plan for Global Warming Countermeasures http://www.city.yokohama.lg.jp/ondan/plan/jikkou-kuiki/pdf/plan-english.pdf

Climate Action Tracker. (2015) http://climateactiontracker.org/countries/bhutan.html

CCAC (2016) Climate and Clean Air Coalition Initiatives http://www.ccacoalition.org/en/initiatives

CNH Industrial (2014) Sustainability Report: Economic, Environmental, and Social Responsibility http://www.cnhindustrial.com/en-us/sustainability/corporate_sustainability_reports/reports/20

Collins, W.D., S.J. Davis, R. Bales, J. Burney, R. Bales, J. Burney, R. McCarthy, E. Rignot, W. Torre, D.Victor. (2016) Pathways for Bending the Curve. SIOC 209 Course: 10 Scalable Solutions for Climate Change Lecture. V.Ramanathan. Scripps Institution of Oceanography, UC San Diego. La Jolla, CA. April 14.

Covenant of Mayors (2015) Signatories Bristol: Action Plan in a Nutshell http://www.covenantofmayors.eu/about/signatories_en.html?city_id=378&seap

Covenant of Mayors (2015) Signatories Donostia San Sebastian: Action Plan in a Nutshell http://www.covenantofmayors.eu/about/signatories_en.html?city_id=352&seap

Covenant of Mayors (2015) Signatories Freiburg: Action Plan in a Nutshell http://www.covenantofmayors.eu/about/signatories_en.html?city_id=24&seap

CTC (2015) Carbon Tax Center: Where Carbon is Taxed. http://www.carbontax.org/where-carbon-is-taxed/

Department of Energy and Environment (2016) Climate Ready DC: The District of Colombia’s Plan to Adapt to Changing Climate. Draft http://doee.dc.gov/sites/default/files/dc/sites/ddoe/service_content/attachments/CRDC%20Draft%20for%20Public%20Comment--Web%20%28Reduced%29_0.pdf

Department of Energy and Environment (2012) Greenhouse Gas Emissions Inventory 2006 to 2011 Fact Sheet http://doee.dc.gov/node/384852

Energy Agency of Madrid (2012) Inventory of Madrid City Greenhouse Gas Emissions 2012. http://mycovenant.eumayors.eu/docs/document/14849_1431508275.pdf

Environment and Health Administration (2011) Stockholm action plan for climate and energy 2012-2015. City of Stockholm. August 23, 2016

EThekwini Municipality Energy Office (2014) Final Summary Document: eThekwini Greenhouse Gas Emissions Inventory 2014
http://www.durban.gov.za/City_Services/energyoffice/Documents/eThekwini_GHG_Inventory_2014_Summary_Final.pdf

European Union (2013) EU Emissions Trading System (EU ETS). Factsheet.
http://ec.europa.eu/clima/publications/docs/factsheet_ets_en.pdf

Food and Agricultural Organization of the United Nations (FAO). (2013) Food Wastage Footprint: Impacts on Natural Resources. Summary Report.
http://www.fao.org/docrep/018/i3347e/i3347e.pdf

Facebook (2015) Facebook Sustainability Data
https://fbsustainability2.files.wordpress.com/2016/05/facebook-sustainability-data-2015_public-disclosure.pdf

Fujitsu Group (2014) CSR http://www.fujitsu.com/global/Images/annualreport2014-pdf-18_tcm100-1103691.pdf

Gas Natural Fenosa (2015) Integrated Annual Report
http://www.gasnaturalfenosa.com/servlet/ficheros/1297152555880/Informe_Integrado_ing.pdf

Gelles, D. How Producing Clean Power Turned Out to Be a Messy Business. New York Times. Aug 13, 2016.

Global City GDP 2014 (Johannesburg). Brookings Institution. Archived from the original 4 June 2013. Retrieved 18 Nov 2017.

Goldman Sachs (2016) Our Operational Impact: Carbon and Energy October 24 2016
http://www.goldmansachs.com/citizenship/environmental-stewardship/our-operational-impact/carbon-energy/index.html

Gonzales, F. and H. Rodriguez (2000) Greenhouse Gas Emissions in Colombia 1998-2010. Colombian Academy of Sciences
http://www.accefyn.org.co/Web_GEI(actualizada)/Archivos_gei/1998_2010_GHG_Emissions.PDF

Google (2016) Google Green: A Better Web: Better for the Environment August 16, 2016
https://www.google.com/green/bigpicture/
Government of the District of Colombia (2010) Climate of Opportunity Climate Action Plan for the District of Colombia Draft
http://doee.dc.gov/sites/default/files/dc/sites/ddoe/publication/attachments/ClimateOfOpportunity_web.pdf

Greater London Authority (2012) London Energy and Greenhouse Inventory (LEGGI) https://data.london.gov.uk/dataset/leggi2012/resource/10e2d257-a8cb-4ed7-b592-fce6e1e971a3

Gunnarson, Vivian. (2006) The City of Stockholm, Sweden Climate Change target: Fossil Fuel Free 2050. http://worldcongress2006.iclei.org/uploads/media/A1_GUNNARSSON_Stockholm_Target_Zero.pdf

Hirschl, B.; F. Reusswig und J. Weiß (2015). Kurzfassung des Endberichts „Entwurf für ein Berliner Energie- und Klimaschutzprogramm (BEK)“, November 2015. im Auftrag des Landes Berlin, Senatsverwaltung für Stadtentwicklung und Umwelt.

H&M (2015) Conscious Actions Sustainability Report 2015 http://sustainability.hm.com/content/dam/hm/about/documents/en/CSR/2015%20Sustainability%20report/HM_SustainabilityReport_2015_final_FullReport_en.pdf

Hoeje-Taastrup Kommune (2014) CO_2 Inventory. Hojetaastrup_CO2_regnskab_2014.pdf

Hoeje-Taastrup Kommune (2015) Climate Action Plan. http://www.bbhub.io/mayors/sites/14/2015/10/Hoeje-Taastrup-Action-Plan.pdf

HP (2015) Sustainability Report https://www.unglobalcompact.org/system/attachments/cop_2016/304611/original/HP_2015_Sustainability_Report.pdf?1469718702

HSBC (2015) Key Facts at a Glance. http://www.hsbc.com/our-approach/reports-and-documentation

ICAP (2016) China- Shenzhen pilot System. International Carbon Action Partnership. https://icapcarbonaction.com/en/?option=com_etsmap&task=export&format=pdf&layout=list&systems%5B%5D=63

ICF International (2007) Greenhouse Gases and Air Pollutants in the City of Toronto: Toward a Harmonized Strategy for reducing Emissions https://www1.toronto.ca/city_of_toronto/environment_and_energy/key_priorities/files/pdf/ghg-aq-inventory-june2007.pdf

IETA (2015) Tokyo: An Emissions Trading Case Study. http://www.ieta.org/resources/Resources/Case_Studies_Worlds_Carbon_Markets/tokyo_case_study_may2015.pdf

IKEA Group (2015) Sustainability Report https://www.unglobalcompact.org/system/attachments/cop_2016/262861/original/IKEA_Group_Sustainability_Report_FY15.pdf?1455752918

Infosys (2016) Sustainability Report https://www.unglobalcompact.org/system/attachments/cop_2016/294361/original/infosys-sustainability-report-2015-16.pdf?1466486796

Intel Corporation (2015) Global Climate Change Policy Statement http://www.intel.com/content/dam/www/public/us/en/documents/corporate-information/environment-climate-change-policy-harper.pdf

IPCC (2014) Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.) IPCC, Geneva, Switzerland.

Jacobson, M.Z., M.A. Delucchi, Z.A.F Bauer, S.C. Goodman, W.E. Chapman, M.A. Cameron, C. Bozonnat, L. Chobadi, J.R. Erwin, S.N. Fobi, O.K. Goldstrom, S.H.Harrison, T.M. Kwasnik, J.Lo, J. Liu, C.J. Yi, S.B. Morris, K.R. Moy, P.L. O'Neil, S. Redfern, R. Schucker, M.A. Sontag, J. Wang, E. Weiner, A.S. Yachanin. (2016) 100% Clean and Renewable Wind, Water, and Sunlight (WWS) All Sector Energy Roadmaps for 139 Countries of the World. Stanford University. Palo Alto, Ca.

Johnson&Johnson (2015) Citizenship & Sustainability Report http://www.jnj.com/sites/default/files/pdf/cs/2015-JNJ-Citizenship-Sustainability-Report.pdf

Kao Corp (2016) Kao Sustainability Report. October 16, 2016 http://www.kao.co.jp/corp/sustainability-reports/en/ecology/lifecycle/

Kin, W., Shin, S., Kim W., Kim, J. (2009) A Preliminary Study on Seoul's Vision for Climate Protection Initiative in 2030. http://global.si.re.kr/sites/default/files/report_data/a2009-PR-01.pdf

KT Corp. (2015) Gigatopia Integrated Report http://file.kt.com/kthome/eng/social/csrReport/csr03/ENG_kt%20Integrated%20Report%202015_151221.pdf

Kuo, F. Climate Change Adaptation Strategies of Taipei Metropolitan and Taiwan http://start.org/download/car-ppt/2-kuo.pdf

La Poste (2014) Registration Document https://www.ipc.be/~/media/documents/public/annual-reports/member-reports/2014/legroupelaposte_2014.pdf

LG Electronics (2016) 2015-2016 Sustainability Report http://www.lg.com/global/sustainability/communications/sustainability-reports
L'Oréal (2015) Progress Report: Sharing Beauty with all. http://www.sharingbeautywithall.com/sites/default/files/cms/sbwa-progress-report-2015_english.pdf

Lotte Shopping Co. (2014) Lotte Shopping 2014 Sustainability Report: Think Tomorrow https://www.unglobalcompact.org/system/attachments/cop_2014/132141/original/2014_LOTTE_SHOPPING_SUSTAINABILITY_REPORT%28'14.12.26%29.pdf?1419826504

Mainichi (2015) Tokyo government aims to cut greenhouse gas emissions by 30 percent from 2000 levels. http://mainichi.jp/english/articles/20151120/p2a/00m/0na/015000c

Mairie de Paris (2012) Plan Climat Energie de Paris http://api-site-cdn.paris.fr/images/70921

Mars Inc. (2014) Principles in Action: Summary 2014. http://www.mars.com/docs/default-source/doing-our-part/principles-in-action/2014-summary/mars_principles_in_action_summary_2014_en.pdf

Mayor of London (2011) Delivering London's Energy Future: Executive Summary. https://www.london.gov.uk/sites/default/files/gla_migrate_files_destination/Energy-future-oct11-exec-summ.pdf

Mayor's Office of Operations (2007) Inventory of New York City Greenhouse Gas Emissions http://www.nyc.gov/html/om/pdf/ccp_report041007.pdf

Metro Group (2015) Condensed Report 2014/15: Metro Group's Carbon Footprint. September 25, 2016. http://reports.metrogroup.de/2014-2015/condensed-report/sustainability/carbon-footprint.html

Microsoft (2015) Microsoft 2015 Citizenship Report https://www.unglobalcompact.org/system/attachments/cop_2015/198171/original/Microsoft_2015_Citizenship_Report.pdf?1445289079

Municipality of Quito (2016) CDP Cities Response. http://www.cdp.net/

Murray, Danielle (2012) San Francisco Mayor's Renewable Energy Task Force Recommendations Report. San Francisco Department of Environment. http://sfenvironment.org/sites/default/files/fliers/files/sfe_re_renewableenergytaskforcerecommendationsreport.pdf

Natura Cosmeticos (2015) 2015 Indicators: Annual Report 2015 https://www.unglobalcompact.org/system/attachments/cop_2016/299521/original/ra2015_indicatorsannualreport_20160523.pdf?14679

Nedbank Group (2014) Nedbank Group Limited Carbon Neutral Journey https://www.nedbank.co.za/content/dam/nedbank/site-assets/AboutUs/Sustainability/Supporting%20Documents/CarbonNeutralJourney.pdf

Nestle (2015) Nestle in Society Creating Shared Value and Meeting our Commitments 2015, https://www.unglobalcompact.org/system/attachments/cop_2016/276781/original/1.Nestle-2015-csv-full-report-en.pdf?1460642314

New Climate Economy Report (2015) Seizing the Global Opportunity http://newclimateeconomy.report/2015/

Nike Inc. (2016) Sustainable Business Report. http://www.sustainablebrands.com/digital_learning/csr_report/next_economy/nike_inc_fy1415_sustainable_business_report

Novartis (2015) Annual Report https://www.novartis.com/sites/www.novartis.com/files/novartis-annual-report-2015-en.pdf
Novartis (2016) Environment Fact Sheet https://www.novartis.com/sites/www.novartis.com/files/environment-factsheet-sept-14-2.pdf

Office of Sustainability (2015) Austin Community Climate Plan. City of Austin http://austintexas.gov/sites/default/files/files/Sustainability/FINAL_-_OOS_AustinClimatePlan_061015.pdf

Peak, M., C. Buntine. (2004) California Clean Vehicle Industry. CALSTART

Pope Francis (2015) Ladauto Si. Encyclical Letter on the care of our common home. http://w2.vatican.va/content/francesco/en/encyclicals/documents/papa-francesco_20150524_enciclica-laudato-si.html

Ramanathan V., J.E. Allison, M. Auffhammer, D. Auston, A.D. Barnosky, L. Chiang, W.D. Collins, S.J. Davis, F. Forman, S. B. Hecht, D. Kammen, C.-Y. C. L. Lawell, T. Matlock, D. Press, D. Rotman, S. Samuelsen, G. Solomon, D.G. Victor, B. Washom, (2015): Executive Summary of the Report, Bending the Curve: 10 scalable solutions for carbon neutrality and Climate stability. University of California, October 27, 2015.

Ramanathan V. et al. Special Collection: Bending the Curve: Ten scalable solutions for carbon neutrality and climate stability. The Regents of the University of California. 12 Dec 2016. http://www.collabra.org/collections/special/bending-the-curve/

Rechtschaffen, C. (2016) Living Laboratories: The State of California. SIOC 209 Course: Scalable Solutions for Climate Change Lecture. V. Ramanathan. Scripps Institution of Oceanography, UC San Diego. La Jolla. CA. May 24.

Reusswig, F; B. Hirschl, W. Lass (2014). “Climate-Neutral Berlin 2050: Results of a Feasibility Study”. March 2014. Senate Department for Urban Development and the Environment.

Robra, J.P. (2010) An emissions inventory of air pollutants for the city of Bogotá, Colombia. Master Project Final Report. Swiss Federal Institute of Technology, Lausanne. https://infoscience.epfl.ch/record/166732/files/PDM_FinalReport_JPR.pdf
Roche (2015) Annual Report 2015 http://www.roche.com/dam/jcr:aff5512d-6aaa-4ca8-b4c3-27e563d838cd/en/gb15e.pdf

Rockström, J. H. J. Schnellhuber, B. Hoskins, V. Ramanathan , P. Schlosser , G. Brasseur , O. Gaffney, C. Nobre , M. Meinshausen, J. Rogelj , L. Wolfgang (2016) The World's Biggest Gamble. Earth's Future. AGU

Royal Philips (2016) Sustainability: Healthy People, Sustainable Planet. September 15, 2016. http://www.philips.com/a-w/about/sustainability/our-approach/ambition-2020.html

Royal Philips (2016) Sustainability: Carbon Footprint October 15, 2016 http://www.philips.com/a-w/about/sustainability/sustainable-planet/green-operations/carbon-footprint.html

Samuelsen, Scott. (2016) Technology Advancement: Meeting Energy Demands and Economic Growth while preserving the Environment. SIOC 209 Course: Scalable Solutions for Climate Change Lecture. V. Ramanathan . Scripps Institution of Oceanography, UC San Diego, La Jolla CA. May 2.

San Francisco Department of the Environment. San Francisco Community-wide Carbon Emissions by Category. http://sfenvironment.org/sites/default/files/fliers/files/sfe_cc_emissions_inventory_summary_1990-2010.pdf

San Francisco Department of the Environment. (2013) San Francisco Climate Action Strategy http://sfenvironment.org/sites/default/files/engagement_files/sfe_cc_ClimateActionStrategyUpdate2013.pdf

San Sebastian City Hall Environment Board. (2015) Hiri Berdea 2030 Environmental Strategy Donostia / San Sebastián http://www.energy-cities.eu/db/San_Sebastian_environmental_strategy_2015_en.pdf

SAP (2016) Sustainability Management and Policies. https://www.unglobalcompact.org/system/attachments/cop_2016/278871/original/UNGC_COP_2016.pdf?1461334037

Sasol (2015) Sasol Online Sustainable Development Information 2015 Our Governance Framework for Sustainable Development https://www.unglobalcompact.org/system/attachments/cop_2015/214781/original/Sasol_2015_Sustainability_Reporting.pdf?1448529371

SB. 1383. Short-lived climate pollutants (CA. 2016)

Schlossberg, T. English Village Becomes Climate Leader by Quietly Cleaning Up Its Own Patch. New York Times. Aug 21, 2016

State of California (2015) Governor Brown Established most Ambitious Greenhouse Gas Reduction Target in North America. https://www.gov.ca.gov/news.php?id=18938.

Seattle Office of Sustainability and Environment (2016) 2014 Seattle Community Greenhouse Gas Emissions Inventory.
http://www.seattle.gov/Documents/Departments/OSE/Climate%20Docs/2014GHG%20inventorySept2016.pdf

Seiko Epson (2015) For Our Customers, For Society: Sustainability Report.
https://www.unglobalcompact.org/system/attachments/cop_2015/184991/original/epson_sr2015_all_e.pdf?1440985468

Sempra Energy (2015) People, priorities, and Performance. http://responsibility.sempra.com/wp-content/uploads/2016/07/2015-Sempra-Energy-CR-Report-PDF-Final.pdf

Seoul Metropolitan Government (2012) Detailed Action Plans for Adaptation Measures to Climate Change (2012-2016) http://www.bbhub.io/mayors/sites/14/2015/06/2.-SMG_Summary_Detailed-Implementation-Plans-to-adapt-to-Climate-Change_EN-1.pdf

Seoul Metropolitan Government (2015) Action Plans for Promise of Seoul. Climate and Environment Headquarters http://www.bbhub.io/mayors/sites/14/2015/06/1-1-Summary-of-Action-Plans-to-implement-Promise-of-Seoul_EN-1.pdf

Seoul Solution (2015) 2030 Seoul Plan https://seoulsolution.kr/content/2030-seoul-plan?language=en

SGS SA (2016) Carbon Emissions. September 24, 2016 http://www.sgs.com/en/our-company/corporate-sustainability/online-sustainability-reports/2015-report/d

Siemens (2015) Sustainability Information 2015
http://www.siemens.com/about/sustainability/pool/en/current-reporting/siemens_sustainability_information2015.pdf

Sodexo (2016) Creating a Better Tomorrow: Corporate Responsibility Report 2016.
http://www.cr.sodexo.com/assets/files/sodexo-corporate-responsibility-report-2016.pdf

Sony (2015) CSR Report 2015
http://www.sony.net/SonyInfo/csr_report/issues/CSR2015E_PDF_all_e.pdf

Stockland (2015) Sustainability at Stockland October 20, 2016.
https://www.stockland.com.au/about-stockland/sustainability

Sweden.se. Climate is Key for Sweden. (2016) https://sweden.se/nature/sweden-tackles-climate-change/

Swedish Energy Agency. (2015) . Sun in the Community.
http://www.energimyndigheten.se/fornybart/solenergi/solenisamhallet/

Swiss Re (2016) Reducing our Environmental Footprint September 24, 2016. http://www.swissre.com/about_us/reducing_footprint.html

Taipei City Government (1991) Taipei City Adaptation Action Plan. https://data.bloomberglp.com/mayors/sites/14/2015/09/Taipei-City_Adaptation-Action-Plan3.pdf

Taipei City Government (2015) Taipei Sets Carbon Reduction Target to Realize Vision of Livable City. http://english.gov.taipei/ct.asp?xItem=145205920&ctNode=8472&mp=100002

Taiwan Semiconductor Manufacturing Company (2015) Environmental Dimension. http://www.tsmc.com/download/csr/2015_tsmc_csr/english/pdf/e_ch5.pdf

Telenet (2014) Working on your future Sustainability Report https://www.unglobalcompact.org/system/attachments/cop_2015/187381/original/01072015_Telenet_Sustainability_Report_2014_final.pdf?1441824757

Thai Oil PCL (2015) Towards the 55th Year of Sustainability https://www.thaioilgroup.com/upload/media_file/20160314094724_SustainabilityReport2015_EN.pdf

The London Plan (2015) Chapter Five: London's Response to Climate Change https://www.london.gov.uk/sites/default/files/gla_migrate_files_destination/London%20Plan%20March%202015%20(FALP)%20-%20Ch5%20London's%20Response%20to%20Climate%20Change.pdf \

The Walt Disney Company (2014) Disney's Environmental Stewardship Goals and Targets https://ditm-twdc-us.storage.googleapis.com/envirogoalsandtargets.pdf

Tokyo Metropolitan Government (2015) Tokyo Environmental Master Plan. Policy Planning Section, General Affairs Division,
Bureau of Environment.
https://www.kankyo.metro.tokyo.jp/en/files/3371113b16ac4fcba42a6d86e8438080.pdf

Toronto Environment and Energy Office (2011) Summary of Toronto's 2011 Greenhouse Gas and Air Quality Pollutant Emissions Inventory. http://www.toronto.ca/legdocs/mmis/2013/pe/bgrd/backgroundfile-57187.pdf

UBS AG (2015) Sustainability Disclosure https://www.ubs.com/global/en/about_ubs/ubs-and-society/information-center.html#objectives

UNEP (2011) Environment Climate Change Outlook: Metropolitan District of Quito. http://www.pnuma.org/deat1/pdf/2011%20-%20ECCO%20Quito%20Summary%20(web).pdf

UN Habitat. Urbanization: Climate Change. http://unhabitat.org/urban-themes/climate-change/

Unilever NV (2015) Making Sustainable Living Commonplace: Annual Report and Accounts 2015. Strategic Report. https://www.unilever.com/Images/annual_report_and_accounts_ar15_tcm244-478426_en.pdf

University of California Annual Report on Sustainable Practices. (2015). University of California Office of the President. http://ucop.edu/sustainability/_files/annual-sustainability-report2015.pdf

Vale (2015) Sustainability Report 2015. https://www.unglobalcompact.org/system/attachments/cop_2016/291261/original/Vale_Sustainability_Report_2015.pdf?1465415218

Vaughn, A. (2016) UK ministers to approve world-leading carbon emissions target. The Guardian. https://www.theguardian.com/environment/2016/jun/28/uk-ministers-world-leading-carbon-emissions-reduction-target-climate-change

Vaxjo Kommun (2015) Energy Plan for the City of Vaxjo. https://data.bloomberglp.com/mayors/sites/14/2015/06/Vaxjo-Energiplan_eng_webb_2011.pdf

Veolia (2014) CSR Performance Digest 2014. https://www.unglobalcompact.org/system/attachments/cop_2015/178021/original/2014_CSR_performance_digest.pdf?1437749810

Volkswagen Group (2015) At Home in America: 2013 Corporate Social Responsibility Report http://www.volkswagengroupamerica.com/documents/VW_CSR_Report_FINAL_Hi_Res_4_27_15.pdf

Volkswagen (2014) Sustainability Report 2014. http://www.volkswagenag.com/content/vwcorp/info_center/en/publications/2015/04/group-sustainability-report-2014.bin.html/binarystorageitem/file/Volkswagen_Sustainability_Report_2014.pdf

Volvo Car Group (2015) Sustainability Report https://www.unglobalcompact.org/system/attachments/cop_2016/283011/original/Volvo_Cars_Sustainability_Report_2015.pdf?1462799925

Walck, S. (2006) Carbon Neutrality: The HBC Story http://www.unepfi.org/fileadmin/events/2006/newyork/walck.

Westpac Group (2015) Annual Review and Sustainability Report. https://www.unglobalcompact.org/system/attachments/cop_2015/214631/original/2015_Annual_Review_Sustainability_Report.pdf?1448508270

World Green Building Council (2014) Green Building City Market Brief: Buenos Aires http://www.worldgbc.org/files/3014/0982/5868/Buenos_Aires_-_City_Market_Brief_Final.pdf

World Green Building Council (2014) Green Building City Market Brief: Mexico City
http://www.worldgbc.org/files/1414/0982/5897/Mexico_City_-_City_Market_Brief_Final.pdf

Table 1: California's Climate Change Legislation Adapted from State of California (2016)

AB* 4420	28 Sept. 1998	California Energy Commission created to inventory GHGs and study the effects
SB** 1771	30 Sept. 2000	California Climate Action Registry created to monitor emissions and set baselines
SB 527	11 Oct. 2001	Amended SB 1771 to include requirement of third party verification
AB 1493	22 July. 2002	"Pavley Bill" mandated regulations to reduce the emissions from passenger vehicles and light-duty trucks as much as possible
SB 812	7 Sept. 2002	Added forest management/ conservation-management practices
AB 1803	18 Jul. 2006	GHG inventory transferred to the Air Resources Board
SB 1	21 Aug. 2006	Adoption of Solar Initiative requires municipal utilities to create their own solar rebate programs
SB 107	12 Sept. 2006	Mandated increase of renewable electricity sold retail to customers from 17% to 20% by December 2010
AB 32	26 Sept. 2006	ARB adopts a statewide GHG limit to the 1990 levels by the year 2020
SB 97	24 Aug. 2007	Directs the government office of planning and research to develop CEQA guidelines for mitigating GHGs and effects
AB 118	14 Oct. 2007	Alternative and Renewable Fuel and Vehicle Technology Program to fund public projects which advance fuel and vehicle types
SB 375	30 Sept. 2008	Sustainable Communities and Climate Protect Act requiring regional GHG targets for passenger vehicles established by ARB
SB X1-2	12 April. 2011	Codified the 33% renewable energy by 2020 goal for all electricity retailers in the state
AB 1504	29 Sept. 2011	Requires Department of Forestry and Fire Protection, and ARB, to assess the capacity of forest and rangeland to meet GHG goals

AB 1538	30 Sept. 2012	Requires the Greenhouse Gas Reduction Fund to be included in the state’s budget
SB 535	30 Sept. 2012	Requires that 25% of funds from the cap and trade program go to benefiting disadvantaged communities
AB1092	29 Sept. 2013	Requires the Building Standards Commission to adopt mandatory building standards for the installation of future electric vehicle charging infrastructure
AB 8	29 Sept. 2013	Extends extra fees on vehicle registrations, boat registrations, and tire sales to fund programs that support the production, distribution, and sale of alternative fuels and vehicle technologies and air emissions reduction efforts
SB 1204	21 Sept. 2014	Creates California Clean Truck, Bus, and Off-Road Vehicle and Equipment Technology Program for development of ZEVs and near zero truck, bus, and off –road vehicle and equipment tech.
SB 1275	21 Sept. 2014	Establishes state goal of 1 million zero-emission and near-zero-emission vehicles in service by 2020, and establishes the Charge Ahead California Initiative requiring planning and reporting on vehicle incentive programs, and increasing access to and benefits from zero-emission vehicles for disadvantaged, low-income, and moderate-income communities
SB 605	21 Sept. 2014	Requires ARB to complete a comprehensive strategy to reduce emissions of short-lived climate pollutants
SB 350	7 Oct. 2015	Establishes targets to increase retail sales of renewable electricity to 50% by 2030, and double the energy efficiency savings in electricity and natural gas end uses by 2030
SB 32	8 Sept. 2016	Mandates at least 40% GHG reductions from 1990 levels by 2030.
SB 1383	19 Sept. 2016	Requires a 50% reduction in black carbon and 40% reduction in methane and hydrofluorocarbon from 2013 levels by 2030

*Assembly Bill, ** Senate Bill

Table 2: UC Campus Case Studies

UC Berkeley	Demand-response tech (PCS- Personal Comfort System) use low wattage devices to warm and cool individuals as opposed to entire floor/building CO_2 sensor network in Oakland- real time neighborhood by neighborhood measurements LED Microscope retrofits project Berkeley and SF partnership Electric launching shared bicycles program 15 LEED certifications (Leadership in Energy and Environmental Design)
UC Davis	Recycled water to cool buildings 22 LEED certifications West Village energy efficient building design aiming for carbon neutral Aggie Sol- "net zero home" project Food supply chain between the Russell Ranch Sustainable Agriculture Research Facility and campus dining services Solar farm Smart lighting initiative Anaerobic digester converts organic waste to biofuels
UC Irvine	Hydrogen Fuel cell bus Photovoltaic (PV) canopies over parking generate 3.2 MW 23 LEED certifications
UC Los Angeles	Electric Vehicle smart grid 24 LEED certifications Turf replacement and drought-tolerant landscaping New bike lanes/infrastructure to encourage alternate modes of transportation Subsidies for 6 public transportation systems
UC Merced	Solar Initiative HQ – 8.5 Acre PV Array Reusable container program tracks reusable containers with student IDs Agreement with Zipcar car share program 17 LEED certifications
UC Riverside	PV→ EV charging system LED lamp replacements Energy efficient freezers in lab Partners with UCSC on greenhouse project New residential designs to save water use 6 LEED certifications
UC San Diego	Micro grid 50% vehicle fleet uses alternative fuels Advancements in EV charging infrastructure Solar Power predictability project- fish eye camera technology Water Action Plan for drought, includes recycled water cooling and irrigation 26 LEED certifications- examples include Keeling apartments with living roof

UC San Francisco	Discounts to employees for EV and PV "Preventing HealthCARE from Becoming HealthHARM" workshop Updated medical center AC to efficient electric chiller 17 LEED certifications
UC Santa Barbara	Lighting research center Efficient water chilling facilities Student funded solar PV installation 62 LEED certifications
UC Santa Cruz	Greenhouses project with solar panel glass Rainwater (and fog condensation) harvesting system for grey water use Climate centric techno-economic analysis tool to analyze best methods Drought experiment plots Program in Community and Agroecology (PICA)- alternative housing incorporates organic gardening and composting 7 LEED certifications

Table 3: Technology measures and other strategies for mitigating SLCPs as adopted by

California, Sweden, and the Climate and Clean Air Coalition. Adapted from CCAC (2016)

SLCPs	California	Stockholm (Sweden)	CCAC
Methane	Livestock and dairy manure management; (scrape manure management systems, solids separation systems, and enteric fermentation) Biomethane projects Reduce Landfill disposal of organics/use for biofuel [Senate Bill 1383, 2016]	Low landfill emissions, use organic waste to make biofuels used primarily for public transportation (even import waste from other countries)	Improve recoverability from oil and gas industries Waste management plans and projects Livestock and manure management
Black Carbon	Diesel Engines → ZEVs, hybrids, EV's, hydrogen fuel cell vehicles, (alternative forms of transportation) Diesel engine retrofits/filters CA freight plan Residential Fireplace and woodstove conversion	Diesel engine retrofit/filter Alternative vehicles and transportation, EVs, ZEVs, ethanol/biofuels etc. Government owned freight operator "SJ" run on hydropower	Green freight action and Soot-free urban bus fleets, Low-sulfur fuels and cleaner diesel vehicles Dispel tech. and knowledge to reduce emissions from brick production Promote clean cook stoves, heat stoves, and fuels Ban agricultural waste burning
HFC's	Phase out of ODSs (Ozone Depleting Substances) and CFCs→phase out of HFCs (replacement of old appliances, use natural refrigerants where possible) Advance semiconductors	Phase out HFCs (prevent growth) with alternatives in refrigerants and air conditioning etc.	Promote equipment design alternatives from high-GWP HFCs in refrigerants and ACs

Table 4: 10 Solutions in California and Stockholm

Solution	**California**	**Stockholm, Sweden**
1	✓AB32; SB 32; SB 1383 (see Table 1)	✓Fossil fuel free by 2040
2		✓Advisors to educate/outreach
3	✓Under2 MOU Leadership, cap and trade linked with Quebec	✓Participates in a number of initiatives like COM, C40, etc.
4	✓Bending the curve	✓Smaller neighborhoods within cities
5	✓Cap and Trade	✓EU Emissions Trading, tax reliefs to power intensive industries for energy plans
6	✓Rebates and standards for clean tech	✓Efficiency standards, subsidize public transit, Carbon Tax, electricity certificate system
7	✓Incentives/rebates for solar and EV, Renewable portfolio	✓Outreach to promote- energy advisors
8	✓High speed rail network, promotion and incentives for ZEVs/EVs goals and mandate, grants for charging infrastructure of battery and hydrogen fuel cell EVs, programs to support near zero and zero emission vehicles and fuels	✓Multimodal infrastructure to promote public transit, most run on renewables or biofuels
9	✓SB1383	
10	✓Scoping Plan/ Forest Plan incorporate conservation management and forestry in carbon inventory (sequestration)	✓Urban Gardening programs

Table 5: Carbon Neutral Technologies in California and Sweden

Carbon Neutral Tech Solutions	**California**	**Stockholm (Sweden)**
Combustion and Fossil Fuels	Alternative energy sources: wind, solar (fish-eye camera project to advance predictability), geothermal, biomass, and hydroelectric plants [goal is 50% renewable electricity by 2020] Flexible energy grids, smart grids Advancing battery and storage technology Increased Electrification of energy Micro grids	Alternative energy sources: wind, solar, hydropower, nuclear, cogeneration from combined heat and power, geothermal, wave power, biofuels [Sweden is currently at 52% renewable energy, goal is fossil fuel free by 2050] Increased Electrification of energy Heating Systems: Oil pumps converted to heat pumps or central heating systems, also "passive heating" projects utilizing body heat, or aquifer thermal energy storage system (stores water in summer, heats homes in winter, cools in summer)
Industry	Fuel switching to alternatives Building retrofits/zero-net energy buildings More efficient heating and cooling systems-such as those with recycled water or smart grid/demand-response Smart grid/advanced communications	Transition to alternative fuels Heat Recovery technology R&D in smart-fuels, carbon capture and storage, and smart grids
Residential	LED (improved lighting), advancement and replacement of outdated low-efficiency appliances, some green roofs, PV Smart meters	Improved efficiency lighting, replacing windows , green roofs, heating systems, solar cells and panels "Echologs" and smart consumption monitoring systems

Transportation	ZEVs, EVs, Hydrogen fuel cell vehicles, hybrids (mandates and regulation) and more charging stations Alternative fuels in public transportation (hydrogen fuel cell, CNG, biofuels) Advancements in materials and engines of petrol vehicles to use less gasoline (fuel efficiency)/ upgrading vehicle fleet	EVs and "green" cars increasing (however, infrastructure emphasis on multi-modal public transit) Public transport fossil fuel free (biogas and ethanol)
Waste and Landfills	Increased collection of gases released Improved recycling/waste diversion rates Zero waste facility with anaerobic digesters which convert food rich waste to biofuels	Efficient recycling (only 1% waste to landfill nationally) Organic waste converted to biofuels for public transportation
Agriculture/ Land-use	Forestry and land use management and monitoring for carbon sequestration Utilizing synergies in R&D of bioenergy, food crops, water system and waste management, and product manufacture	"Plantagon" vertical greenhouses- urban agriculture