Mitigation Strategies for a Changing Climate in National City, CA

Public Health 700D “Global Climate Change”

Fall 2015 • Public Health • PH 700D

Jeremy McKinstry & Zohir Chowdhury
Table of Contents

Acknowledgments ................................................................................................................. 4
  Sage Project Staff .................................................................................................................. 4
About Sage .................................................................................................................................. 5
About National City .................................................................................................................... 5
Executive Summary ................................................................................................................... 6
Introduction ............................................................................................................................... 8
Implementation of a Pedestrian and Bicycle Master Plan ....................................................... 18
  Bike Share Program .................................................................................................................. 19
  Phase-Based Implementation .................................................................................................. 22
  Improving Existing Bicycle Lanes ......................................................................................... 26
  Pedestrian and Bicycle-Friendly Overpasses ......................................................................... 26
  Additional Bicycle Lanes ........................................................................................................ 27
  Protected Bicycle Lanes .......................................................................................................... 27
  Improvements to Recreational Areas and Infrastructure .......................................................... 28
  Solar Bikeway .......................................................................................................................... 31
  Education, Promotion, and Safety ............................................................................................ 32
  Benefits .................................................................................................................................... 33
  Emission Reduction Potential .................................................................................................. 34
  Limitations and Weaknesses .................................................................................................... 37
Strategies to Reduce Environmental Impact and Aid in Mitigation from Transportation, Industry, and Port Emissions .................................................................................................................. 39
  Community Education and Involvement .................................................................................. 39
Transportation Emissions ........................................................................................................... 40
  Traffic Roundabouts ................................................................................................................ 41
  Emission Reductions ............................................................................................................... 42
Environmental Zones .............................................................................................................. 43
  Emission Reductions ............................................................................................................... 44
Converting the 805 to a Boulevard ............................................................................................. 45
  Emission Reductions ............................................................................................................... 46
Improving Public Transportation ............................................................................................... 47
  Emission Reductions ............................................................................................................... 47
LED Streetlights ....................................................................................................................... 48
  Emission Reductions ............................................................................................................... 49
Group Grocery Ordering System ................................................................................................. 50
  Emission Reductions ............................................................................................................... 50
<table>
<thead>
<tr>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric Cars in 2050</td>
<td>51</td>
</tr>
<tr>
<td>Emission Reductions</td>
<td>52</td>
</tr>
<tr>
<td>Transportation Summary</td>
<td>53</td>
</tr>
<tr>
<td>Limitations and Weaknesses</td>
<td>53</td>
</tr>
<tr>
<td>Port Emissions</td>
<td>54</td>
</tr>
<tr>
<td>Shore Power</td>
<td>55</td>
</tr>
<tr>
<td>Emission Reductions</td>
<td>55</td>
</tr>
<tr>
<td>On-Road Transportation</td>
<td>56</td>
</tr>
<tr>
<td>Emission Reductions</td>
<td>56</td>
</tr>
<tr>
<td>Solar Power Plant</td>
<td>57</td>
</tr>
<tr>
<td>Emission Reductions</td>
<td>58</td>
</tr>
<tr>
<td>Power-To-Gas Facility</td>
<td>59</td>
</tr>
<tr>
<td>Create a Waste Treatment Facility</td>
<td>60</td>
</tr>
<tr>
<td>Emission Reductions</td>
<td>61</td>
</tr>
<tr>
<td>Port Summary</td>
<td>62</td>
</tr>
<tr>
<td>Limitations and Weaknesses</td>
<td>62</td>
</tr>
<tr>
<td>Industry Emissions</td>
<td>63</td>
</tr>
<tr>
<td>LED Lighting</td>
<td>64</td>
</tr>
<tr>
<td>Emission Reductions</td>
<td>64</td>
</tr>
<tr>
<td>Green Roofs/Rooftop Gardens</td>
<td>65</td>
</tr>
<tr>
<td>Emission Reductions</td>
<td>65</td>
</tr>
<tr>
<td>Energy Efficient Technologies</td>
<td>66</td>
</tr>
<tr>
<td>Emission Reductions</td>
<td>67</td>
</tr>
<tr>
<td>Cap and Trade System</td>
<td>68</td>
</tr>
<tr>
<td>Emission Reductions</td>
<td>69</td>
</tr>
<tr>
<td>Urban Forests</td>
<td>70</td>
</tr>
<tr>
<td>Emission Reductions</td>
<td>71</td>
</tr>
<tr>
<td>Industry Summary</td>
<td>72</td>
</tr>
<tr>
<td>Limitations and Weaknesses</td>
<td>72</td>
</tr>
<tr>
<td>Recommendations and Conclusions</td>
<td>73</td>
</tr>
<tr>
<td>Bike share system</td>
<td>73</td>
</tr>
<tr>
<td>Addressing Transportation Emissions</td>
<td>74</td>
</tr>
<tr>
<td>Addressing Industry Emissions</td>
<td>75</td>
</tr>
<tr>
<td>Addressing Port Emissions</td>
<td>76</td>
</tr>
<tr>
<td>Works Cited</td>
<td>78</td>
</tr>
<tr>
<td>Appendix: Calculations</td>
<td>84</td>
</tr>
<tr>
<td>Bike Share</td>
<td>84</td>
</tr>
<tr>
<td>Transportation</td>
<td>86</td>
</tr>
<tr>
<td>Industry</td>
<td>88</td>
</tr>
<tr>
<td>Port</td>
<td>90</td>
</tr>
</tbody>
</table>
Acknowledgements

I would first like to thank Professor Zohir Chowdhury, who instructed our class on both global climate change and the state of California’s stalwart approach to mitigating climate change. I am also grateful for my classmates from Public Health 700D, who provided realistic ideas for mitigating climate change in National City. Without them, writing this report would not have been possible. Lastly, I would like to offer a special thanks to Professor Jessica Barlow and the Sage Project. Through the Sage Project, the students in Public Health 700D were presented with a chance to apply our “learned knowledge” to a real-world situation. Through this project, we were able to provide assistance and ideas to an underrepresented and underserved community right in our own backyard.

Sage Project Director and Staff

Jessica Barlow  Program Director
Piper Whalen  Graphic Design Intern
About the Sage Project

The Sage Project is a partnership between San Diego State University (SDSU) and a city or government entity in the San Diego region. The mission of the program is to engage students from across the University to assist the local government with projects that address their smart growth, quality of life, and sustainability goals. Students have the opportunity to engage in meaningful real-world projects and make positive contributions to a community in SDSU’s service area. The program’s vision is to connect SDSU students and faculty with high-priority, high-need community projects, thereby generating interest and fresh ideas that create momentum and provide real service to the community. The Sage Project embodies the University’s commitment to serving local students, engaging alumni, and contributing to the public good by focusing thousands of hours of course-based student involvement with high-impact activities.

The program is based on the highly successful and award-winning Sustainable City Year Program (SCYP) at the University of Oregon and is a part of the SCYP network. National City, California, is the Sage Project’s 2013-2014 partner city. Participating courses come from the following disciplines: Anthropology; Audiology; City Planning; Civil Engineering; Communication; Criminal Justice; Geography; Graphic Design; Homeland Security; International Security and Conflict Resolution; Marketing; Political Science; Public Administration; Public Health; and Speech, Language, and Hearing Sciences.

About National City

National City is a highly urban community of about 60,000 residents in south San Diego County. It is the second oldest city in the county and boasts a rich history, a diverse community, and is known as one of the most walkable cities in San Diego County. Located just south of downtown San Diego and just north of the US-Mexico border, the city is flanked by freeways and is home to large-scale industries. National City is a mid-size city that faces big city challenges, and, like many municipalities, the city is challenged to meet community needs and new demands of sustainability. By providing new ideas and human capacity, this partnership with the Sage Project will help National City implement sustainability concepts and practices into projects that will improve livability.
Executive Summary

The climate change mitigation strategies outlined in this report were created through the partnership between National City and the SDSU Sage Project during the fall of 2014. Graduate students in the Public Health 700D course titled “Global Climate Change,” taught by Professor Zohir Chowdhury, elected one of two project options: designing a pedestrian and bicycle master plan or devising strategies to aid in environmental impact and mitigation from port, industry, and transportation emissions. The goal of both of these projects was to find strategies for reducing greenhouse gas (GHG) emissions within National City and to improve the overall health of its residents.

National City already has a Climate Action Plan (CAP), which was published in 2011. This plan provides an emissions inventory for the city as well as forecasting emission data for the future. This data includes reduction targets that the city hopes to reach for the year 2020, as well as 2030. This plan also includes strategies to be implemented that will help to reduce emissions (National City, 2011). It is already 2015, and the 2020 reduction target of 15% emission reductions from 2005 levels is looming. It is urgent that the city implement additional strategies in order to reach the goals outlined in the CAP. New data will need to be collected on emissions within the next five years, as the data currently available is outdated, having been collected in 2005 (National City, 2011).

The first class project topic, designing a pedestrian and bicycle master plan, sought ways to improve the current infrastructure within the city to further support alternative forms of transportation. One method to support this change is to improve connectivity within the city. There are many schools, retail centers, parks, and residential communities which can benefit from new physical infrastructure. The goal of this project was not only to reduce GHG emissions, but also to provide health and environmental benefits. This report will expand upon the following ideas related to pedestrian and cycling infrastructure:

- Phase-by-phase implementation of a bike share system
- Improvements to existing bicycle lanes
- Addition of new bicycle lanes
- Protected bicycle lanes
- Improvements to recreational areas and infrastructure
The second class project topic, formulating strategies to reduce environmental impact and aid in mitigation from port, industry, and transportation emissions, sought first to identify GHG emissions, air pollutant emissions, and other environmental impacts from the port, industry, and freeways. After the above emission sources were identified, the groups then provided ways to mitigate these impacts to improve the quality of life and environment within the city. This report will expand on the following ideas to address these environmental impacts:

- Traffic roundabouts
- Environmental zones
- A group grocery delivery system
- LED streetlights
- Addition of a solar power plant, power-to-gas facility, and waste treatment plant
- A cap and trade system
- Shore power
- Urban forests

This report will conclude by highlighting the most compelling strategies for implementation within National City, including calculations of potential GHG reductions. These strategies should not be viewed as comprehensive plans, but rather as individual ideas that can be adapted into National City’s current CAP. These strategies will help to reduce GHG emissions as well as improve the quality of life for all residents within National City.

In order to meet 2020 goals, it is urgent that these strategies be adapted as soon as possible. Though California has emerged as a global leader in working to combat a changing global climate, without the participation of every community, both large and small, this battle will be lost. Governor Brown recently announced a new aggressive executive order that would call for emission reductions to 40 percent below 1990 levels by 2030. This is even more aggressive than President Obama’s plan to reduce carbon dioxide emissions by 30 percent below 2005 levels by 2030 (Associated Press, 2015). If this new executive order is passed, it will call for a new inventory of current GHG emissions, a re-evaluation of the current CAP, and the implementation of additional aggressive climate change mitigation strategies.
Introduction

What is climate change? The United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere, and which is in addition to natural climate variability observed over comparable time periods (UNFCCC, 2011). The UNFCCC is an international treaty that was created to address the threats of climate change and encourage the reduction of GHG emissions. Although the UNFCCC contains no enforceable standards, it has provided the framework for negotiating future international treaties. The Intergovernmental Panel on Climate Change (IPCC) is the leading international body for assessing the science related to global climate change.

The IPCC was created in 1988 with the goal of providing policymakers with regular assessments of the scientific basis for climate change, its potential impacts and future risks, and adaptation and mitigation strategies (IPCC, 2015). The IPCC is made up of three working groups, each with a distinctive role in assessing climate change science. Working Group I (WG I) assesses the scientific aspects of the global climate system and climate change. Working Group II (WG II) deals with the negative and positive aspects of climate change, the vulnerability of socio-economic and natural systems to climate change, and adaptation strategies that can be employed. Working Group III (WG III) assesses options for mitigating climate change through the limitation or prevention of GHG emissions and by enhancing activities that remove them from our atmosphere (IPCC, 2015).

In 2007, the IPCC published their 4th annual report. In this report, they concluded that climate change is the result of human activity, that the cost of action is significantly lower than the cost of inaction, and that catastrophic effects will occur if we continue to allow climate change to go unchecked (IPCC, 2015). These catastrophic events include a rising global temperature, rising sea level, increasing severe weather patterns, and a reduction in air quality (IPCC, 2015). These factors will affect many aspects of our lives including health, agriculture, water supplies, and ecosystems. In November 2014, the IPCC finalized the Fifth Assessment Report, which provided an update on the scientific and socio-economic knowledge from previous reports. It increased the confidence level to “extremely likely” that human influence has been the major cause of warming since 1950. It also stated that reducing emissions will continue to increase in price in the future, especially if government inaction continues. Finally, all models from this report predicted that by 2100, global mean temperature rise from pre-industrial levels will exceed 1.5°C (IPCC, 2015).
There have already been many observations that prove the existence of climate change. These events include the retreating of glaciers, more extreme weather events (e.g. drought in California), and shrinking sea ice in the northern hemisphere (IPCC, 2015). Evidence of climate change in California can be viewed in Figure 1. In the future, climate change will only intensify, and we must find ways to not only mitigate its effects, but also to adapt to a changing world.

IPCC research suggests that a 60% reduction of GHGs below 1990 levels is necessary to reverse global warming and stabilize the climate (National City, 2011). The current goal, which was agreed upon at the 2010 Cancun Climate Change Conference, is to prevent a global temperature increase of more than 2°C. Any increase over this limit is predicted to result in irreversible effects on Earth’s climate systems (UNFCCC, 2010). The state of California began passing legislation to help mitigate the effects of climate change as early as 2002. Since then, much more legislation has been passed and climate action plans have been adopted at the state, county, and city levels. California has emerged as a leader in the battle against climate change.
**Figure 1** Evidence of climate change in California.

The state of California has passed much legislation in an attempt to mitigate global climate change, as summarized in Table 1. The first bill, AB 1493, also known as Pavley, stated that GHG emissions from passenger vehicles, light-duty trucks, and other personal, non-commercial vehicles must be reduced. In 2005, Executive Order S-3-05, also known as the Greenhouse Gas Initiative, set statewide emissions target reductions to 2000 levels by 2010, to 1990 levels by 2020, and to 80% below 1990 levels by 2050. This bill also identified the California Environmental Protection Agency (Cal/EPA) as the lead agency for establishing these emissions reductions. In 2006, the Global Warming Solutions Act, AB 32, required the California Air Resources Board (CARB) to adopt a statewide GHG emissions limit of 1990 levels by 2020. It also appointed a Climate Action Team to coordinate overall climate policy. The Sustainable Communities and Climate Protection Act, SB 375, was passed in 2008 and called for the CARB to develop GHG emission reduction targets for passenger vehicles in 2020 and 2035. It also called for planning organizations to develop sustainable community strategies. In 2011, the Renewable Portfolio Standard (SB X1-2) states that California utility companies must provide 33% of their electricity from renewable resources by 2020 (State of California, 2011).
Table 1  Important climate change regulation passed in California.

<table>
<thead>
<tr>
<th>BILL &amp; DATE OF ISSUANCE</th>
<th>TITLE</th>
<th>DESCRIPTION</th>
<th>IMPLEMENTING AGENCY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Executive Order S-345S</td>
<td>Greenhouse Gas Initiative</td>
<td>Set statewide GHG emissions targets to 2000 levels by 2010, 1990 levels by 2020, 80% below 1990 levels by 2050</td>
<td>California Air Resources Board (ARB)</td>
</tr>
<tr>
<td>Assembly Bill (AB) 32</td>
<td>Global Warming Solutions Act</td>
<td>State must reduce GHG emissions to 1990 levels by 2020</td>
<td>ARB</td>
</tr>
<tr>
<td>Senate Bill (SB) 97</td>
<td>CEQA Guideline Amendments</td>
<td>Guidelines for addressing GHG emissions in CEQA documents must be formulated and adopted</td>
<td>California Office of Planning and Research (OPR)</td>
</tr>
<tr>
<td>SB 375 (2008)</td>
<td>Sustainable Communities and Climate Protection Act</td>
<td>GHG emissions from passenger vehicles must be reduced; set targets (developed by ARB) for 2020 and 2035; and prepare sustainable communities strategies</td>
<td>Metropolitan planning organizations (MPO)</td>
</tr>
<tr>
<td>AB 1493 (2002)</td>
<td>Air Quality</td>
<td>GHG emissions must be reduced from passenger vehicles, light-duty trucks, and other non-commercial vehicles for personal transportation</td>
<td>ARB</td>
</tr>
<tr>
<td>Executive Order S-LQ7</td>
<td>The Low Carbon Fuel Standard (LCFS)</td>
<td>The carbon intensity of California’s transportation fuels must be reduced by at least 10% by 2020</td>
<td>ARB</td>
</tr>
<tr>
<td>SB X1-2 (2011)</td>
<td>Renewable Portfolio Standard</td>
<td>California investor-owned utilities must provide at least 30% of their electricity from renewable resources by 2020</td>
<td>California Public Utilities Commission</td>
</tr>
<tr>
<td>SB X7 (2009)</td>
<td>Statewide Water Conservation</td>
<td>State must achieve 20% reduction in per capita urban water use by 2020</td>
<td>Department of Water Resources</td>
</tr>
<tr>
<td>CCR Subarticle 1 § 95300 (2006)</td>
<td>Heavy-Duty Vehicle Greenhouse Gas Emission Reduction Measure</td>
<td>Require existing trucks/trailers to be retrofited with the best available technology and/or ARB-approved technology</td>
<td>ARB</td>
</tr>
</tbody>
</table>
National City has adopted its own Climate Action Plan (CAP) and strategies to reduce emissions. This plan sets emission reduction targets that are consistent with statewide goals. As illustrated in Table 2, the goal is to reduce GHG emissions to 1990 levels by 2020, which is a reduction of 15% from 2005/2006 levels (National City, 2011). It then calls for additional reductions by 2030. It is estimated that through the CAP, GHG emissions will be reduced by 156,127 MTCO2e from the 2030 business-as-usual (BAU) predictions (National City, 2011). The CAP calls for GHG reductions from all sectors, and then goes on to outline strategies that will be implemented in order to achieve these forecasted emissions reductions.

Table 2 National City emissions reductions targets for 2020 and 2030 as forecasted by the CAP (National City, 2011)

<table>
<thead>
<tr>
<th></th>
<th>Community Emissions</th>
<th>Government Operations Emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Base Year (2005/2006)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quantity of CO2e emissions in 2005/2006 (metric tons)</td>
<td>550,714</td>
<td>5,077</td>
</tr>
<tr>
<td><strong>Target Year (2020)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Business-as-usual projection of CO2e emissions in 2020 (metric tons)</td>
<td>587,386</td>
<td>5,774</td>
</tr>
<tr>
<td>Percent CO2e reduction from baseline targeted by target year (%)</td>
<td>15%</td>
<td>15%</td>
</tr>
<tr>
<td>Quantity of CO2e reduction targeted (metric tons)</td>
<td>119,379</td>
<td>1,459</td>
</tr>
<tr>
<td><strong>Target Quantity of CO2e emissions in 2020 (metric tons)</strong></td>
<td>468,107</td>
<td>4,315</td>
</tr>
<tr>
<td><strong>Target Year (2030)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Business-as-usual projection of CO2e emissions in 2030 (metric tons)</td>
<td>704,067</td>
<td>6,686</td>
</tr>
</tbody>
</table>
Currently, over 90% of the community emissions within National City are from two major sources: the transportation sector and the commercial and industrial sector (National City, 2011). Figure 2 illustrates the 2005 community-wide emissions inventory for National City. Table 3 illustrates the major emission generators and where these emissions come from. Most of the projects sought ways to reduce emissions from these major sources. Reducing transportation emissions is especially challenging because National City is surrounded on three sides by major freeways (Interstate 5 to the east, California State Route 54 to the south, and Interstate 805 to the west); thus, many of the city’s transportation emissions are not only being generated by residents of National City, but also by other commuters and travelers who use these freeways.

![Figure 2: Community Wide Emission Inventory 2005 (National City, 2011)]
Another major contributor to current GHG emissions is the Unified Port of San Diego. The port is not only located in National City, but also extends into portions of San Diego, Chula Vista, Imperial Beach, and Coronado. Overall, the emissions generated from port activities were responsible for 826,429 MTCO2eq (Port of San Diego, 2013). This number encompasses emissions not just from National City, but all parts of the port. However, given that most of the coastal area within National City is dominated by the port, these emissions must be addressed as well. Transportation is also the largest emission source from the port; this includes both on-road and off-road (vessels, boats, etc.) transportation. Figure 3 compares source emissions from the port to community source emissions.

<table>
<thead>
<tr>
<th>Sector</th>
<th>Major Uses that Generate Emissions</th>
<th>Source of Emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial/Industrial</td>
<td>Gas use: heat buildings, fire boilers and generation of electricity</td>
<td>11% natural gas</td>
</tr>
<tr>
<td></td>
<td>Electric use: lighting, heating, power appliances and equipment</td>
<td>89% electricity</td>
</tr>
<tr>
<td></td>
<td>95% On-road Transportation</td>
<td>90% gasoline</td>
</tr>
<tr>
<td></td>
<td>30% local roads and 70% freeways</td>
<td>10% diesel</td>
</tr>
<tr>
<td></td>
<td>5% Off-road Transportation</td>
<td>80% diesel</td>
</tr>
<tr>
<td></td>
<td>70% construction equipment, 14% industrial equipment, 9% light commercial equipment and 7% lawn garden equipment</td>
<td>12% gasoline</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8% natural gas</td>
</tr>
<tr>
<td>Solid Waste</td>
<td>Active and inactive landfills (only 75% of Methane gets captured)</td>
<td>Methane out of waste</td>
</tr>
</tbody>
</table>

Table 3  Major Emissions by Uses and Source (National City, 2011)
The Port of San Diego has also developed its own climate action plan. This CAP uses 2006 as a baseline year and then projects emissions for 2020, 2035, and 2050, as displayed in Figure 4. These projections take into account the impacts of future development projects and increases in cargo and cruise activities (Port of San Diego, 2013). The port has set reduction goals of 10% less than 2006 baseline levels by 2020 and 25% less than 2006 levels by 2035 (Port of San Diego, 2013). The port intends to reach these target levels through new policies, programs and regulations.
The final contributor to GHG emissions in National City is the Navy. No data was available for emissions generated by the Navy during the time of this project, therefore the Naval activities will not be discussed further in this report. It is important that the Navy adopt emissions reductions strategies as well. The best way to mitigate climate change involves the adoption of sustainable practices from all generators of GHG emissions within National City, including the Navy. Hopefully, in the future, the Navy will also adopt a climate action plan.

Figure 4  Port emissions by sector. Data also includes projected reductions for 2020, 2035, and 2050 as predicted by the Port of San Diego CAP (Port of San Diego, 2013, p. 12).
Implementation of a Pedestrian and Bicycle Master Plan

The current state of the bicycle lanes within National City is inadequate to support a bike share system. There are three classifications of bike lanes: class I, class II, and class III. The safest lane, class I, provides a completely separated lane for the exclusive use of cyclists and pedestrians and prohibits the use of motorized vehicles. A class II bike lane provides a striped line for one-way bike travel on a street or highway. A class III bike lane or “sharrow” is a bike lane in which cyclists and motorists both must share the roadway (Transportation Alternatives, 2009). These bike lane classifications can be viewed in Figure 5. Class III bike lanes are usually found on lower volume roadways. The only class I bikeway present in National City is the Sweetwater Bike Path. All of the other bike lanes in National City are either class II or class III. Class III lanes in particular are dangerous and can be very intimidating for residents interested in utilizing bicycles as a method of transportation. Additionally, current bike lanes are poorly connected to residential areas, schools, parks, retail centers, and work places; improving bike lane connectivity can increase bicycle usage.

Figure 5  (A,B,C); (A) depicts a class I bike lane. (B) depicts a class II bike lane. (C) depicts a class III bike lane or “sharrow.”

Retrieved from http://bikingrules.org/biking/laneprimer
Bike Share Program

A major improvement to bicycle infrastructure within National City would be the introduction of a bike share program. A bicycle share system is a service in which bicycles are made available for shared use to individuals on a short-term basis. Bicycles can be borrowed and returned at various locations throughout the city, and daily, monthly, or yearly membership options are available. Recently, bike share systems have been appearing in many cities not only within the United States, but also globally as well. In the year 2000, there were only 6 bike share systems with a fleet of around 4,000 bicycles. As of 2013, there were over 600 bike share systems across 53 countries with a bicycle fleet of over 643,000. This growth can be viewed in Figure 6, while Figure 7 displays the worldwide distribution of bike share systems. China is leading this race, with 81 systems and nearly 440,000 bicycles (Midgley, 2013).

Figure 6  Growth in global bicycle share systems and fleet size since 2000.
DecoBike, a bike share system, was recently launched in San Diego. Figures 8 and 9 provide illustrations of a DecoBike station located in Balboa Park. Though most of the stations are located in the downtown and North Park areas, an expansion of this existing partnership into National City should be explored. If this is not possible, there are many other successful bike share systems currently operating in the US, including B-cycle, which is present in over 30 cities nationwide. National City is an excellent candidate for implementation of a bike share system because of its compact land area of 9.1 square miles (this includes coastal and marine area), favorable year-round climate, and compatible public transit installations (i.e. trolley stations). Given this compact city size, accessible trolley stations, and complimentary climate, the entire city could be bikeable with the addition of a bike share system and improvements to current bike lanes.

![Global expansion of bike-sharing](image)

**Figure 7** Worldwide distribution of bicycle sharing countries, systems, and fleets.

A bike share system is convenient and easy to use. The most established bike sharing system in the U.S., B-cycle, is integrated with a mobile application which allows users to rent and return bikes through their devices. They can also view all of the nearby stations and the availability of bicycles at said stations. Their bicycles also come equipped with baskets, which make running errands easier. If a simple vehicular trip to the grocery store could be replaced with a bicycle trip, it could go a long way in reducing GHG emissions as well as improving the overall health of the residents (B-Cycle, n.d.).

Figure 8  DecoBike Station at Balboa Park.  
Photo taken by J. McKinstry

Figure 9  DecoBike pay station.  
Photo taken by J. McKinstry
Phase-Based Implementation

A complete bike share system in National City would not need to be installed all at one time. A phase-based implementation may be advantageous for several reasons. Installing a bike share system in phases would promote rider safety through a gradual increase of cyclists throughout the city, progressively acclimating motorists and pedestrians to bikers. It would also reduce the financial risk because the program could be cancelled with minimal economic impact if it were shown to be ineffective. The first phase of this approach connect the current trolley stations within National City (8th St. & 24th St.) to the 6 largest employers within the city: Walmart, Paradise Valley Hospital, the Port of San Diego, Naval Base San Diego, the city, and the school district. A map of phase 1 can viewed in Figure 10. Currently, a lot of the existing bicycle lanes in National City are class III, which would be inadequate for this project. As stated earlier and to ensure the success of this project, it is recommended that all class III lanes be upgraded to at least class II. Residents will be more likely to use the system if they feel safe while riding the bikes through the city.

Figure 10  Phase 1 implementation of bike share system. Rally flags represent trolley stations; green flags represent largest employers; green lines represent existing class III bike lanes. Map prepared by E. Natuzzi, 2014.
The second phase would connect communities with local retail and recreational locations. These locations would include Pepper Park, Kimball Park, Las Palmas Park, El Toyon Park, and Plaza Towne Shopping Center. This phase would also require the creation of additional bike lanes to increase the connectivity within the city. It is recommended that these lanes also be class II to help ensure the safety of cyclists. This phase can be viewed in Figure 11.

Figure 11  Phase 2 of National City Bike Share Program implementation; rally flags indicate trolley stations; red flags indicate recreational and retail locations; green lines indicate existing class III bike lanes; red lines indicate additional recommended bike lanes. Map prepared by E. Natuzzi, 2014.
Phase three would connect residential communities with local schools. This phase would begin with colleges, high schools, and middle schools and finish with grade schools. They recommend first connecting ITT Technical Institute, Sweetwater High School, National City Middle School, and Granger Junior High School. Additional schools can be added later based on a successful trial period. A map of this phase can viewed in Figure 12. This phase would also require additional bicycle lanes to be added for connectivity purposes. By this phase of implementation, it is paramount that all existing bike lanes within National City are at least class II. This phase introduces school-aged children into the system, and their safety is one of the keys to success and continued adaptation of a bike share system.

Figure 12 Phase 3 of National City Bike Share Program Implementation; rally flags indicate trolley stations; yellow flags indicate recommended schools; green lines indicate existing class III bike lanes; red lines indicate additional recommended bike lanes. Map prepared by E. Natuzzi, 2014.
Phase four would build on all the previous phases as well as complete the Bayshore Bikeway connections between National City, Chula Vista, Imperial Beach, and downtown San Diego with a class I bikeway. The Bayshore Bikeway can viewed in its entirety in Figure 13. National City could also partner with adjacent cities and explore the option of replacing the Bayshore Bikeway with a bike path paved with solar panels. This project could provide energy saving and lighting for the path. More information on solar bike lanes will be provided below.

![Bayshore Bikeway in its entirety](http://api.ning.com/files/N6RdP7ceccGN*oG*-6*ywd2s7ybkylabpX*5jkTB75PuOxq21G87HtskjaUxduo8fr2LdKvXELzEDF3s4IiYmY2xldzyRDC1/ScreenShot20120920at3.53.12PM.png)
Improving Existing Bicycle Lanes

In order for this system to be successful, improvements must be made to the existing bike lanes throughout the city. This is especially important on the busier streets such as 4th Street and 18th Street, which currently have class III bike lanes. The Bayshore Bikeway on Harbor Avenue and Tidelands Avenue should also be converted to a class I bikeway. The Bayshore Bikeway connects many communities within San Diego and is frequently used by many residents. Currently, most of the bikeway is either class I or class II, except in National City where it is class III. This is unacceptable, especially for safety reasons. Harbor Avenue experiences heavy traffic due to its location by the port and naval base. The speed limit is 45 mph and without a proper class I bikeway, commuters are subject to not only the dangers of motorists, but also the noise pollution caused by traffic. Wooden barriers made from recycled wood or green walls (made of trees, plants, and shrubs) could be installed to solve both of these problems.

Pedestrian and Bicycle-Friendly Overpasses

The addition of pedestrian- and bicycle-friendly overpasses would further improve the safety of residents traveling without a motor vehicle. An overpass is a bridge pathway that provides right of way for bikers and pedestrians completely separated from automobiles. These could be added in high-traffic areas and would improve the safety of pedestrians and commuters. They could also improve traffic by eliminating the necessity of traffic lights where they are added. Removing traffic lights will also reduce vehicle idling, which will reduce GHG emissions. An overpass could be added above Highland Avenue, connecting the Wal-Mart Supercenter to the commercial center across the street (Pedestrian and Bicycle Information Center, n.d.). A map displaying this proposed overpass can be viewed in Figure 14.

Figure 14  Proposed overpass is indicated by red line. This would provide an alternative, safer route from Wal-Mart to the commercial center across the street. Map prepared by R. Luna.
Additional Bicycle Lanes

In addition to improving current bicycle lanes, new bike lanes should be constructed within the city as well. This would promote the overall connectivity of the city and help to ensure the success of a bike share program. Better connections should be added between the Bayshore Bikeway and Kimball Park and then from Kimball Park to the Sweetwater Bikeway. We also propose the addition of bike lanes to National City Boulevard, Highland Avenue, and Plaza Boulevard. These are all frequently traveled roads that are home to many commercial locations. Adding bicycle lanes to these locations will make them more accessible to cyclists, and thus reduce vehicle emissions.

Protected Bicycle Lanes

Protected bicycle lanes offer safety and health benefits to pedestrians, cyclists, and motorists and have been shown to provide economic benefits as well. They have also been shown to increase bicycling where they are installed (People for Bikes n.d.). These “green” bike lanes could be implemented along some of the main roads within National City. They would shield cyclists and pedestrians from traffic as well as promote bicycling, which can reduce GHG emissions. These protected bicycle lanes could be installed along National City Boulevard, Highland Avenue, E24th Street, Plaza Boulevard, and E18th Street. This could create up to 7 miles of shielded bike lanes, as illustrated in Figure 15.

Figure 15 Proposed Protected Bicycle Lanes. Map prepared by A. Gee.
Improvements to Recreational Areas and Infrastructure

The overall goal of implementing a pedestrian and bicycle master plan is to increase the amount of cyclists within National City. Implementing a bike share program, improving current bicycle lanes, and incorporating additional bike lanes will create the proper infrastructure to make cycling in National City a desirable alternative to driving. Once this is established, improvements must be made within the city to help support a cycling lifestyle and increase the participation rate for a bike share system. Individuals are more likely to consider cycling if there are unspoiled bicycle paths and pristine parks and recreational areas to visit.

One area in particular need of improvement is the Sweetwater Bike Path. This area is currently the only class I bike lane in the city, and it is currently plagued by pollution and urban decay. The installation of waste and recycling bins along the path could help reduce the amount of litter and waste. Additionally, because this bike path runs parallel to the 54 freeway, separated only by a chain-link fence, it is an excellent candidate for installation of a green wall. This wall would not only improve the aesthetic of the path, but also provide safety and benefit the environment. A green wall mitigates noise pollution caused by the freeway and provides plants to help absorb some of the carbon dioxide emissions from traffic. Figure 16 displays the proposed barrier. The Sweetwater Bike Path is also in need of updated signage, as the current sign is very small and covered with stickers. All bike share systems and recreational areas should be equipped with a stationary map that shows all of the bike paths within National City. Finally, the addition of solar panel LED lighting along the path would provide safety and security for those using the path at night.

![Figure 16](http://www.fhwa.dot.gov/environment/noise/noise_barriers/design_construction/noise_title.jpg)

**Figure 16** (A) Existing “barrier” on Sweetwater Bike Path. Photo taken by J. McKinstry. (B) Proposed noise barrier.

As mentioned above, there is excessive litter and waste along the Sweetwater Bike Path. The addition of trash and recycle receptacles could help to reduce this problem. Plastic bag dog waste stations could also be added to cater to individuals who use this area to spend time with their pets. The empty dirt lot found in the center of the path is an area ripe for potential development. Currently, this area is pretty bare, only containing three benches and a few trees. This area could be better utilized as a rest stop along the bike path with any number of new installations, including a small café, free air service for tires, bicycle supplies, an eco-friendly restroom, or picnic tables with ample shading. Figure 17 displays the current empty lot and a proposed café.

![Figure 17](http://www.bikestopcafes.com/Front%20of%20Building%20half%20size.jpg)
Kimball Park is another region with potential for improvement. Kimball Park is the largest park within the city, centrally located adjacent to the public library. Currently, the park only has 2 bicycle racks, so additional racks is a must. Other improvements could be the addition of a koi pond, a stationary outdoor workout area, a pavilion for picnics, or the addition of a stage for dance and cultural performances. An example of an outdoor workout area can be viewed in Figure 18.

Bicycle racks should also be added throughout the city at recreational areas, schools, and businesses. Currently, there simply are not enough bicycle racks in the city. Parking meters could also be added in busy commercial locations, thus decreasing incentive to drive and increasing incentive to use a bicycle at no cost.

![Proposed outdoor workout area that could be implemented in Kimball Park.](http://www.transitmiami.com/wp-content/uploads/2010/04/P1010372.jpg)
Solar Bikeway

A 70-meter solar bike lane opened in the Netherlands last year. This bike lane is displayed in Figure 19. By 2016, they hope to expand the path to 100 meters. This solar bike path was created by embedding silicon solar cells into the concrete of the path and then covering them with a layer of tempered glass. Though the angle of the path is not ideal, generating 30% less energy than rooftop solar panels, the tilt assists the rain in washing off dirt (Tobal, 2014). At its current length, the solar bike lane in the Netherlands only generates enough electricity to provide power for three homes a year (Alter, 2014). However, due to its location, a solar bike lane in National City has a much higher solar energy potential than one in the Netherlands. This technology could be used on the entire 24-mile Bayshore Bikeway, as well as streets throughout the city. The limitations of this technology are that it only works in direct sunlight, it will have a high installation cost, and it could require maintenance. Despite these limitations, installation of a solar bike lane in National City could serve as a model project in sunny Southern California.

![Figure 19 SolaRoad in Netherlands.](http://cdn.phys.org/newman/gfx/news/hires/2014/solaroadwori.jpg)
Education, Promotion, and Safety

In order for a bike share system to be successful in National City, proper bicycle safety education and advertisement is necessary. Educational programs could be created in local schools and be led by the local police department. Seminars could also be held in public locations, such as the public library, by the biking coalition and police department. Advertisement could consist of social media, TV and radio advertisements, newspaper segments, postings on local bulletin boards, and flyers at local businesses. Local events, such as a “Bike to Work Day” or “Bike to School Day,” would be good ways to increase bicycle awareness. A flier for the 2015 Bay Area Bike to Work Day is displayed in Figure 20. Businesses could also partner with the city and offer incentives, such as reduced health care costs, for employees who choose to bike to work. The city or bike share company could also consider a mileage program to reward those who frequently use the system.

![Bike to Work Day flier](http://www.commuterinfo.net/imgManager/1000000918/BTWD-2015-Logo-Current%20(1).jpg)

Figure 20  Bike to Work Day flier.

It is very important to educate the residents on how cost effective a bike share system is. In 2013, AAA (formerly known as the American Automobile Association) estimated that the cost of driving 15,000 miles a year was $9,122. This includes fuel costs, maintenance costs, and insurance costs (Copeland, 2013). DecoBike currently offers a discounted annual membership for $99, with the usual price being $125 (DecoBike, 2015). Maintenance and insurance costs are covered in this membership, meaning the savings of utilizing a bike share system could be astronomical. This is especially important in National City, where in 2012 the median household income was only estimated to be $36,935 per year. (City-data, 2015).
Benefits

There are many benefits to implementing a bike share system in National City. The positive effects of increased bicycling will not only improve public health, but also benefit local businesses. The first benefit of a bike share system is the reduction of GHG emission, the extent of which is dependent on participation rates and will be discussed in the emissions reductions section. A bike share system can also improve personal health and the overall quality of life in a city by increasing the amount of daily physical activity its residents engage in. Improvement in overall health will save both the city and state health care providers money as well. The California Department of Health Services performed a study that showed a 5% increase in rates of physical activity and healthy weight over five years could save the state over $6 billion in health care costs. The same study showed that a 10% increase could save around $13 billion (Chenoweth, 2005). A Dutch study was also conducted that found that workers who met recommended levels of physical activity (over 20 minutes, 3 times a week) had four fewer sick days per year than workers who did not meet these levels (Proper et al., 2006). Both of these studies show a correlation between improved health and money saved.

A bike share system could also help to improve the local economy in National City. A study conducted by researchers at the University of Minnesota found that cyclists spent $7 to $14 per trip on shopping, dining, and entertainment at local businesses while using the Nice Ride bike share. Over the season this equated to $150,000 in spending (Lee, 2012). In National City the season would be year-round due to favorable climate conditions, which would result in additional spending. A study in Toronto found that bicycling increases exposure to local businesses and that people who biked or walked in these areas spent more money per month than people who drove in the same areas (Clean Air Partnership, 2009). Implementation of a bike share system will also increase job opportunities. This not only includes the initial construction jobs, but also maintenance jobs, call center technicians, service staff, managers, and supervisors (Velib’, 2010). As noted above, a bike share system could also provide savings in personal transportation costs which can then be spent by consumers to fuel the local economy.
Finally, the addition of bike paths has been linked to an increase in adjacent property value. In a survey conducted by the National Association of Realtors and the National Association of Home Builders, homebuyers indicated that having a path for biking, walking, or jogging was the second most important characteristic of a desirable neighborhood. A 2006 study conducted by the University of Delaware found that the presence of a bike path slightly increased property value and ease of sale or had no effect. This study also found that a close bike path that was properly maintained was expected to increase property value by $8,800 (2006 dollars). Increased property values can then lead to increased city value (Racca & Dahnju, 2006).

**Emission Reduction Potential**

To predict the GHG emission reduction potential, bike share usage must first be estimated. Boulder B-Cycle has been active since 2011 and has available data on annual trips made from 2011 through 2014. This data can viewed in Figure 21. The population of Boulder, CO was 103,166 in 2013, which is comparable in size to National City. By accounting for the remaining difference in population and other differentiating factors, we estimated the monthly use of bike share in National City. The 2013 population of National City was divided by the 2013 population of Boulder to acquire a factor to apply for the trips in National City. Also, because the climate in Colorado is much different than the climate in Southern California, usage rates are likely to be much lower there during the winter months than they would be in National City. To attempt to account for this seasonal variability a yearly average increase was taken for the summer months (May through September) and applied to the whole year for National City. The climate in the months of May through September is most similar to the year round climate in National City. This data was used to predict the trips per month in National City for 2017 to 2020, and this can be viewed in Figure 22. It is difficult to predict numbers beyond this date given that bike share systems have only been around for about 15 years.
Figure 21  Boulder B-cycle trips per month for the years 2011 through 2014. Data retrieved from https://boulder.bcycle.com/.

Figure 22  Projected monthly bike share usage for National City, CA for the years 2017 through 2020. Data is based on usage rates for Boulder B-cycle.
Based on these acceptance rates, the bike trips (a trip is defined as a bike rental and return) per year were then totaled and this information was used to calculate greenhouse gas emissions. The average bicycle trip was estimated to be 2 miles, based on the close proximity of everything within National City. The amount of miles traveled per year by bike were then estimated and used to calculate the gallons of gasoline saved by using the EPA average of 21.6 mph. The EPA estimation of 1 gallon of gasoline as equivalent to 20pds of CO2 emissions was used to calculate the total emissions saved per year. The EPA estimate of 113 gallons of gasoline producing 1 MTCO2e was then used to predict the GHG emission reductions from the implementation of a bike share system. All of these calculations can be viewed in Table 4.

Table 4  Projected bike share emission reductions for National City, CA (2017-2020).

<table>
<thead>
<tr>
<th></th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Bicycle Trips</td>
<td>16,037</td>
<td>20,337</td>
<td>23,098</td>
<td>30,263</td>
</tr>
<tr>
<td>Total Miles Traveled (Avg. Trip = 2 miles)</td>
<td>32,074</td>
<td>40,674</td>
<td>46,196</td>
<td>60,526</td>
</tr>
<tr>
<td>Gallons of Gasoline Saved (21.6mpg)</td>
<td>1,485</td>
<td>1,883</td>
<td>2,139</td>
<td>2,802</td>
</tr>
<tr>
<td>Emissions Reductions (Pds/CO2)</td>
<td>29,700</td>
<td>37,660</td>
<td>42,780</td>
<td>56,040</td>
</tr>
<tr>
<td>Emissions Reductions (MTCO2e)</td>
<td>13</td>
<td>17</td>
<td>19</td>
<td>25</td>
</tr>
</tbody>
</table>
Limitations and Weaknesses

The biggest limitation for a bike share system is the initial cost of implementation. This could be offset by partnering with an established system, such as B-cycle or Deco-Bike. Cost could also be offset by sponsorships from both local and larger businesses; advertising; private donations; federal, state, and local funds; loans; and grants. Based on report by Fehr and Peers (2012), it was estimated that each station installed would cost about $45,000. The first phase calls for the implementation of 7 stations, so the initial cost would be around $315,000. These station costs take into account the stations themselves, the bicycles, the bicycle docks, membership cards, software, user-interface technology, equipment maintenance, storage racks, traffic barriers, development of a system map, map racks, marketing, legal services, and accounting services. The annual operating costs were estimated to be around $1,500 per bicycle. Therefore, if initially seven stations were implemented, each having 6 bicycles, that would bring the annual operations costs to about $63,000. Operations costs take into account equipment maintenance and replacement; bicycle rebalancing; program administration; marketing; security; and liability insurance. Taking all of this into account the initial phase of the bike share system proposal would cost $378,000. It is assumed that this cost could be substantially reduced through the above measures (Fehr & Peers, 2012).

Implementation of additional bike lanes and improvement to existing lanes may be met with financial and engineering challenges. Construction would be required on existing roads to both implement new bike lanes and upgrade existing bike lanes. In some cases sidewalks, breakdown lanes, and current traffic lanes may have to be adjusted. However, these projects could provide construction jobs to a city with a higher than average unemployment rate. The success of this project relies on residents’ acceptance of a cycling culture. It seems that many residents in southern California have a vehicle-centric ideology, but this may be due to poor public transportation. This could be offset through educational programs that make residents aware of the health and financial benefits of cycling.

A final challenge is the difficulty of accomplishing an impactful reduction in GHG emissions. In order for the emissions reductions to be significant, membership rates would have to be very high. Initially this will be hard to achieve, but with proper advertising and educational programs, high membership rates could be achieved. Based on 2005 data from the master data file, there were 14,750 households located in National City. According to data from a New York Times article published in 2008, the average household owns 2.28 vehicles. This allows us to estimate that the residents of National City own about 33,630 vehicles. Given the estimate of 101,686 trips made per day on local roads, the average is about 3 trips made per day per vehicle within National City. If the implementation of the bike share system were able to change 1 of these 3 vehicles into a bicycle trip (a trip to a store, park, restaurant, work, school, etc.), this could result in
a reduction of 10,058 MTCO2e from the 109,829 MTCO2e of emissions from local roads. This is about a 9% reduction in vehicle emissions from local roads. Those are the kind of numbers that we would need to achieve in order to make a significant reduction in CO2 emissions. With current trends showing great growth in bike share systems, it is possible to reach these numbers between 2030 and 2050.
Strategies to Reduce Environmental Impact and Aid in Mitigation from Transportation, Industry, and Port Emissions

Transportation was the dominant source of community emissions from the emissions inventory which was conducted in 2005. Together with industry, these two sectors were responsible for 90% of community-wide emissions (National City, 2011). Therefore, it is of utmost importance that strategies be implemented to reduce emissions from these sources. The National City Marine Terminal, owned by the Unified Port of San Diego, is also a major contributor to GHG emissions within National City. This marine terminal is operated by Pasha Automotive Services and is considered to be the most advanced facility of imports and exports on the western coast of the United States (Port of San Diego, n.d.). This section of the report addresses several strategies to reduce emissions from these major sectors. It is important to examine all of these strategies, as one strategy alone will not provide enough emissions reductions to meet CAP goals. With Governor Brown’s announcement of a new executive order calling for emissions reductions to 40 percent of 1990 levels by 2030, implementation of these strategies becomes even more paramount (Leber, 2015).

Community Education and Involvement

Educating and involving the citizens in sustainable practices to reduce GHG emissions is essential to establishing and maintaining a more sustainable community. In addition to providing educational seminars in schools and the public library, the construction of an information center for sustainability could provide citizens with strategies that the city is using to reduce GHG emissions. Kimball Park, with its large size and central location, would be a suitable location for this center. The center could also educate residents on methods to conserve energy and water, recycling, and other sustainable practices. The information provided by the center could also support activities such as tree planting and community gardening which would help make people feel a part of the community.
Transportation Emissions

Transportation is a major contributor to community emissions within the city. In 2005, of the total community emissions of 550,714 MTCO2eq, 359,029 MTCO2eq alone (over 67% of total emissions) came from transportation. The majority of these emissions are from state highways, with these emissions totaling 215,554 MTCO2e. All three of the freeways surrounding National City are heavily traveled, with an average of 500,000 vehicles utilizing them for travel each day. This freeway traffic information can be viewed in Table 5. The easiest emissions to address are the 109,829 MTCO2e that came from local roadways. These emissions can be addressed within the city, while reducing the freeway emissions will require assistance from the state (National City, 2011).

Table 5 Freeway Information (Government State of California, 2013)

<table>
<thead>
<tr>
<th>Freeway</th>
<th>Size</th>
<th>Annual Average Daily Travel (AADT) 2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interstate 5:</td>
<td>8 lane freeway 200 to 440 foot-wide row</td>
<td>180,000 vehicles</td>
</tr>
<tr>
<td>Interstate 805:</td>
<td>8 to 10-lane freeway 290 to 750 feet foot-wide row</td>
<td>200,000 vehicles</td>
</tr>
<tr>
<td>California State Route 54:</td>
<td>6 lane freeway</td>
<td>120,000 vehicles</td>
</tr>
</tbody>
</table>
Traffic Roundabouts

Traffic roundabouts, circular intersections where drivers are able to travel in a counter-clockwise motion around a center island, cut down on vehicle emissions. These alternatives to traditional intersections eliminate the need for traffic lights or signals. While using a roundabout, drivers must travel at slower speeds to yield to other drivers, cyclists, and pedestrians (Baranowski 2014). They have been shown to reduce fatal and injury accidents by over 76% because they create less conflict points than traffic intersections. This reduction of conflict points can be viewed in Figure 23. By limiting drivers to traveling in a counter-clockwise direction, direct left turns are eliminated, which greatly reduces the number of conflict points. Figure 24 displays the proper usage of a traffic roundabout. The slower speeds reduce the amount of driver to pedestrian conflict points (Chittenden County RPC, 2011).

![Traffic Roundabout and Intersection Diagram](http://farm4.staticflickr.com/3834/9577583353_3b2498f632_z.jpg)

**Figure 23** Traffic roundabout safety.

Retrieved from http://farm4.staticflickr.com/3834/9577583353_3b2498f632_z.jpg
They also cut down on emissions because they eliminate the prolonged idling that occurs at traffic lights and cut down on the repetitive pattern of accelerating and braking. These actions cause the engine to burn more fuel, which results in higher carbon dioxide emissions (Barth & Boriboonsomsim, 2008). Traffic roundabouts are also able to increase traffic flow with controlled speeds, which results in a shorter delay than would be encountered in a typical intersection (Baranowski, 2014). A study conducted by Kansas State University determined that the installation of a traffic roundabout could result in a 16%-59% decrease in carbon dioxide emissions.

**Emission Reductions**

This proposal suggests the addition of twelve traffic roundabouts in National City at the following intersections: E 8th Street and Euclid Ave; E Plaza Blvd and Highland Ave; E Plaza Blvd and D Ave; E 18th St, West Ave and National City Blvd (5-way intersection); E 24th St and D Ave; E 30th St and D Ave; E 30th St and Highland Ave; E 30th St and Highland Ave; and Sweetwater Rd and Plaza Bonita Rd. In a report by Silva-Send (2009), it was estimated that one traffic roundabout saves about 20,000 gallons of gasoline, which is equivalent to 177 MTCO2e. Therefore, the addition of 12 roundabouts by the year 2020 could reduce GHG emissions by 2,124 MTCO2e per year.

**Figure 24** Demonstration of how to correctly use a traffic roundabout for (A) automobile drivers and (B) pedestrian and cyclists (Federal Highway Administration 2014).
Environmental Zones

According to 2005 data, children's asthma hospitalization rates in National City were 57% higher than the county average. This major concern could be addressed through the addition of “environmental zones” throughout the city. These zones are already used in Germany and other countries in Europe to reduce emissions as well as vehicle miles traveled (Strompen, 2014). These zones would charge vehicles with high emission rates a fee to enter them. Lower emission vehicles would have a lower fee, and zero emission vehicles would be free. Residents would be required to get stickers based on their personal vehicle emissions, with prices dependent on the emissions of their vehicle. These stickers would need to be renewed every year. There is already an abundance of car dealerships and auto body shops in National City who could issue stickers, which would increase their business as well. An example of the different vehicles classes is displayed in Table 6 below.

Table 6  Three emission classes (Strompen, 2014)

<table>
<thead>
<tr>
<th>Different types of stickers</th>
<th>Requirements for the cars</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High emissions (e.g. SUVs and older cars)</td>
<td>$150 for the term of one year</td>
</tr>
<tr>
<td></td>
<td>Middle or low emissions (e.g. new, small or hybrid cars)</td>
<td>$100-$50 for the term of one year</td>
</tr>
<tr>
<td></td>
<td>No emissions (e.g. electric cars)</td>
<td>$0</td>
</tr>
</tbody>
</table>
The zone could consist of all residential areas within the city excluding freeways, the port, and industrial areas. This would help reduce emissions from local roadways within the city and improve the overall health of residents. A phase-based implementation strategy would be ideal, as it would allow residents to adapt to the new policy. A description of the phases can be viewed in Table 7 below. It would be necessary to improve public transportation, bike lanes, and walkways within National City to provide adequate alternative transportation options for reducing vehicle miles traveled. Implementation of this system in National City could serve as a model for surrounding communities.

<table>
<thead>
<tr>
<th>Phase 1</th>
<th>All cars are allowed to enter the Environmental Zone of National City. Except of cars which didn´t get any sticker.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase 2</td>
<td>Cars with a yellow or green sticker can enter the Environmental Zone. Entering is forbidden for cars with a red sticker or without a sticker.</td>
</tr>
<tr>
<td>Phase 3</td>
<td>Only cars with a green sticker can access the Environmental Zone of National City. It is not allowed for cars with a red, yellow or without any sticker.</td>
</tr>
</tbody>
</table>

### Emission Reductions

The environmental zone would only target the emissions from local roads, as the highways would not be considered part of the zone. Table 8 provides estimates for incremental emissions reductions via implementation of the environmental zone. It is assumed that, if implemented immediately, this zone would provide a 5% reduction in emissions by 2020. This would reduce emissions by 5,491 MTCO2e. Phase two is estimated to reduce emissions by 25% by 2030, equivalent to 27,457 MTCO2e. Finally, phase three would provide a 50% reduction in emissions by 2050, equivalent to 54,915 MTCO2e. If executed correctly, the implementation of an environmental zone in National City could provide a significant reduction in emissions by 2050.

<table>
<thead>
<tr>
<th>Year</th>
<th>Emission Reductions (5%)</th>
<th>Emission Reductions (25%)</th>
<th>Emission Reductions (50%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2020</td>
<td>5,491</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2030</td>
<td>27,457</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2050</td>
<td>54,915</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Converting the 805 to a Boulevard

Conversion of the section of the 805 freeway that travels through National City into a boulevard would significantly reduce transport emissions. The 5 freeway already runs north to south, making the 805 redundant. Additional lanes could be added to the 5 in National City to support additional traffic flow from the converted 805 freeway. Because state highways are a major source of transportation emissions, conversion of the 805 freeway would provide a very significant reduction in GHG emissions. Execution of this strategy would require assistance from the state. Figure 25 and Figure 26 illustrate the addition of a boulevard. Converting the 805 to a boulevard would open up additional land which could be converted to green spaces used for recreational purposes and as places to plant trees, further reducing CO2 emissions.

On this new boulevard, the traffic speed would be 50 mph, as opposed to the current 65 mph speed limit of the 805 freeway. A Dutch pilot study found that lowering the speed limit to 80 km/h (50 mph) can reduce CO2 emissions from cars by 30% in the long term. This study also found that driving at lower speeds in general reduces CO2 emissions from transportation (CE Delft, 2010). Given an estimate of 50,000 vehicles traveling on the new boulevard each day in contrast to the 200,000 vehicles traveling each day on the 805 freeway, we would expect a significant reduction in GHG emissions. The conversion to a boulevard would also open up this area for more local development, which could provide additional boosts to the economy.

![Figure 25](image)

*Figure 25  Course of new boulevard. Map prepared by P. Briglmeir.*
Emission Reductions

The average annual daily traffic (AADT) on the 805 freeway is 200,000 vehicles per day, with the total AADT from freeways in National City reaching 500,000 vehicles per day. Therefore, it was estimated that the 805 contributed 86,221.6 MTCO2e. Assuming that 50% of the AADT (100,000 vehicles per day) would use other forms of transportation with no additional emissions, we could expect a reduction of 43,111 MTCO2e. Finally, assuming that an additional 25% of AADT (50,000 vehicles per day) would still use the boulevard, but traveling at lower speeds, we could expect an additional reduction of 6,467 MTCO2e (assuming a 30% CO2 reduction). If this project were completed by 2020, it could reduce emissions by 49,578 MTCO2e per year. Additional reduction of GHG emission could be achieved by converting open area from the old 805 to green space.

Figure 26 Proposed boulevard structure. (Adapted from National City, 2011)
Improving Public Transportation

Transportation emissions can be reduced by improving public transportation. Table 9 displays a comparison of mode of commute between National City and San Diego County. One approach would be to add new bus routes and streamline existing ones. Another would be to increase the frequency of bus and trolley stops during rush hour. Currently, in most places, buses and trolleys only arrive every 15 minutes during the week (even less frequently on weekends). This results in long wait times at bus and trolley stops, which are a major deterrent to use of public transportation. During rush hour, bus frequency could be increased to every 5 minutes. This would make the system much more rapid and would provide additional jobs for residents within the city. Public transportation could also be made more effective through the addition of special “bus only lanes,” allowing buses to avoid traffic. Bus only lanes, which are already utilized in many cities throughout the world, could also allow provide buses with an electrical power source and provide additional GHG emissions reductions.

### Table 9  Transportation method in National City compared to San Diego County (National City, 2011)

<table>
<thead>
<tr>
<th>Mode of Commute</th>
<th>National City</th>
<th>San Diego County</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drove Alone</td>
<td>60.7%</td>
<td>74.4%</td>
</tr>
<tr>
<td>Carpoled</td>
<td>14.0%</td>
<td>10.9%</td>
</tr>
<tr>
<td>Public Transit</td>
<td>6.9%</td>
<td>3.4%</td>
</tr>
<tr>
<td>Walked</td>
<td>3.7%</td>
<td>3.0%</td>
</tr>
<tr>
<td>Biked</td>
<td>0.6%</td>
<td>0.6%</td>
</tr>
<tr>
<td>Worked From Home</td>
<td>12.5%</td>
<td>6.1%</td>
</tr>
<tr>
<td>Other</td>
<td>1.6%</td>
<td>1.3%</td>
</tr>
</tbody>
</table>

Emission Reductions

Emission reductions from public transportation are dependent on the strategies which are adopted. As seen in Table 9, above, National City already has better participation in public transportation than the rest of the county, indicating that National City residents are already open to public transportation. A population open to public transportation coupled with the small land area of National City makes increasing public transit use from 6.9% to 10% by 2020 a realistic goal. A 3% decreased in residents who drive alone would achieve desirable GHG emission reductions.
LED Streetlights

Converting all the streetlights on the freeways and roads in National City to LED streetlights will significantly reduce GHG emissions as well as city energy costs. LED lights have many benefits as compared to conventional lighting including size and efficiency, longer life, and lower temperatures (Lee, n.d.). They will also increase the visibility range of drivers because they improve the light output and color rendition of streetlights as well, which increases safety by decreasing the number of accidents. This strategy was recently adopted in Chula Vista, which installed 3,987 Autobahn LED Series Roadway Luminaries from American Electric Lighting. Figure 27 presents before and after pictures from this project in Chula Vista. The project was funded by the Qualified Energy Conservation Bonds (QECB), which aids state and local governments in these types of projects. These streetlights will reduce energy consumption by over 45%, have an expected payback of 8 years, and should not require maintenance for at least 20 years (American Electric Lighting, 2014).

![LED streetlight before and after photos from Chula Vista.](http://www.americanelectriclighting.com/Library/Case_Studies/stories/chula1.asp)
Emission Reductions

In 2008, it was estimated that there were 1,820 street lights in National City (City of National City, 2008). According to the 2005 emissions inventory, street lights used 648,591 kWh of electricity and were responsible for 231 MTCO2e of emissions. This amounted to 64% of the emissions from all lighting (National City, 2011). In the project in Chula Vista, 4,300 streetlights were changed, which resulted in annual savings of 770,000 kWh of electricity (San Diego Gas & Electric, 2012), equivalent to about 179 kWh per light. Therefore, if all 1,820 street lights in National City were switched to LED lights, a total of 325,780 kWh of electricity could be saved. This is a 50% reduction in electricity usage, which would reduce GHG emissions by 116 MTCO2e. Implementation of this strategy would not only reduce emissions, but also reduce electricity usage costs.
Group Grocery Ordering System

A group grocery delivery system could be implemented within National City to further reduce GHG emissions. In a study by Newman and Kenworthy (2009), it was shown that, on average, US cities use 2.5 times more energy for transportation per capita than European cities. A study by Tehrani and Karbassi (2005) found that a transition to e-commerce could result in an 88% reduction in fuel consumption and a 25% reduction in emissions. A more recent study in Seattle, WA showed that when personal vehicle travel is replaced with a delivery system, vehicle miles traveled (VMT) can be reduced by 85%-95%, while CO2 emissions can be reduced by 80%-90% when using a proximity-assigned set of customers (Wygontik & Goodchild, 2012).

With this system, customers would be able to order food from a grocery store online or over the phone up to one week in advance. To lower cost to consumers, delivery fees could be waived or reduced depending on the number of customers in the area and grocery stores could offer membership options for frequent customers. This system could provide multiple benefits, including the reduction of GHG emissions due to lower VMT and increased convenience for customers. Requiring supermarkets to employ electric vehicles would further reduce GHG emissions. Figure 28 displays an image of a group grocery delivery van.

![Figure 28 Group grocery delivery van.](http://www.dispatch.com/content/graphics/2013/10/17/grocery-delivery-art-g8up4tkf-1grocery-deliveryfs-1.jpg.jpg)

Emission Reductions

The goal of this strategy would be to achieve a 15% household participation rate by 2020 and a 30% participation rate by 2030. In a study by McConville et al. (2011), it was estimated that the average distance to a grocery store was .86 miles. In 2014, the average household made 1.6 trips to a grocery store per week (Statista, 2015). Using these statistics, if 15% participation were achieved by 2020, it would result in 157 MTCO2e emission reductions per year. If 30% participation were achieved by 2030, it would result in 313 MTCO2e emissions reductions per year.
Electric Cars in 2050

In order to reach statewide emission goals by 2050, a shift must be made in personal vehicle usage. Given the preference for personal vehicles in southern California and the poor state of public transportation, a shift toward electric vehicles makes sense. Electric vehicles convert 59%-62% of electrical energy from the grid to power at the wheels, whereas conventional gasoline vehicles only convert about 17%-21% of energy stored in gasoline to power at the wheels. Electrical vehicles are also much more environmental friendly than conventional vehicles, as they emit no tailpipe emissions. The only source of higher emissions generated from electrical vehicles is the energy required in the manufacturing process (US Department of Energy, 2014). Current electrical vehicles have proven to be very efficient, and given the current growth of technology, they are expected to be even more efficient by 2050.

Currently, the Nissan Leaf can get 126/101 mpg-equivalent city/highway, and it can travel 84 miles on a single charge (U.S. News Rankings & Reviews, 2015). The Tesla Model S is an electric car that has been generating attention not only for its efficiency, but also for its sleek design. It can get around 95 mpg and boasts a top speed of 121 mph. It can also travel much farther than the Leaf, boasting a range of at least 240 miles, and Tesla offers unlimited charging at their network of Supercharger stations (Hearst Communications, Inc., 2015). Figure 29 displays an image of a Supercharger Station and the Tesla Model S. There are over 400 Supercharger stations throughout the US and Canada, with one coming soon to San Diego County. These Supercharger stations can charge the Model S in 30 minutes (providing 170 miles of travel) and are conveniently placed near restaurants, shopping centers, and WiFi hot spots (Tesla Motors, 2015).

Figure 29  Tesla Model S and Supercharger station. Image retrieved from http://ecoconceptcars.ru/wp-content/uploads/2012/09/Tesla-Supercharger.png
Emission Reductions

By 2050, technology is expected to advance significantly, and electrical vehicles will be more efficient and cheaper. Cheaper prices will make them more readily available to the general public, and more electrical vehicles on the road will help reduce transportation emissions from local roadways even further. There are too many variables at play including population increases, technological advances, and an economy shifting towards renewable energy to make an accurate calculation of emissions reductions in 2050, but they are expected to be significant.
Transportation Summary

Table 10 2020 emission reductions from transportation strategies.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Emission Reduction in 2020 (MTCO$_2$e)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic Roundabouts (12 roundabouts)</td>
<td>2,124</td>
</tr>
<tr>
<td>Environmental Zones (phase 1)</td>
<td>5,491</td>
</tr>
<tr>
<td>805 to Boulevard</td>
<td>49,578</td>
</tr>
<tr>
<td>LED Streetlights</td>
<td>116</td>
</tr>
<tr>
<td>Group Grocery Ordering System (15% participation)</td>
<td>157</td>
</tr>
</tbody>
</table>

Limitations and Weaknesses

Freeways, as the majority contributor to GHG emissions, are the biggest limiting factor to reducing emissions from the transportation sector. It will be very difficult to reduce emissions from the freeways due to the heavy volume of traffic (500,000 vehicles per day). To combat this problem, National City could collaborate with San Diego County to generate solutions.

The major challenge to converting the 805 to a boulevard in National City is the need for state approval as well as a large amount of funding. Also, traffic redirected from the converted 805 can be expected to generate additional traffic on the 5.

Improving public transportation would also require funding, which could be provided by major stakeholders such as SANDAG and Caltrans. Though converting all streetlights in National City to LED may seem to be cost-prohibitive, Chula Vista, with twice the number of streetlights as National City, was able to get funding for a similar project.

Creating environmental zones throughout the city may also be met with several challenges. Cars would need to be routinely inspected to determine their emissions, which would require a monitoring program to enforce fines. However, this limitation can also be seen as a strength in that it would provide additional employment to a city that has a higher unemployment rate than the national average.

Traffic roundabouts would require construction time to implement as well as incur significant costs. A source of funding would need to be acquired to complete this project.

Though a shift toward electrical vehicles is occurring, it may take five to ten years for electrical vehicles to be affordable to the general population. Recently, hybrid cars have become much more affordable, providing an alternative option until electrical vehicles are more readily available. Table 10 displays a summary of 2020 emission reductions from strategies outlined in this section.
Port Emissions

The main imports at the Port of San Diego are vehicles, lumber, and cargo. Pasha Automotive and Distribution Services operates a facility there that can handle more than 500,000 vehicles a year. One out of every eight cars that gets imported to the US arrives there, which makes it the most advanced vehicle import/export facility on the west coast. The cars are then either sold in National City or moved by rail to other locations. The Burlington Northern Santa Fe Railway and the San Diego and Imperial Valley Railway currently operate these railways. These industries, along with the naval base, are the major stakeholders in the port district who have the financial ability to reduce emissions, and they have all shown interest in reducing emissions and conserving energy (Port of San Diego, 2013).

In 2006, the port was responsible for 826,429 MTCO2e. However, this includes all five cities that make up the Unified Port of San Diego (Port of San Diego, 2013). Without proper evaluation of the specific emissions from the port in National City, we can only make a gross estimation of current emissions. The simplest way to provide such an estimate is to divide the total port emissions by five (as the total emissions are a combination of five cities). Based on this estimate, the following strategies will be based on the assumption that the port in National City is responsible for 165,286 MTCO2e.
Shore Power

The Port of San Diego recently switched to a shore-power system at the Tenth Avenue Marine Terminal. This project was funded by the Capital Improvement Program (CIP) and cost $4.25 million (Port of San Diego, 2014). Shore power allows vessels at berth to use electrical power provided by the port instead of running diesel engines. An image of this technology can be viewed in Figure 30. This technology has been shown to reduce air pollution from vessels at berth by 95% (Port of Long Beach, n.d.). The environmental benefits have already been demonstrated at the Tenth Avenue Marine Terminal. It has reduced GHG emissions by over 50% (over 2000 MTCO2e) and reduced nitrogen oxide emissions by 95% (70 tons/year) (Port of San Diego, 2014).

Emission Reductions

If the National City Marine Terminal (NCMT) were to install this same technology, similar reductions in GHG emission are expected. The NCMT has 7 berths compared to the Tenth Avenue Marine Terminal’s 8. Therefore, it is estimated that GHG emissions would be reduced by about 2000 MTCO2e. It would also reduce the NOx emissions and provide health benefits for both workers and residents. If solar energy generated at the port were used to power this technology, GHG emissions would be reduced even further.
On-Road Transportation

The Unified Port of San Diego differs from other ports in that 38% of its GHG emissions were created from on-road transportation (Port of San Diego, 2013). These emissions could be reduced by placing additional regulations on heavy duty trucks, especially those using diesel fuels. Alternatively, vehicle fleet and equipment could be switched to electrical power. For example, zero-emissions trucks have been successfully installed at the Port of Long Beach. Their port uses hybrid catenary trucks, which run along an overhead system of electrical wires, to eliminate diesel emissions, and this can be viewed in Figure 31. These trucks are also able to run on diesel, compressed natural gas (CNG), or a battery system. This permits the trucks to continue operating, even when not using the overhead electrical system (Morrison, 2013). The port in National City could implement a similar fleet of trucks using the Long Beach system as a model.

![Zero-emission-truck from Long Beach](http://lbpost.com/images/addison/Aji/Siemens01.jpg)

Figure 31 Zero-emission-truck from Long Beach. Image retrieved from http://lbpost.com/images/addison/Aji/Siemens01.jpg

Emission Reductions

Assuming that 38% of port emissions in National City were also from on-road transportation, we can estimate National City port emissions from on-road transportation at 62,809 MTCO2e. If zero-emission trucks were implemented in National City, there would be a significant reduction in GHG emissions from the port. In 2020, assuming that 15% of on-road transportation were to use this system, emissions could be reduced by 9,421 MTCO2e. By 2030, assuming that 30% of on-road transportation were to use this system, emissions could be reduced by 18,843 MTCO2e. There would also be significant improvements in air quality with a reduction in diesel usage.
Solar Power Plant

Installation of a solar power plant at the port would reduce GHG emissions. The port, the Navy, and SDG&E have all shown interest in utilizing renewable energy to meet new energy efficiency policies. The port contains many large parking lots where imported vehicles are offloaded. Solar panels could be added to these areas to not only generate electricity, but also shade and protect the cars being stored in the area. The “SEAT al Sol” project (pictured in Figure 32), a similar solar power plant in Martorell, Spain serves as a successful model for this project. The power plant in Martorell includes 53,000 solar panels over an area of 270,000 square meters. The project cost €35 million ($45 million) and is expected to generate 15 million kWh of clean energy per year (Shrestha, 2013). A similarly sized project in National City is shown in the map in Figure 36.

The solar energy potential in National City is much higher than in Spain, so a solar plant built at the port would generate more power than the Martorell plant. The figure below shows a comparison of solar irradiation in the US, Germany, and Spain. National City has almost twice the photovoltaic resources of Germany, but Germany has about five times the installed capacity of the US. Spain has about \( \frac{3}{4} \) the photovoltaic resources of National City, but Spain has three times the installed capacity of the US. This shows the US still has a lot of potential to grow in terms of solar power, especially in the southwestern US (MADEMANDESIGN, 2011).

![Figure 33  Photovoltaic solar resource comparison between the US, Spain, and Germany.](https://seedhousestl.com/2011/12/06/solar-panels-possible/)

**Emission Reductions**

Assuming that annual average peak hours for solar energy in San Diego are 2,150 hours (National Renewable Energy Laboratory, 2015), and the capacity of the solar plant was assumed to be 11 MW (Global Energy Network Institute, 2010), energy production would be 23.65 GWh per year. Given that photovoltaic cells are assumed to generate about 30 MTCO2e per GWh over the course of their lifetime (National Renewable Energy Laboratory, 2012), it follows that the average emissions from the energy mix are 302 MTCO2e per GWh. This means that the savings from solar energy would be 272 MTCO2e per GWh with the potential to reduce emissions by 6,433 MTCO2e per year.
Power-To-Gas Facility

Power-To-Gas is a new storage technology in which electricity is converted to hydrogen. This hydrogen can then be used to generate synthetic methane through methanation (CO2 + 3H2 → CH4 + H2O). Audi built the first industrial Power-To-Gas facility in Werlte, Germany in 2013, illustrated in Figure 34, below. This plant is able to produce about 1,000 metric tons of synthetic methane per year, chemically binding 2,800 metric tons of CO2. The plant is also able to convert 6MW of input power. The only by-products produced in this project are water and oxygen, which makes it a sustainable practice. The methane produced at the plant can be fed into the gas grid, burned in a power unit to generate electricity and heat, or used in vehicles with gas engines. The plant was built on 4,100 m2 of land, so it is assumed that a plant of similar size and performance could be built in National City (Green Car Congress, 2013), possibly in an unused area of the port. Emission reductions were calculated in conjunction with the waste treatment facility.

Figure 34  Audi Power-To-Gas Plant (Green Car Congress, 2013)
Create a Waste Treatment Facility

A waste treatment facility could provide CO2 input for the Power-To-Gas plant. The treatment could also be used to generate electricity and heat through anaerobic digestion (a process that uses microbes to break down organic material in the absence of oxygen, illustrated in Figure 35). The additional digestate can also be used as biofertilizer. This facility could also help to relieve landfill spaces and help in the waste diversion process. 30% of all waste generated in National City is from plant and food debris, and therefore it can be used as organic material (ICLEI, 2009), amounting to 16,315 tons. However, the biogas plant (waste treatment facility) would require 50,000 tons of organic waste, requiring the city to look into importing waste from neighboring cities. Existing facilities of similar size are able to generate 5,850 MWh/year of electricity, 9,325 MWh/year of thermal energy, and cost around $17.5 million. (RIS International Ltd., 2005).

![Anaerobic digestion](image)

Figure 35  Anaerobic digestion (Waste Awareness Wales, 2014)
Emission Reductions

Assuming the waste treatment facility produces 5,850 MWh of electricity per year, the city can expect an emission reduction of 1,767 MTCO2e. Next, we assume that the waste treatment facility is capable of producing 9,325 MWh of natural gas, resulting in an additional reduction of 1,693 MTCO2e in emissions. Finally, we assume that the 4309 MTCO2e that would normally be released as emissions is instead digested and that 2,800 MTCO2e is used by the power-to-gas facility. This results in an emissions reduction of 1,509 MTCO2e. Therefore, in total, the waste treatment plant could reduce emissions by 4,969 MTCO2e. The power-to-gas facility would reduce emissions by 2,800 MTCO2e, while also providing 1,000 MT of usable synthetic methane. Combined, the addition of these two facilities could reduce emissions by 7,769 MTCO2e.

Figure 36  Possible locations for the solar power plant, power-to-gas facility, and waste treatment facility. Map prepared by P. Briglmeir & M. Zapf using Google Maps.
Port Summary

Table 11  2020 emission reductions from port strategies

<table>
<thead>
<tr>
<th>Measure</th>
<th>Emission Reduction in 2020 (MTCO₂e)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shore Power</td>
<td>2,000</td>
</tr>
<tr>
<td>Zero-emission-trucks (15%)</td>
<td>9,421</td>
</tr>
<tr>
<td>Solar Power Plant</td>
<td>6,433</td>
</tr>
<tr>
<td>Waste Treatment Facility</td>
<td>4,969</td>
</tr>
<tr>
<td>Power-to-Gas Facility</td>
<td>2,800</td>
</tr>
</tbody>
</table>

Limitations and Weaknesses

The aforementioned port emissions reduction strategies depend on the support of the Unified Port of San Diego, the port industries, and the Navy. Also, the emissions from the port are not currently included in the National City Climate Action Plan. The port in National City makes up only a fraction of the Unified Port of San Diego, so the other involved cities would have to adapt similar strategies to provide significant reductions to GHG emissions. Shore power and zero-emissions-trucks will both require high initial costs, but the emission reductions that they can provide should not be overlooked. Additionally, the CIP may be able to fund the shore power project, just like they did for the Tenth Avenue Marine Terminal.

A solar power plant would require carry a heavy initial cost, but it should be able to pay for itself with time. The power-to-gas facility and the waste treatment plant would also have high initial costs; however, they would both be able to generate energy, while at the same time making significant GHG emission reductions. The waste treatment facility would also require additional organic wastes to operate at full potential. This waste could be imported from surrounding cities, especially given the state’s strict waste diversion standards. Both of these facilities would also require land for construction, which may present permitting challenges. Table 11 provides potential 2020 emission reductions from the strategies outlined in this section.
Industry Emissions

In 2005, industry was responsible for 139,026 MTCO2e. This was the second highest total from any sector, and it represents over 25% of total emissions from National City (National City, 2011). To reduce emissions from industry, stricter regulations must be placed on industrial practices. Alternatively, emissions could be reduced by offering companies incentives to switch to more energy efficient practices, including renewable energy. Given the solar potential of San Diego, the installation of solar panels could prove cost effective for industry and lead to reductions in GHG emissions due to less electricity consumption.
LED Lighting

There are many ways to reduce GHG emissions from industry. One such way is offering incentives or requiring businesses to switch to LED lighting. LEDs, light-emitting diodes, are able to produce light when an electrical current is passed through them. LED lighting differs from conventional incandescent bulbs in that they do not lose 90% of their energy as heat and are equipped with a heat sink to absorb the little heat that they produce. An office featuring LED lighting is pictured in Figure 37. LED lights emit light in a specific direction, unlike conventional lighting which wastes energy by emitting it in all directions (Energy Star, 2014). Lighting makes up about 20% of the total energy usage in National City, and LED lighting has the potential to reduce this energy consumption by up to 75%. In commercial and industrial buildings, lighting contributes to 38% of the total electricity consumed, while all other buildings only need about half (19%) this amount (U.S. Energy Information Administration, 2009). Based on CAP data, it was assumed that National City has a 25% distribution of office buildings, meaning that lighting would be 23.5% of total electricity. This calculation will be explained further in the appendix.

![Figure 37 LED lighting in an office.](http://www.energysmartindustry.com/admin/images/uploadedimages/ProImg/4a96bc37ce925.jpg)

Emissions Reductions

In 2005, emissions from commercial electricity totaled 125,269 MTCO2e. With an estimated 23.75% of this coming from lighting, emission from commercial lighting totaled 29,751 MTCO2e. Based on the assumption that LED lighting has the potential to reduce energy consumption by 75%, a switch in all commercial buildings by 2020 could result in a reduction in emissions of 22,314 MTCO2e.
Green Roofs/Rooftop Gardens

Offering incentives for businesses to switch to green roofs also has the potential to reduce GHG emissions. A green roof is simply a vegetative layer that is grown on the rooftop of any building (pictured in Figure 38). They are able to remove heat from the air through evapotranspiration, which leads to reductions in temperature on the roof and in the surrounding air. They provide many benefits including reducing energy use, reducing air pollution, reducing GHG emissions, improving human health and comfort, enhancing stormwater management and water quality, and improving quality of life (EPA, 2013). Green roofs have been shown to reduce energy demand for cooling by at least 10% and cooling from electricity demand by around 13% (U.S. Energy Information Administration, 2009). Green roofs can also be built as rooftop gardens to provide fresh produce to residents.

Emission Reductions

It was first assumed that each business could have 50 m2 of green roofs, and this would total 150,000 m2 throughout the city. Next it was assumed that 13% of the commercial electricity was used for cooling. This would be 16,285 MTCO2e. Finally, it was assumed that green roofs could provide a 10% reduction in energy demand for cooling. This is would result in an emission reduction of 1,629 MTCO2e. Green roofs also have the added benefit of being able to sequester CO2. A two year study at Michigan State University concluded that green roofs were able to sequester 1.52 metric tons of carbon per acre (375 gCO2e/m2) (Natural Resources Defense Council, 2012). Therefore, if 150,000 m2 of green roofs were added to businesses in National City, an additional 56 MTCO2e would be sequestered. Overall, green roofs could reduce emissions by 1,685 MTCO2e.
Energy Efficient Technologies

Industries can also convert to more efficient technologies and rely more on renewable energy resources. Some of these technologies include more efficient pumps and pipes to reduce the energy used for pumping water; using technology that does not require water, such as powder coating for automobiles, appliances, and furniture; waste heat recovery for preheating (pictured in Figure 39), electricity supply, or domestic hot water; and providing more education to companies and employees that will create a more sustainable and efficient working environment (PPG Industries, Inc., 2015). Reducing waste and wastewater from industry would also result in emissions reductions. Incentives could be offered to companies who adapt these strategies to increase participation.

Figure 39  Heat recovery system.

Emission Reductions

It was first assumed that 50% of total waste and wastewater emissions were from the commercial and industrial sectors. This would result in 8,789 MTCO2e of emissions. The goal for 2020 is a 10% reduction in these emissions, which would result in an emission reduction of 879 MTCO2e. By 2030, the goal would be a 25% reduction, which would result in a reduction of 2,197 MTCO2e. Finally, by 2050 the hope is a 50% reduction, which would reduce emissions from this sector by 4,395 MTCO2e. These emissions reductions are shown in Table 12. The faster and more extensively that these technologies are adopted, the greater the extent of emission reductions.

<table>
<thead>
<tr>
<th>Year</th>
<th>Emission Reduction (MTCO2e)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2020 (10%)</td>
<td>879</td>
</tr>
<tr>
<td>2030 (25%)</td>
<td>2,197</td>
</tr>
<tr>
<td>2050 (50%)</td>
<td>4,395</td>
</tr>
</tbody>
</table>
Cap and Trade System

The European Emission Trading System, a cap-and-trade system, has proven to be quite successful in reducing GHG emissions. It covers over 11,000 power and industrial plants in 31 countries. Overall, the system covers around 45% of the EU’s GHG emissions. This system operates by placing a cap on the total amount of certain greenhouse gases that can be emitted by certain industries. This cap is then slowly decreased over time, thus reducing emissions. Within this cap companies can buy or sell allowances as needed (European Commission, 2014). Figure 40 graphically illustrates this system.

Figure 40  Cap-and-Trade System. Image retrieved from http://moderlatina.com/wp-content/uploads/2013/06/Cap-trade-1.1-image-Earthy-issues-copy.jpg
The first emissions trading system was launched in Tokyo in 2011. In the first year, over 1,100 participating commercial and industrial facilities were able to reduce CO2 emissions by 13%. By the second year, emissions had been reduced by over 7 million tons of CO2 with an additional reduction of 10% (Siemens, 2014). A similar system can be implemented in National City to govern the port activity, lumber industry, and other larger companies that can afford it. This system, however, must ensure the competitiveness of smaller companies, otherwise it could hinder the growth and development of National City. The system can be introduced in phases, which will allow it to be discontinued should it prove to be inefficient. The phases are outlined in Table 13.

Table 13  National City emission trading system implementation

<table>
<thead>
<tr>
<th>Phase</th>
<th>Implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase 1: 2016-2019</td>
<td>Implementation of system; Reduce emissions by 20%</td>
</tr>
<tr>
<td>Phase 2: 2020-2029</td>
<td>Correct problems from phase 1; Reduce emissions by 40%</td>
</tr>
<tr>
<td>Phase 3: 2030-2050</td>
<td>Correct problems from previous phases; Reduce emissions by 80%</td>
</tr>
</tbody>
</table>

### Emission Reductions

It was assumed that the implementation of a cap-and-trade system in National City would cover 75% of the emissions from industrial sources. This would result in 104,270 MTCO2e to be controlled by the cap and trade. The first 20% reduction would result in an emissions reduction of 20,854 MTCO2e by 2020. The second reduction of 40% would result in an emissions reduction of 41,708 MTCO2e by 2030. The final 80% reduction would result in an emissions reduction of 83,416 MTCO2e by 2050. Table 14 summarizes these emission reductions.

Table 14  Potential emission reductions from cap-and-trade system (MTCO2e)

<table>
<thead>
<tr>
<th>Year</th>
<th>Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>2020 (20%)</td>
<td>20,854</td>
</tr>
<tr>
<td>2030 (40%)</td>
<td>41,708</td>
</tr>
<tr>
<td>2050 (80%)</td>
<td>83,416</td>
</tr>
</tbody>
</table>
Urban Forests

The use of urban forests within the city can also provide emissions reductions. An urban forest is created by planting trees and vegetation in an urban area (pictured in Figure 41). The plants are then able to sequester CO2 as they grow. Planting trees in parking lots and near buildings also has the added benefit of proving shade and reducing surface and air temperatures, leading to an overall reduction in energy use. Urban forests also have the added benefit of controlling stormwater and improving air quality (McPherson, Simpson, Peper, Maco, & Xiao, 2005).

There are a number of ways to increase the number of trees within the city. The city can provide incentives to industries and residents willing to plant trees on their properties. Programs can be implemented in schools that educate youth on the importance of tree planting and allow them to spend time outdoors. Community events can increase community awareness and help make residents feel involved in combating climate change. The National Wildlife Federation (NWF) has a program called Trees for the 21st Century that helps to educate youth about trees and their importance to our environment. They have a tree bank consisting of trees that have been donated for planting use in community tree planting events, workshop or demonstration events, or youth or community service events (National Wildlife Federation, n.d.). Big Trees Nursery in Escondido and Briggs Tree Company in Vista are also possible sources for obtaining trees.

Figure 41  Urban Forest. Image retrieved from http://sfrc.ifas.ufl.edu/urbanforestry/Images/Cd%20Latina.JPG
Emission Reductions
A study found that the annual offset of growing one tree was .0227 MTCO2e (American Clean Energy, 2014). Therefore, if 10,000 trees were planted by 2020, it would result in annual emission reductions of 227 MTCO2e. If 25,000 trees were planted by 2030, it would result in an annual reduction of 568 MTCO2e. Finally, if 50,000 trees were planted by 2050, it would result in an annual reduction of 1,135 MTCO2e. See Table 15, below.

Table 15  Urban forest potential annual emission reductions (MTCO2e)

<table>
<thead>
<tr>
<th>Year</th>
<th>Emission Reductions (MTCO2e)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2020 (10,000 trees)</td>
<td>227</td>
</tr>
<tr>
<td>2030 (25,000 trees)</td>
<td>568</td>
</tr>
<tr>
<td>2050 (50,000 trees)</td>
<td>1,135</td>
</tr>
</tbody>
</table>
Industry Summary

Table 16  2020 emission reductions from industry

<table>
<thead>
<tr>
<th>Measure</th>
<th>Emission Reduction in 2020 (MTCO₂e)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LED Lighting in Buildings</td>
<td>22,314</td>
</tr>
<tr>
<td>Green roofs</td>
<td>1,685</td>
</tr>
<tr>
<td>Industry efficiency (10%)</td>
<td>879</td>
</tr>
<tr>
<td>Cap-and-trade (20%)</td>
<td>20,854</td>
</tr>
<tr>
<td>Urban Forest (10,000 trees)</td>
<td>227</td>
</tr>
</tbody>
</table>

Limitations and Weaknesses

There are several limitations to these proposed projects for reducing industry emissions. To get businesses to switch to LED lighting, legislation must be passed or the proper incentives must be provided. Though the LED lights will eventually pay for themselves, they require an initial investment for installation. The same is true for the installation of green roofs and more energy efficient technologies. If a cap and trade system is adopted, carbon credits can be offered to the companies that switch to energy efficient technologies.

There are a weakness with the proposed emission trading system, the most obvious being that it could hinder economic development. The system has been successful in Europe because it covers around 11,000 power stations and manufacturing plants throughout the European Union. The system would be a much smaller in National City. Additionally, if other cities in San Diego County do not also adopt a similar system, National City could have a hard time competing with neighboring cities. The city would have to supplement companies for their products to remain competitively priced to offset the price they pay for carbon credits.

The main limitation of an urban forest is the initial investment in buying the trees. Trees and vegetation will take time to grow and sequester carbon, requiring at least 15-20 years to have a significant impact on emissions. The increased amount of vegetation will also require an increased amount of water. With the price of water continuously increasing this could prove problematic. Using treated wastewater provided by the Padre Dam facility or Pure Water San Diego could mitigate these costs and water demands. Table 16 provides a summary of potential 2020 emission reductions from the industry sector.
Recommendations and Conclusions

Bike share system

A phase-by-phase implementation of a bike share system is recommended within National City. Although the initial calculations show minimal reductions in GHG emissions for 2020, there is potential for more significant reductions in the future. This is due to the fact that bike share systems have grown exponentially since 2000. Between 2000 and 2013 the global number of bike share systems has increased from 6 to over 600. Between these same years, the bicycle fleet size has increased from 4,000 to over 643,000 (Midgley, 2013). The increase in the number of trips in the Boulder B-Cycle system provides evidence to support this exponential growth as well. The system first opened in 2011, and there were a total of 18,604 bicycle trips that year. In 2014, the fourth year of operation, this number increased to 43,143 total bicycle trips. This equates to a 232% increase in usage from 2011 (Boulder B-Cycle, 2015).

The climate of National City also supports the success of a bike share system. The coldest months are from December through March, with the coldest being December and January. The average temperature for these two months is 56°F (AreaVibes Inc., 2015). These temperatures are warm enough to support comfortable year-round biking. San Diego only receives an average of 42 days of precipitation, totaling 10.3 inches, per year (Current Results Nexus, 2015). This low annual precipitation further encourages outdoor activities, such as cycling.

National City also boasts a compact land area of 7.3 square miles (National City: City Overview, 2010). This encourages alternative modes of transportation such as biking and walking. The city also boasts two trolley stations, the 24th Street Station and the 8th Street Station. These provide great locations for bike share stations and allow the workforce to be the initial target population for implementation of a bike share system. This would provide the workforce with an alternative option of transportation.

Most importantly, implementation of a bike share system would encourage residents to engage in additional physical activity and therefore improve overall health. This is especially critical given the obesity epidemic that has more than doubled since 1980 (WHO, 2015). Health benefits have been illustrated in studies by Chenoweth (2005) and Proper et al. (2006). These studies have shown that improved health of the workforce, not only benefits the workers, but also the employers as well.

Economically, the implementation of a bike share system should provide a boost to the local economy in National City. Studies by Lee (2012) and Clean Air Partnership (2009) have shown that bicycling increases residents’ exposure to local businesses, which results in additional spending. In a study by Velib’ (2010), it was demonstrated that implementation of a bike share system would also create additional jobs. Finally, a study by Racca and Dahnju (2006) illustrated that the presence of a bike share system can lead to an increase in local property values.
Addressing Transportation Emissions

According to 2005 CAP data, transportation was the greatest contributor to GHG emissions within National City (359,029 MTCO2e). State highways were responsible for 60% (215,554 MTCO2e) of these emissions (National City, 2011). Given that this source of emissions is hard to address, mitigation strategies should be applied to local roadways. The addition of 12 traffic roundabouts is recommended. The addition of these roundabouts is estimated to not only reduce emissions by 2,124 MTCO2e, but also improve safety (Chittenden County RPC, 2011). Additional roundabouts can be added later to reduce emissions further. The city should also look into converting streetlights to LED light, similar to the project that was recently completed in Chula Vista. These streetlights will not only reduce GHG emissions, but also improve safety and decrease maintenance, which will save the city money (American Electric Lighting, 2014). Finally, the city should look into partnering with local supermarkets to set up a group grocery ordering system. Studies have shown that the implementation of a group grocery ordering system not only reduces GHG emissions, but also results in less traffic on local roadways and provides convenience for customers (Tehrani & Karbassi, 2005; Wygonik & Goodchild, 2012). Table 17 provides a summary of 2020 GHG emission reductions that can be achieved in the transportation sector.

Table 17 2020 Emission Reduction Strategies for Transportation Sector

<table>
<thead>
<tr>
<th>Measure</th>
<th>Emission Reduction in 2020 (MTCO2e)</th>
<th>Percentage of Total Transportation Emissions (359,029)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic Roundabouts (12 roundabouts)</td>
<td>2,124</td>
<td>---</td>
</tr>
<tr>
<td>Environmental Zones (phase 1)</td>
<td>5,491</td>
<td>---</td>
</tr>
<tr>
<td>805 to Boulevard</td>
<td>49,578</td>
<td>14%</td>
</tr>
<tr>
<td>LED Streetlights</td>
<td>116</td>
<td>---</td>
</tr>
<tr>
<td>Group Grocery Ordering System (15% participation)</td>
<td>157</td>
<td>---</td>
</tr>
<tr>
<td>Total</td>
<td>57,465</td>
<td>16%</td>
</tr>
</tbody>
</table>
Addressing Industry Emissions

Industry was responsible for 25% (139,026) of community-wide GHG emissions (National City, 2011). To combat this, the city should either require or provide incentives for all commercial/industrial buildings to switch to LED lighting. It was estimated that this could reduce emissions by 22,314 MTCO2e. Green roofs are another strategy that should be explored. Green roofs not only reduce GHG emissions, but also reduce energy use, reduce air pollution, improve human health and comfort, enhance stormwater control, and have the potential to provide residents with fresh fruits and vegetables (EPA, 2013). Greening of the city through urban forests is also recommended. Urban forests will reduce GHG emissions, reduce energy use, control stormwater, and improve air quality (McPherson, Simpson, Peper, Maco, and Xiao, 2005). They also provide a great way to bolster community involvement and raise residents’ awareness of climate change mitigation efforts within National City. A summary of GHG emission reduction strategies for industry can be viewed in Table 18.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Emission Reduction in 2020 (MTCO2e)</th>
<th>Percentage of Total Industrial Emissions (139,026)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LED Lighting in Buildings</td>
<td>22,314</td>
<td>16%</td>
</tr>
<tr>
<td>Green roofs (150,000 m²)</td>
<td>1,685</td>
<td>---</td>
</tr>
<tr>
<td>Industry efficiency (10%)</td>
<td>879</td>
<td>---</td>
</tr>
<tr>
<td>Cap-and-trade (20%)</td>
<td>20,854</td>
<td>15%</td>
</tr>
<tr>
<td>Urban Forest (10,000 trees)</td>
<td>227</td>
<td>---</td>
</tr>
<tr>
<td>Total</td>
<td>45,959</td>
<td>33%</td>
</tr>
</tbody>
</table>
Addressing Port Emissions

Port emissions in National City were estimated to total 165,286 MTCO2e, which represents 1/5 of total port emissions (Port of San Diego, 2013). On-road emissions were responsible for 38% of total emissions, so this should be the first area addressed. It is recommended that zero-emission trucks be explored, as they are estimated to provide significant emission reductions. They were recently installed at the Port of Long Beach, so this system can serve as a model (Morrison, 2013). A solar power plant should also be considered given the high photovoltaic potential in Southern California (National Renewable Energy Laboratory, 2015). This plant could have the added benefit of providing shade and protection to the large number of cars offloaded in National City. Shore Power, which was recently installed at the Tenth Avenue Marine Terminal, should also be expanded to National City. This technology was estimated to reduce emissions by 2,000 MTCO2e, so it should be able to provide similar emissions reductions in National City (Port of San Diego, 2014). A summary of strategies to reduce GHG emissions from the port can be viewed in Table 19.

Table 19 2020 Emission Reduction Strategies from Port

<table>
<thead>
<tr>
<th>Measure</th>
<th>Emission Reduction in 2020 (MTCO2e)</th>
<th>Percentage of Total Port Emissions (165,286)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shore Power</td>
<td>2,000</td>
<td>1%</td>
</tr>
<tr>
<td>Zero-emission-trucks (15%)</td>
<td>9,421</td>
<td>6%</td>
</tr>
<tr>
<td>Solar Power Plant</td>
<td>6,433</td>
<td>4%</td>
</tr>
<tr>
<td>Waste Treatment Facility</td>
<td>4,969</td>
<td>3%</td>
</tr>
<tr>
<td>Power-to-Gas Facility</td>
<td>2,800</td>
<td>2%</td>
</tr>
<tr>
<td>Total</td>
<td>25,623</td>
<td>16%</td>
</tr>
</tbody>
</table>
Works Cited


Appendix: Calculations

Bike Share

First, I predicted usage rates in National City for the years 2017-2020 based on usage rates of Boulder B-cycle from 2011-2014. I took population of NC (2013) and divided it by population of Boulder (2013)… 59,834/103,166 = .58

I then used this factor to create baseline estimates for National City (I multiplied the .58 by the trips per month for the first year in Boulder). I then used excel and took the average increases per year for the months of May through September for Boulder B-cycle (these months are most similar to National City in terms of climate). I then took these increases and applied them to the respective year in NC to produce my predictive graph (Note: this graph is most likely an estimate due to the extremely low usage in the winter months in Boulder).

Total bicycle trips assumed for 2017 = 16,037 2 miles = assumed average trip length (Note: a trip is defined as a rental and return- one-way travel)

16,037 * 2 = 32,074 miles traveled in 2017… Then used EPA estimate of 21.6 mpg for typical passenger vehicle (United States Environmental Protection Agency, 2011)

32,074/21.6 = 1,485 gallons of gasoline saved from biking… Then used EPA estimate of emissions from 1 gallon of gasoline being equivalent to 20 pounds of CO2 (United States Environmental Protection Agency, 2011)

1,485 * 20 = 29,700 lbs of CO2 emissions saved… Then used EPA estimate of 113 gallons of fuel being equivalent to 1 MTCO2e (U.S. Environmental Protection Agency, 2014)

1,485/113 = 13 MTCO2e saved from biking in 2017

Total bicycle trips assumed for 2018 = 20,337

20,337 * 2 = 40,674 miles traveled in 2018

40,674/21.6 = 1,883 gallons of gasoline saved from biking

1,883 * 20 = 37,660 lbs of CO2 emissions saved

1,883/113 = 17 MTCO2e saved from biking in 2018

Total bicycle trips assumed for 2019 = 23,098

23,098 * 2 = 46,196 miles traveled in 2019

46,196/21.6 = 2,139 gallons of gasoline saved from biking

2,139 * 20 = 42,780 lbs of CO2 emissions saved
2,139/113 = 19 MTCO2e saved from biking in 2019

Total bicycle trips assumed for 2020 = 30,263

30,263 * 2 = 60,526 miles traveled in 2020

60,526/21.6 = 2,802 gallons of gasoline saved from biking

2,802 * 20 = 56,040 lbs of CO2 emissions saved

2,802/113 = 25 MTCO2e saved from bike in 2020

Final calculation for a significant reduction in transportation emissions: 33,630 trips per day*365 days per year=12,274,950 trips per year...12,274,950 trips*2 miles per trip=24,549,900 miles...24,549,900 miles/21.6 MPG=1,136,569.444 gallons of gasoline saved...1,136,569.444 gallons/113 gallons of gasoline per MTCO2e =10,058 MTCO2e
Transportation

Roundabouts
Each roundabout assumed to save 20,000 gallons of gasoline

\[
\frac{20,000}{113} \text{ (gallons of fuel per 1 MTCO2e)} = 177 \text{ MTCO2e per roundabout}\text{...plan implements } 12 \text{ roundabouts}
\]

\[
12 \times 177 = 2124 \text{ MTCO2e emission reductions per year}
\]

Environmental Zone
109,829 MTCO2e = emissions from local roads in NC

2020 assumes a 5% reduction in emissions from an environmental zone

\[
109,829 \times .05 = 5,491 \text{ MTCO2e reduction in emissions for 2020}
\]

2030 assumes a 25% reduction in emissions from an environmental zone

\[
109,829 \times .25 = 27,457 \text{ MTCO2e reduction is emissions for 2030}
\]

2050 assumes a 50% reduction in emissions from an environmental zone

\[
109,829 \times .5 = 54,915 \text{ MTCO2e reduction in emissions for 2050}
\]

Changing the 805 to a Boulevard

215,554 MTCO2e emissions from freeways in NC...200,000 average annual daily traffic (AADT) on 805...500,000 AADT from all NC highways (Government State of California, 2013)

\[
\frac{200,000}{500,000} = .4 \text{ or 40% of traffic from 805}
\]

\[
.4 \times 215,554 = 86,222 \text{ MTCO2e assumed emissions from 805}
\]

Assume 50% of AADT will use alternative modes of transportation...

\[
(.5) \times 86,222 = 43,111 \text{ MTCO2e reduced emissions}
\]

Assume 25% of AADT will use boulevard traveling at lower speeds (50 mph)... assume 30% reduction in CO2 emissions (CE Delft, 2010)

\[
.25 \times .3 \times 86,222 = 6,467 \text{ MTCO2e reduction in emissions}
\]

\[
43,111 + 6,467 = 49,578 \text{ MTCO2e emission reductions}
\]
LED Streetlights

1,820 streetlights in NC (City of National City, 2008)...Streetlights were responsible for 648,591 kWh of electricity and 231 MTCO2e (ICLEI, 2009)

Chula Vista changed 4,300 streetlights, which resulting savings of 770,000 kWh electricity (San Diego Gas & Electric, 2012)

770,000/4,300 = 179 kWh per light

179 * 1,820 = 325,780 kWh savings in NC

325,780/648,591 = .5023 or 50.23%

.5023 * 231 = 116 MTCO2e in emission reductions

Group Grocery Ordering System

Assume that average distance to grocery store is .86 miles (McConville et al., 2011)...2014 average household made 1.6 trips to grocery store per week (Statista, 2015)

.86 * 2 (to and from) * 1.6 * 52 wk/yr = 143.104 miles per year per household

17,798 households in NC (ICLEI, 2009)...2020 assume 15% participation rate

17,798 *.15 = 2,670 households...2,670 * 143.104 = 382,088 miles per year

382,088/21.6 (mpg) = 17,689 gallons of gasoline

17,689/113 = 157 MTCO2e in emission reductions for 2020

For 2030, we assume 30% participation rate... (.3) * 17,798 = 5,339.4 households

5,339.4 * 143.104 = 764,089.5 miles per year

764,089.5/21.6 = 35,374.5 gallons of gasoline

35,374.5/113 = 313 MTCO2e in emission reductions for 2030
Industry

LED Lighting
125,269 MTCO2e emissions from industrial/commercial electricity
It was assumed in office buildings 38% of total electricity is consumed for lighting…It was assumed that in all other building 19% of total electricity is consumed for lighting (U.S. Energy Information Administration, 2009)
It was then assumed that there was a 25% distribution of office buildings in NC (National City, 2011)
(.25 *.38) + (.75 *.19) = .2375 or 23.75% of electricity for lighting in all buildings
125,269 * .2375 = 29,751.39 MTCO2e emissions from lighting
It was then assumed that the installation of LED lighting would result in a 75% reduction of lighting emissions (U.S. Energy Information Administration, 2009)
29,751.39 * .75 = 22,314 MTCO2e in emission reductions

Green Roofs
125,269 MTCO2e emissions from industrial/commercial electricity
13% = percentage of electricity demand for cooling (U.S. Energy Information Administration, 2009)
125,269 * .13 = 16,284.97 MTCO2e emissions for cooling
Assume green roofs can reduce energy demand from cooling by 10% (U.S. Energy Information Administration, 2009)
16,285 * .1 = 1,629 MTCO2e in emission reductions

Energy Efficient Technologies
14,308 MTCO2e emissions from solid waste…3,269 MTCO2e emissions from water and wastewater
14,308 + 3,269 = 17,577 MTCO2e total emissions…assume 50% from industry…8,789 MTCO2e
For 2020 assume a 10% reduction…8,789 * .1 = 879 MTCO2e reduction in emissions
For 2030 assume a 25% reduction…8,789 * .25 = 2,197 MTCO2e reduction in emissions
**Cap-and-Trade System**

139,026 MTCO2e emission from commercial/industrial sector

Assume cap-and-trade will cover 75% of these emissions

\[ 139,026 \times 0.75 = 104,270 \text{ MTCO2e in emissions} \]

For 2020 assume a 20% reduction in emissions...\[ 104,270 \times 0.2 = 20,854 \text{ MTCO2e in reductions} \]

For 2030 assume a 40% reduction in emissions...\[ 104,270 \times 0.4 = 41,708 \text{ MTCO2e in reductions} \]

For 2050 assume a 50% reduction in emissions...\[ 104,270 \times 0.8 = 83,416 \text{ MTCO2e in reductions} \]

**Urban Forest**

Assume 1 tree = .0227 MTCO2e annual offset in emissions

(American Clean Energy, 2014)

For 2020 plant 10,000 trees...\[ 10,000 \times 0.0227 = 227 \text{ MTCO2e annual emission reductions} \]

For 2030 plant 25,000 trees...\[ 25,000 \times 0.0227 = 568 \text{ MTCO2e annual emission reductions} \]

For 2050 plant 50,000 trees...\[ 50,000 \times 0.0227 = 1135 \text{ MTCO2e annual emission reductions} \]
Port
Unified Port of San Diego total = 826,429 MTCO2e
826,429/5 cities = 165,285.8 MTCO2e value assumed for National City
for all calculations

Solar Power Plant
2,150 = assumed photovoltaic energy potential for San Diego (National Renewable
Energy Laboratory, 2015)
11 MW = assumed capacity of solar power plant (Global Energy Network Institute, 2010)
2,150 * 11 = 23,650 MWh = 23.65 GWh
30 MTCO2e = assumed emissions per photovoltaic cell during life time
(National Renewable Energy Laboratory, 2012)
302 MTCO2e = assumed emissions per GWh from conventional energy
(National City, 2011)
302 – 30 = 272 MTCO2e  272 * 23.65 = 6,433 MTCO2e in emission reductions

Shore Power
Tenth Avenue Marine Terminal reported 2000 MTCO2e in emission reductions after
implementation of shore power, so we assume the same for National City

Zero-Emissions-Trucks
165,286 MTCO2e = assumed emissions from NC port 38% of total port emissions
attributable to on-road transportation...we assume the same for NC
165,286 * .38 = 62,808.68 MTCO2e attributed to on-road transportation
Assumed 15% reduction in on-road emissions by 2020 with implementation of
zero-emissions-trucks
62,809 * .15 = 9,421 MTCO2e reduction in 2020
Assumed 30% reduction in on road emissions by 2030 with implementation
62,809 * .30 = 18,843 MTCO2e reduction in 2030
Waste Treatment Facility
5,850 MWh/yr = 5.85 GWh/yr = assumed electrical output of facility
302 MTCO2e = emissions per GWh electricity
5.85 * 302 = 1,767 MTCO2e emission reductions from electrical power
9,325 MWh/yr = 9.325 GWh/yr = assumed thermal output of facility
181.52 MTCO2e per GWh = emissions from natural gas
9.325 * 181.52 = 1,693 MTCO2e emission reductions from thermal energy
3,041 = MTCO2e emissions from food waste 1,268 = MTCO2e emissions from plant debris
3,041 + 1,268 = 4,309 – 2,800 (resulting CO2) = 1,509 MTCO2e
1,767 + 1,693 + 1,509 = 4,969 MTCO2e

Power-to-Gas Facility
Assumed to be able to bind the 2,800 MTCO2e from waste treatment plant based on output of Audi plant in Germany