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TECHNICAL APPENDIX

INVESTING IN A BETTER MASSACHUSETTS: AN ANALYSIS OF JOB CREATION AND COMMUNITY BENEFITS FROM GREEN INVESTMENTS

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STUDY OVERVIEW

This Technical Appendix is a companion document to *Investing in a Better Massachusetts: An Analysis of Job Creation and Community Benefits from Green Investments*. It explains in detail the 18 programs analyzed in the primary report, how jobs and community benefits were modeled for each program, and how the programs were combined into a *Green Investment Portfolio.* The methodology and underlying data used in this study is open to be repurposed for derivative work, with attribution to the study authors.

The study consists of three main stages:

1. **Data Collection and Jobs:** 29 individual projects in Massachusetts were deconstructed into line-item expenditures and coded into IMPLAN, an economic input-output model that maps the flow of dollars, commodities, and labor between 546 sectors in the state. Each dollar invested in IMPLAN ripples throughout the state economy and measures resulting employment, output, labor income, and other fiscal impacts.
2. **Fuel Reductions:** 20 out of 29 projects had sufficient data to estimate their greenhouse gas emissions reductions and/or fossil fuel savings, using a combination of project-specific literature and peer-reviewed energy models.
3. **Health and Time Savings:** An air quality model was constructed to calculate the down-wind public health benefits of 17 projects that reduce fossil fuel consumption. An additional benefit module was constructed to estimate the physical activity, traffic fatality prevention, and traffic congestion savings of seven transportation projects.

The 29 individual project results were grouped and weighted in the following progression:

<u>29 Projects</u> > <u>18 Programs</u> > <u>3 Investment Areas</u> > <u>1 *Green Investment Portfolio*</u>

The primary report provides jobs and community benefit results at the program, investment area, and portfolio level. The projects, programs, and investment areas can be individually examined for job creation potential, public health benefits, and other merits. Additionally, the data can be re-manipulated into new portfolios to reflect funding packages under consideration in Massachusetts.

METHODOLOGY

1. IMPLAN JOBS IMPACT ANALYSIS

1.1 IMPLAN Overview

For each program described in this report, we collected detailed project-level expenditures that we entered into an economic input-output model called IMPLAN (Version 6). IMPLAN is a commonly used tool on job creation, including technical reports for government agencies and academic papers in peer-reviewed journals. Economic input-output models such as IMPLAN are often used to evaluate the impact of a policy or investment, particularly when empirical data gathering is difficult or impossible.

IMPLAN maps the flow of economic activity between 546 industries and institutions, with each dollar tracked throughout the state economy with resulting employment, output, labor income, and fiscal impact estimates. All 29 projects in this study were deconstructed into line-item expenditures using available budgetary data and run through IMPLAN's 2019 Massachusetts dataset to subsequently ripple throughout the state economy.

Obtaining a complete picture of jobs and economic impacts requires tracking the *direct*, *indirect*, and *induced impacts* of each investment, which is nearly impossible with observational methods, as it would require verifying the unique supply chain of every impacted firm, as well as the unique spending pattern of every impacted worker.

Direct effects are the result of direct payments to industries to carry out a given program (i.e., paying construction firms to build public transit).

Indirect effects are the result of how direct industries then subsequently pay other industries to conduct their business (i.e., a construction firm subsequently purchasing heavy-duty equipment for the project).

Induced effects are the result of how households spend new income across the economy (i.e., construction workers subsequently spend income on food, services, housing, and other non-work expenses)

1.2 Immediate vs Long-Run Impacts in IMPLAN

The projects modeled in this study boost the state economy in two ways. First, each program requires upfront capital which boosts demand for various goods and services in order to carry out the given investment. Second, the investment itself creates cost savings for households, businesses, and institutions once implemented, which increases the spending power of consumers.

Upfront Capital Investment
Every project examined in this report includes some form of initial investment or capital expense. For each project described in this report, we collected detailed expenditure data from existing

projects underway or under consideration in Massachusetts. This includes all costs associated with the project's infrastructure, including design, engineering, construction, and material costs.

We modeled these capital costs as an increase in the economic output of various industries. For example, a one million dollar expense for a new road would be coded in IMPLAN as a one million dollar increase in the economic output of *Industry 54 - Construction of New Highways and Streets*.[1] The source data for these project expenditures can be found in section 7 of this document.

Cost Savings and Spending Power
Investment programs in this study, in most cases, also result in financial savings for consumers and grantees. Those savings increase the spending power of the state economy, and are used on a variety of goods and services to support additional jobs. Our IMPLAN analysis includes direct financial savings for consumers and grantees, as well as indirect financial savings, as defined below:

- **Short-Run Savings:** In some cases, upfront project expenses also create immediate financial savings for consumers and businesses. For example, the *Low Carbon Buses* program provides funds for transit agencies to offer free fares to encourage ridership. These funds create financial savings for transit riders who otherwise would have paid for their trip that day. IMPLAN can direct these financial savings to other typical household expenditures, which leads to additional job creation in our study.

- **Long-Run Savings:** Seventeen out of 29 projects examined in this study measurably reduce fossil fuel consumption over their lifetimes and save households, businesses, and institutions money. For example, the *Low Carbon Buses* program also provides funds for local transit agencies to expand service, which will lead to decreased personal vehicle use and savings on fuel costs. Some households will spend these indirect savings on other goods and services, and transit agencies will use these savings to cover operational costs or make additional transit investments.

  The fuel savings from each project was translated into dollar savings using the EIA's *Annual Energy Outlook* for fuel prices, with a discount rate applied.[2] The resulting dollars of fuel savings were modeled in IMPLAN as increased household or business spending power, to estimate the jobs supported when consumers and businesses spend money on other goods and services in-state rather than imported fossil fuel energy.

The methodology for calculating fuel savings from each project is case-specific, and is outlined in further detail in section 2 of this Technical Appendix.

[1] See IMPLAN's website for a full list of industry codes used in IMPLAN: https://implanhelp.zendesk.com/hc/en-us/articles/115009674428-IMPLAN-Sectoring-NAICS-Correspondences
[2] EIA, "Annual Energy Outlook 2020: New England Energy Prices by Sector and Source." t.ly/S1iP

1.3 IMPLAN Limitations

Proper application of our jobs and economic analysis requires a careful understanding of the scope of the study. Economic input-output models provide meaningful insights into economy-wide employment, but are not without limitations.

Static and Linear Industry Relationships
Industries in this model are constructed as single, snapshot-level relationships rather than time-sensitive evolving businesses with ever changing conditions. Thus, future technologies and supply chains may lead to different employment outcomes in particular industries compared to what this study estimates.

Investment impacts scale linearly without sensitivity to the magnitude of investment. Thus, in IMPLAN's economic flows, a dollar investment and a billion dollar investment in a given industry will lead to the same proportional outcomes, even if an investment of such size exceeds the production or workforce capacity of the region in question. Evaluating capacity constraints is outside the scope of this study, as our investment programs are normalized to a million dollar scale.

Geographic Detail
All job estimates provided in this study are located within Massachusetts. Jobs supported out of state or abroad are excluded from the study's results. Distributional analysis at the county level is possible in IMPLAN, but requires geographic specificity to the projects implemented and where each line item expenditure occurs. This information is outside the scope of this study and a key focal point of future research when investment programs are rooted in location-specific proposals.

Net vs Gross Impacts
This study strictly looks at the gross number of jobs that are supported by investment programs, not whether these jobs are net positive jobs. When modeling these programs in IMPLAN, the model assumes that each investment is a new additional influx of spending into the Massachusetts economy. In reality, these funds must originate from somewhere. If the source of revenue of these programs comes from within the state, those revenues would have otherwise been circulated in some way that supports jobs as well. Depending on where revenue comes from, some of the jobs identified in this study may represent a transfer of jobs from one sector of the economy to another, rather than an overall gain in employment.

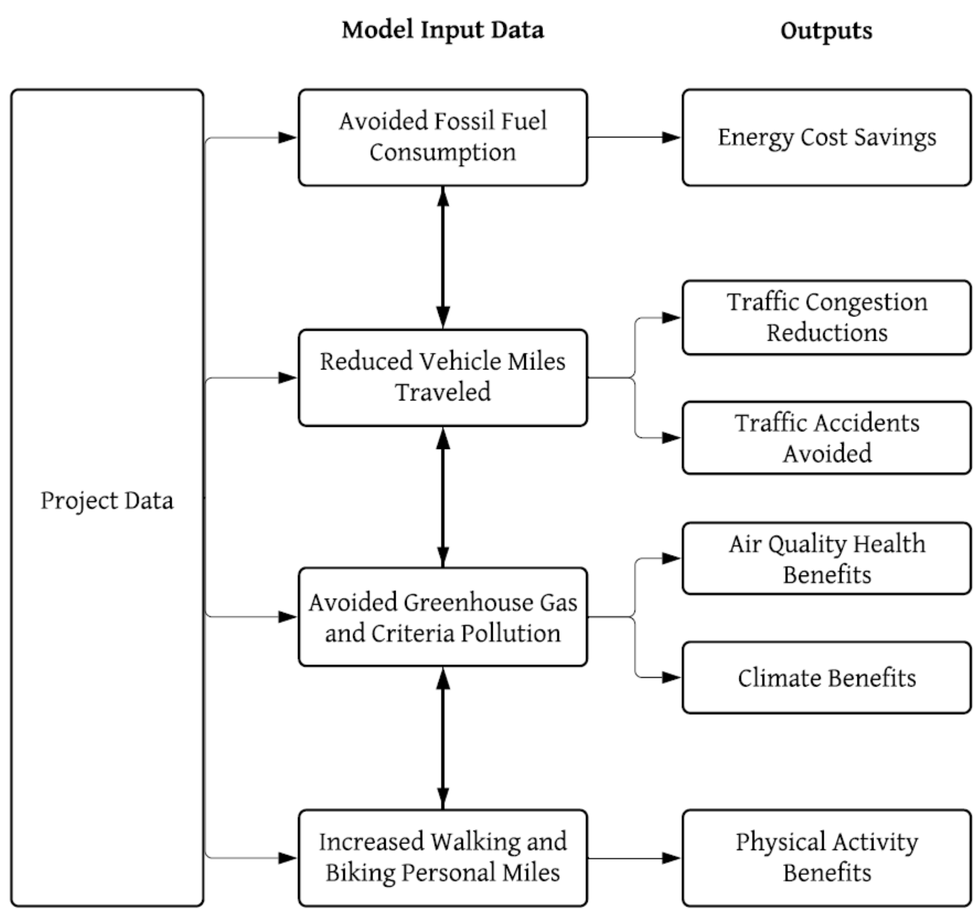
Such analysis would require counterfactual scenarios of where funds for these investments come from. Absent these details, we use an average economy-wide benchmark, as well as a jobs analysis of the ten largest industries in the state, in order to inform the relative effectiveness of the *Green Investment Portfolio* compared to typical spending patterns. The details of these benchmarks can be found in section 6.3 of this Technical Appendix.

2. BENEFITS ANALYSIS DATA FRAMEWORK

Beyond IMPLAN, this study also models six different benefits of each project in dollar terms: energy cost savings,[3] traffic congestion reduction, air quality improvements, traffic accidents avoided, and climate benefits.

These benefits are all derived from three core variables: the fossil fuel consumption avoided by the project, the vehicle-miles-traveled (VMT) reduced by the project, and/or the greenhouse gas emissions avoided by the project. Some transportation projects also provide health benefits through increased physical activity, which is derived from an increase in walking and biking personal-miles-traveled (PMTs).

Table 1. Benefits Analysis Data Framework



[3] As noted in the previous section, the project's energy cost savings were also re-run through IMPLAN as increased spending power for households, businesses and institutions, leading to additional job creation. The other five benefits measured in this report were not compatible with IMPLAN and thus their job impacts were not modeled in this report.

For the majority of *Green Investment Portfolio* projects, we used project-specific literature to estimate the core variables. Many of these estimates are provided directly in the budget proposal used, for example a rail project scoping study that provides an estimated reduction in VMTs. Other projects required additional modeling tools using project data as inputs, such as using the EPA's AVERT tool to calculate the fuel savings and greenhouse gas emissions avoided from investments that impact the regional electricity grid.

Some projects only report enough data to calculate one core variable. For these projects, we established standard equations to freely convert between VMT reductions, fossil fuel consumption avoided, and greenhouse gas emissions, using the EIA's emissions factors and fuel economy projections.[4]

Twenty of the 29 *Green Investment* projects have measurable VMT reductions, fossil fuel energy savings and/or greenhouse gas (GHG) emissions reductions. These impacts were standardized to a "per million dollars invested" using the capital cost estimates of each project, and then converted into the corresponding benefits in dollars terms.[5]

2.1 VMT-Based Project Multipliers

Nearly every program and project in the *Clean Transportation and Sustainable Development* investment area's fuel savings and greenhouse gas emissions reductions are based on a reduction in vehicle miles traveled (VMT). Using the AAA *Your Driving Costs* 2019 factsheet,[6] we derived an estimate of annual gasoline fuel costs per mile of driving in Massachusetts.[7,8] With these two estimates, we calculated the total fuel cost and gasoline consumption avoided from a given project's reduction in VMT.[9]

Project-specific methodology is described below. More detailed source documentation for each project can be found in section 7 of this document.

Green Line Extension - To estimate the gasoline fuel savings of the *Green Line Extension* project, we calculated the total VMT reduction over the project's lifetime. The *Green Line Extension* project's capital costs are approximately $1.8 billion, and annual expected VMT reductions are 9,390,720 miles. Thus, the project will reduce VMT by 131,168 miles per million dollars, over the first 25 years of operation.

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[4] EIA, https://www.eia.gov/energyexplained/units-and-calculators/british-thermal-units.php, https://www.eia.gov/tools/faqs/faq.php?id=76&t=11
[5] For more information on project cost estimates, see section 7.
[6] AAA, "Your Driving Costs: How Much are you Really Paying to Drive?" https://exchange.aaa.com/wp-content/uploads/2019/09/AAA-Your-Driving-Costs-2019.pdf
[7] This estimate was adjusted to reflect gasoline and electricity prices in New England, as well as the average annual VMT per vehicle and average fuel efficiency in Massachusetts. We used the "2019 Weighted Average" cost estimates in the AAA brochure.
https://www.eia.gov/state/seds/data.php?incfile=/state/seds/sep_fuel/html/fuel_mg.html&sid=US
[8] https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/ma_fy21_hsp.pdf
[9] We assumed a lifetime of 25 years for *Light and Commuter Rail*, *Transit-Oriented Development*, *Ferry Expansion and Electrification*, and *East-West Rail* projects when estimating the gasoline fuel savings. Massachusetts regulations will require ZEV sales to make up 100 percent of all new light-duty vehicle sales by 2035. Based on a 15 year average lifetime of an internal combustion engine vehicle (ICEV), we can assume that nearly all gasoline-powered vehicles will be retired by 2050, so the gasoline fuel savings of VMT reductions cannot extend beyond 2050.

South Coast Rail - To estimate the gasoline fuel savings of the *South Coast Rail* project, we calculated the total VMT reduction over the project's lifetime. The *South Coast Rail* project's capital costs are approximately $1.1 billion, and annual expected VMT reductions are 17,994,400 miles, based on a 271-day year used in the report for commuter rail use. On a million dollar basis, the project will reduce VMT by 406,083.0 miles over the first 25 years of operation.

North South Rail Link - To evaluate the gasoline savings and avoided greenhouse gas emissions from the *North South Rail Link* project, we estimated the lifetime VMT and greenhouse gas emissions reduced per million dollars invested. We used an average project cost of the four alternatives presented in the NSRL Feasibility Assessment, excluding the "No NSRL" alternative: Central Artery (two-track), Pearl/Congress Alignment (two-track), South/Congress Alignment (two-track), and Central Artery (four-track). Capital costs of the project are approximately $8.3 billion.

Fuel savings - We used an average of each NSRL alternative's annual VMT reduction projection to estimate the fuel savings and avoided car ownership costs of the project per year. Using a lifetime of 25 years, the *North South Rail Link* project's lifetime VMT reduction is 331,953.1 miles per million dollars invested.

Greenhouse gas emissions - As currently proposed, the *North South Rail Link* project would increase greenhouse gas emissions because the increase in emissions from diesel-powered trains would outweigh the expected decrease in emissions from reduced passenger vehicle travel.

Clean Vehicles - The *Clean Vehicles* program was modeled after existing investment programs in California. For this program, we looked at the quantified emissions reductions from programs administered through California Climate Investments (CCI), which are estimated using calculators from the California Air Resources Board.[10]

Greenhouse gas emissions - Using the CCI project database, we extracted data on total funding and expected greenhouse gas emissions reductions for all projects administered between 2015 and 2019. Project data that lacked funding or quantifiable emissions reductions was excluded from our estimates. Using only the projects with quantified GHG emissions reductions, we calculated the ratio of total project funding to a quantity of GHG reductions, and subsequently scaled this ratio to calculate the expected GHG emissions ($mtCO_2e$) avoided per one million dollars invested in each CCI program.

Fuel savings - We assumed an annual emissions per vehicle of 4.6 metric tons CO_2,[11] average vehicle lifetime of 12 years,[12] average fuel efficiency of 22 miles per gallon,[13] and 11,500 miles driven annually per vehicle to convert greenhouse gas emissions reductions to gallons of gasoline consumption avoided. Then we scaled avoided gallons of gasoline consumption to a one million dollars investment in the *Clean Vehicles* program.

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[10] https://ww2.arb.ca.gov/resources/documents/cci-quantification-benefits-and-reporting-materials
[11] Ibid.
[12] AARP, https://www.aarp.org/auto/trends-lifestyle/info-2018/how-long-do-cars-last.html
[13] EPA, "Greenhouse Gas Emissions from a Typical Passenger Vehicle." t.ly/xVua

Low Carbon Buses - The *Low Carbon Buses* project is modeled after the Low-Carbon Transit Operations Program (LCTOP) administered through CCI. The program reduces gasoline consumption by decreasing personal vehicle use and diesel fuel consumption by switching from diesel to electric buses. Diesel and gasoline fuel savings were calculated separately and subsequently combined to estimate the *Low Carbon Buses* total fuel savings.

> *Gasoline Savings* - Using the CCI project database, we extracted data on total funding and expected VMT reductions from six of the most recent CCI investments that replace or expand transit bus fleets with electric buses — which best reflect the *Low Carbon Buses* project. On a million dollar basis, these investments are expected to decrease VMT by 270,519.9 miles per year.[14] Assuming an average project lifetime of 12 years for BEBs, lifetime VMT is equivalent to 3,246,238.7 miles per million dollars invested.
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> *Greenhouse gas emissions* - Using the CCI project database, we extracted data on total funding and expected greenhouse gas emissions reductions for all LCTOP projects administered between 2015 and 2019. Project data that lacked funding or quantifiable emissions reductions was excluded from our estimates. Using only the projects with quantified GHG emissions reductions, we calculated the ratio of total project funding to a quantity of GHG reductions, and subsequently scaled this ratio to calculate the expected GHG emissions (mtCO_2e) avoided per one million dollars invested in each CCI program for the public health and climate benefits modeling described below.
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> *Diesel Savings* - We converted the expected emissions reductions described above to lifetime gallons of diesel per million dollars invested, using the emissions factor of diesel provided by CARB.[15]

Transit-Oriented Development - The *Transit-Oriented Development* program is modeled after the Affordable Housing and Sustainable Communities (AHSC) Program administered through California Climate Investments (CCI). Using the CCI project database, we extracted data on total funding and expected VMT reductions from five of the most recent AHSC investments that report greenhouse gas emissions reductions, gallons of fuel avoided, and VMT reductions to best reflect the *Transit-Oriented Development* program. On a million dollar basis, these investments are expected to reduce VMT by 748,424.7 miles over the program's lifetime.[16]

Active Mobility - To estimate the fuel savings from the *Active Mobility* program, we used capital cost and VMT reduced per mile of active mobility infrastructure from the Transportation and Climate Initiative (TCI) State Investment Tool.[17] Using the tool's assumptions for VMT reductions per walking facility type, we calculated the total VMT reductions per million dollars invested in *Active Mobility*. These estimates were weighted according to population density in each county in Massachusetts: "core" (7.14 percent), "suburban" (57.14 percent), and "rural" (35.71 percent).[18] We assumed a 20 year

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[14] California Climate Investments, "Implemented Projects Historic Database," *Accessed April* 2021.
[15] CARB,
https://ww2.arb.ca.gov/our-work/programs/ab-32-coi-fee-regulation/common-carbon-cost-fuel-fee-rates
[16] California Climate Investments, "Implemented Projects Historic Database," *Accessed April* 2021.
[17] Cambridge Systematics, Inc., "State Investment Tool Documentation." September 2020, t.ly/FS3T
[18] The population density per square mile is as follows: "Core" counties have between 10,000 and 72,000 people; "suburban" counties have 500 to 3,999 people; and "rural" counties have less than 500 people per square mile.

lifetime for active mobility infrastructure, which reduces lifetime VMT by 317,847.0 miles per million dollars invested.

Ferry Expansion and Electrification - Boston Harbor Now provides different fare scenarios for two ferry routes, and their expected increases in ridership and decreases in VMT from each scenario. We used the standard "$6.50 fare" scenario for both ferry routes, which would decrease annual VMT by 587,452 miles and 368,491 miles for the Inner Harbor "ideal vessels" route and the Quincy and Columbia Point route, respectively. The lifetime VMT reductions expected by the *Ferry Expansion and Electrification* program are 468,171.1 miles per million dollars invested.

East-West Rail - To evaluate the gasoline savings from the *East-West Rail* project, we estimated the lifetime VMT reduced per million dollars invested. We used an average project cost of the three main alternatives presented in the East-West Rail Final Report: Alternative 3, Alternative 4, and Hybrid 4 and 5. For each alternative, we used an average of the "Hartford" and "Downeaster" estimates, resulting in a total project cost of $3.4 billion. We also used an average of each alternative's annual VMT reduction projection to estimate the fuel savings and avoided car ownership costs of the project per year. Using a lifetime of 25 years, the *East-West Rail* project's lifetime VMT reduction is 236,255.4 miles per million dollars invested.

2.2 Energy-Based Project Multipliers

Residential Energy Efficiency - The *Residential Energy Efficiency* project is modeled after residential *MassSave* initiatives. These investments make residential buildings more energy efficient and reduce heating oil, propane, natural gas, and electricity consumption. *MassSave Data* provides detailed information on reductions in fuel consumption and greenhouse gas emissions by fossil fuel source for each type of residential initiative, as well as their capital costs.[19] Scaling the fuel savings and GHG reductions for 2020 planned investments, every million dollars invested in *Residential Energy Efficiency* reduces fuel consumption by 6,507 MWh electricity, 398,797 therms of natural gas, and 19,786 MMBtu of oil and propane, equivalent to 7,092 short tons of CO_2e, over the program's lifetime.

Commercial and Industrial Energy Efficiency - The *Commercial and Industrial Energy Efficiency* project is modeled after commercial and industrial *MassSave* initiatives. These investments make residential buildings more energy efficient and reduce heating oil, propane, natural gas, and electricity consumption. Scaling fuel savings and GHG reductions reported for for 2020 planned *MassSave* investments, we found that every million dollars invested in *Commercial and Industrial Energy Efficiency* reduces lifetime fuel consumption by 36,787 MWh electricity and 2 MMBtu of propane, but increases natural gas and oil consumption by 275,991 therms and 3,990 MMBtu, respectively.[20] These fuel savings are equivalent to 16,236 short tons of CO_2e per million dollars invested.

Water Efficiency - The *Water Efficiency* program is modeled after the Water-Energy Grant program administered through California Climate Investments (CCI). Using the CCI project database, we extracted data on total funding, avoided fossil fuel electricity generation, and expected greenhouse gas emissions reductions from all projects administered between 2015 and 2019. On a million dollar

[19] MassSave Data, "Electric & Gas CO_2 Equivalent Emissions Reductions Summary" https://www.masssavedata.com/Public/GHGReductions#
[20] Ibid.

basis, these investments are expected to decrease fossil fuel generation by 45.3 gigawatt-hours (GWh) over their lifetime.[21]

To estimate the fuel savings and greenhouse gas emissions from *Water Efficiency*, we modeled the program's lifetime capacity in the EPA's AVoided Emissions and geneRation Tool (AVERT).[22] If an energy policy is modeled in Massachusetts, AVERT provides greenhouse gas and co-pollutant emissions for all six New England states.[23] We used the Massachusetts-specific emissions reduction for our public health and fuel savings multiplier since those occur within the state, and the New England region's emissions reduction for our climate multiplier since climate damages occur globally. Every million dollars invested in *Water Efficiency* reduces lifetime greenhouse gas emissions by 9,429 short tons in Massachusetts, and by 24,930 short tons in the New England region.

Residential Solar - The *Residential Solar* program is modeled after the Single-Family Energy Efficiency and Solar PV, Single-Family Solar Photovoltaics (PV), and Large Multi-Family Energy Efficiency and Renewables programs administered through California Climate Investments (CCI). Using the CCI project database, we extracted data on total funding, expected megawatt-hours (MWh) of clean energy produced, and greenhouse gas emissions reductions from all projects administered between 2015 and 2019. On a million dollar basis, these investments are expected to increase solar capacity by 7 megawatts (MW) over their lifetime.[24]

To estimate the fuel savings and greenhouse gas emissions from *Residential Solar*, we modeled the program's lifetime capacity in AVERT. Every million dollars invested in *Residential Solar* reduces lifetime greenhouse gas emissions by 2,420 short tons in Massachusetts, and by 5,980 short tons in the New England region.

Offshore Wind - Total capacity and capital costs of the *Offshore Wind* program are provided by the National Renewable Energy Laboratory's Offshore Wind Jobs and Economic Development Impact (JEDI) model. We subsequently scaled the annual capacity to a one million dollar investment. Assuming a lifetime of 25 years,[25] we found that the lifetime capacity per one million dollars invested is approximately 4.1 MW of clean electricity.

To estimate the fuel savings and greenhouse gas emissions from *Offshore Wind*, we modeled the program's lifetime capacity in AVERT. Every million dollars invested in *Offshore Wind* reduces lifetime greenhouse gas emissions by 3,102 short tons in Massachusetts, and by 8,250 short tons in the New England region.

Battery Storage - To estimate the greenhouse gas emissions reductions and energy savings from *Battery Storage*, we used capital cost and emissions reductions estimates from the Massachusetts Energy Storage Initiative Study.[26] The study provides detailed information on ten "use cases" of

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[21] California Climate Investments, "Implemented Projects Historic Database," *Accessed April 2021.*
[22] U.S. EPA, Avoided Emissions and Generation Tool (AVERT), https://www.epa.gov/avert/avert-web-edition
[23] AVERT evaluates how energy policies and programs such as energy efficiency and renewable energy lead to changes in carbon dioxide (CO_2) and co-pollutant emissions from electric power plants at a county, state, or regional level.
[24] California Climate Investments, "Implemented Projects Historic Database," *Accessed April 2021.*
[25] UMass Dartmouth Public Policy Center, "Proposed Vineyard Wind Offshore Wind Energy Project: Estimated Contribution to Employment and Economic Development for 400 & 800 MW' t.ly/qSDW
[26] Massachusetts Department of Energy Resources, "Massachusetts Energy Storage Initiative Study." t.ly/XUO3

battery storage, ranging from residential storage to distributed storage at investor owned utility substations, and includes high and low costs and ten year greenhouse gas emissions reductions for each battery storage use case. We calculated an average between the high and low cost scenarios, which is approximately $1.16 billion for 1,766 MW of energy storage. On a one million dollar investment scale, *Battery Storage* will reduce greenhouse gas emissions by 862.8 metric tons of carbon dioxide.

Community Microgrids - The *Community Microgrids* program is modeled after four proposed community-level microgrids in Massachusetts. Each microgrid has estimated lifetime greenhouse gas emissions reductions and/or lifetime energy savings from avoided or reduced natural gas and electricity consumption. Using an average of the capital costs and emissions reductions from each microgrid, we found that every million dollars invested in *Community Microgrids* reduces greenhouse gas emissions by 2,216.6 metric tons of carbon dioxide.

Irrigation and Water Efficiency - The *Irrigation and Water Efficiency* program is modeled after the State Water Efficiency and Enhancement Program (SWEEP) administered through California Climate Investments (CCI). Using the CCI project database, we extracted data on total funding, avoided fossil fuel electricity generation, and greenhouse gas emissions reductions from all projects administered between 2015 and 2019. On a million dollar basis, these investments are expected to reduce fossil fuel generation by 36.0 GWh over their lifetime.[27]

To estimate the fuel savings and greenhouse gas emissions from this program, we modeled the program's lifetime capacity in AVERT. Every million dollars invested in *Irrigation and Water Efficiency* reduces lifetime greenhouse gas emissions by 7,498 short tons in Massachusetts, and by 19,820 short tons in the New England region.

2.3 Greenhouse Gas Emissions Multipliers

Some projects in the *Green Investment Portfolio* do not reduce fossil fuel consumption, but they still reduce greenhouse gas emissions through carbon sequestration or trapping and reusing methane gas. Their greenhouse gas emissions reduction per one million dollars invested are used to estimate climate benefits, described in Section 3.

Urban Greening - The *Urban Greening* program is modeled after the Urban and Community Forestry Program administered through California Climate Investments (CCI). Using the CCI project database, we extracted data on total funding and expected greenhouse gas emissions reductions for all Urban and Community Forestry projects administered between 2015 and 2019. Using only the projects with quantified GHG emissions reductions, we calculated the ratio of total project funding to a quantity of GHG reductions, and subsequently scaled this ratio to calculate the expected GHG emissions ($mtCO_2e$) avoided per one million dollars invested in each CCI program for the public health and climate benefits modeling described below. Every million dollars invested in *Urban Greening* avoids 4,755.7 metric tons of CO_2e.

Herring River Restoration - The *Herring River Restoration* project sequesters carbon dioxide through healthy coastal wetlands. We used an estimate from TerraCarbon's *Herring River Carbon Project Feasibility Study*, which estimates the amount of carbon dioxide sequestered over 40 years as

[27] California Climate Investments, "Implemented Projects Historic Database," *Accessed April 2021.*

a result of the project.[28] Using capital costs from the project's environmental impact statement, we found that every million dollars invested in *Herring River Restoration* avoids 3,672.7 metric tons of CO_2e.

Dairy Digesters - The *Dairy Digesters* program is modeled after the Dairy Digester Research and Development Program administered through California Climate Investments (CCI). Using the CCI project database, we extracted data on total funding and expected greenhouse gas emissions reductions for all Dairy Digester projects administered between 2015 and 2019. Using only the projects with quantified GHG emissions reductions, we calculated the ratio of total project funding to a quantity of GHG reductions, and subsequently scaled this ratio to calculate the expected GHG emissions (mtCO_2e) avoided per one million dollars invested in each CCI program for the public health and climate benefits modeling described below. Every million dollars invested in *Dairy Digesters* reduces greenhouse gas emissions by 39,917.4 metric tons of CO_2e.

3. CLIMATE BENEFITS MODELING

Of the 29 projects in the *Green Investment Portfolio*, 20 had sufficient data to derive lifetime climate benefits from the investment. To estimate climate benefits, we used the Biden Administration's social cost of carbon, adjusted to 2021, of $52 per metric ton CO_2e to convert greenhouse gas emissions reductions described in section 2 to a dollar estimate of avoided climate damages per million dollars invested.[29]

4. TRANSPORTATION BENEFIT ANALYSIS

Transportation-related *Green Investments* in this study create their own set of community benefits, separate from air quality, due to reduced personal vehicle use. Reduced vehicle use leads to reduced traffic congestion, reduced traffic accidents, and increased physical activity. All three of these benefits are measured in dollars in the report.

Congestion reduction, traffic accidents avoided, and brake and tire wear benefits are calculated for a given project based on the amount of vehicle miles traveled (VMTs) avoided by the investment. Physical activity benefits were calculated based on the person-miles of travel (PMTs) created by a given investment.

4.1 Congestion Time Savings

Our methodology for estimating traffic reductions follows the methodology used by Cambridge Systematics, Inc. in a 2020 study of the Transportation Climate Initiative, as prepared for Georgetown Climate Center.[30] To analyze reduced congestion as a result of reduced VMT, we divided the reported nationwide hours of traffic delay reduced from public transportation (865 million in 2012) by the estimated VMT reduced from public transportation (44.8 billion), according to the Texas Transportation Institute.[31] This obtains a factor of 0.02 hours of delay avoided per VMT reduced.

[28] TerraCarbon, "Herring River Carbon Project Feasibility Study." October 2019, t.ly/qKt0
[29] U.S. Interagency Working Group on Social Cost of Greenhouse Gases, "Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide." February 2021, is.gd/TsKPD7
[30] Cambridge Systematics, Inc., "State Investment Tool Documentation." September 2020, t.ly/FS3T
[31] Texas Transportation Institute, "Urban Mobility Report." December 2012, https://static.tti.tamu.edu/tti.tamu.edu/documents/umr/archive/mobility-report-2012.pdf

This factor was converted from time savings into a dollar value, using an official U.S. DOT value of travel time of $24.30 dollars per person-hour. After adjusting this 2014 value upward for 2021 inflation, we find that every VMT reduced saves $0.56 dollars in personal travel time.

This factor of $0.56 was then multiplied by the VMT reduction estimates of each transportation project other than the *Clean Vehicles* project, which does not reduce VMTs. The methodology for calculating project-specific VMT reductions can be found in section 2.1 of this document.

4.2 Traffic Accidents Avoided

We also follow the methods of Cambridge Systematics, Inc. to estimate the traffic accidents avoided from reduced VMTs. First, we examined national accident data from the Bureau of Transportation Statistics to calculate that 36,096 fatalities and 2,740,000 injuries occurred from vehicle crashes in 2019, out of a total of 3,261,772 million vehicle-miles traveled. This study divided total fatalities and injuries by total VMTs to obtain avoidance factors of 0.012 fatalities and 0.2 injuries avoided per million VMT reduced.

Crash reduction benefits are valued at $9.6 million per fatality, in 2016 US dollars, by the U.S. DOT, which we adjusted upward for inflation to $10.52 million. Traffic injuries are valued at $490,000 based on the value provided in the Federal Transit Administration (FTA)'s 2021 New Starts and Small Starts reporting templates.[32] When both dollar values are multiplied by the avoidance factors, we find that a VMT reduced avoids $0.126 in fatalities and $0.025 in injuries, for a final benefit factor of $0.15 in avoided fatalities/injuries per VMT reduced.

This factor of $0.15 was then multiplied by the VMT reduction estimates of each transportation project other than the *Clean Vehicles* project, which does not measurably reduce VMTs. The methodology for calculating project-specific VMT reductions can be found in section 2.1 of this Technical Appendix.

4.3 Brake and Tire Wear Health Benefits

In addition to air pollution from tailpipe emissions, such as exhaust from fuel combustion and burnt oil, driving vehicles also creates non-exhaust emissions from brake wear, tire wear, road dust, and other sources of particulate matter. We estimate the amount of fine particulate matter ($PM_{2.5}$) emissions from brake and tire wear using passenger car particulate matter emissions factors per VMT from the EPA MOtor Vehicle Emission Simulator (MOVES).[33] Every passenger car VMT reduced avoids 2.77 milligrams (mg) of $PM_{2.5}$ from brake wear and 1.28 mg of $PM_{2.5}$ from tire wear. We estimate the monetary damages of these $PM_{2.5}$ emissions using data from the Center for Air, Climate, and Energy Solutions (CACES) at the county level where a transportation investment would occur.[34] We used a state-level weighted average of CACES damages for projects that do not have a specific location in the state, such as *Active Mobility* investments which can occur anywhere in the state. For more information on how air pollution is modeled in this study, see section 5.

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[32] U.S. DOT, https://www.transit.dot.gov/funding/grant-programs/capital-investments/about-program
[33] U.S. EPA, "Brake and Tire Wear Emissions from On-road Vehicles in MOVES3." November 2020, https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1010M43.pdf
[34] More information on CACES can be found in section 5 of this Technical Appendix.

This factor $PM_{2.5}$ damages per mile traveled was then multiplied by the VMT reduction estimates of each transportation project other than the *Clean Vehicles* project, which does not measurably reduce VMTs. The methodology for calculating project-specific VMT reductions can be found in section 2.1 of this Technical Appendix.

4.4 Physical Activity Health Benefits

Active mobility, primarily walking and cycling, is associated with improved health outcomes, including reduced risk of mortality. Investments in active mobility infrastructure and public transportation increases the likelihood of walking and cycling, and therefore, these deliver positive health returns from increased physical activity. Research finds that one million walking person-miles of travel (PMT) will prevent 1.7 deaths, and one million biking PMT will prevent 0.5 deaths. Using a value of a statistical life (VSL) of $9.6 million, the monetized health benefits of walking and biking per mile are $16.32 and $4.80, respectively.

Existing research assumes that all new transit trips will include a one-quarter mile walk on each end,[35] or one-half mile per trip, so we used that assumption to estimate the total miles of walking from new transit trips per million dollars invested in six of the public transit *green investment* projects. We then estimated the monetized value of these walking trips for each project using the $16.32 estimate per mile above. Project-level physical activity health benefits can be found in section 8 of this document.

Green Line Extension - The *Green Line Extension* project is expected to increase transit ridership by 45,000 trips per day.[36] Annually, this equals 16.4 million trips, which would result in 8.2 million miles walked per year as a result of the project. With just under $1.8 billion in capital costs, walking per million dollars invested is estimated at 4,588.4 miles per year. Assuming a minimum project lifetime of 25 years, this is equivalent to 114,710.6 miles over the project's lifetime per million dollars invested.

South Coast Rail - The *South Coast Rail* project is expected to increase transit ridership by 875,000 trips annually, which would result in 437,500 miles walked per year as a result of the project.[37] With just over $1.1 billion in capital costs, increased walking per million dollars invested is estimated at 394.9 miles per year. Assuming a minimum project lifetime of 25 years, lifetime PMT equivalent to 9,873.2 miles over the project's lifetime per million dollars invested.

North South Rail Link - The *North South Rail Link* project is expected to increase transit ridership by 62.7 million trips annually, which would result in 31.3 million miles walked per year as a result of the project.[38] With almost $8.3 billion in capital costs, increased walking per million dollars invested

[35] Raifman, M., Lambert, K.F., Levy, J.I. et al. Mortality Implications of Increased Active Mobility for a Proposed Regional Transportation Emission Cap-and-Invest Program. J *Urban Health* (2021). https://doi.org/10.1007/s11524-020-00510-1
[36] Mass.gov, "About the Green Line Extension Project" https://www.mass.gov/info-details/about-the-green-line-extension-project#related-
[37] MassDOT and MBTA, "South Coast Rail Draft Supplemental Environmental Impact Report: Executive Summary." January 2018, https://www.mass.gov/doc/south-coast-rail-dseir-executive-summary/download
[38] MassDOT and MBTA, "North South Rail Link Feasibility Reassessment Final Report: Cost Estimates and Analysis" January 2019, https://www.mass.gov/doc/chapter-6-7/download

is estimated at 3,782.6 miles per year. Assuming a minimum project lifetime of 25 years, lifetime PMT is equivalent to 94,565.4 miles per million dollars invested.

Low Carbon Buses - The *Low Carbon Buses* project is modeled after the Low-Carbon Transit Operations Program administered through California Climate Investments (CCI), which expands bus services and replaces diesel-powered transit buses with hybrid or electric buses. Using the CCI project database, we extracted data on total funding and expected ridership increases from 6 of the most recent CCI investments that replace or expand transit bus fleets with electric buses — which best reflect the *Low Carbon Buses* project. On a million dollar basis, these investments are expected to increase walking PMT by 8,629.6 miles per year.[39] Assuming an average project lifetime of 12 years for BEBs, lifetime PMT is equivalent to 103,554.6 miles per million dollars invested.

Ferry Expansion and Electrification - The *Ferry Expansion and Electrification* project is expected to increase transit ridership by 1.4 million trips annually, which would result in 677,000 million miles walked per year as a result of the project.[40] With almost $51 million in capital costs for the two new ferry routes modeled, increased PMT per million dollars invested is estimated at 13,253.7 miles per year. Assuming a minimum project lifetime of 25 years, lifetime walking PMT is equivalent to 331,341.4 miles per million dollars invested.

East-West Rail - The *East-West Rail* project is expected to increase transit ridership by 377,025 trips annually, which would result in approximately 188,500 miles walked per year.[41] With over $3.4 billion in capital costs, increased walking per million dollars invested is estimated at 55.0 miles per year. Assuming a minimum project lifetime of 25 years, lifetime PMT is equivalent to 1,375.3 miles per million dollars invested.

Active Mobility - The *Active Mobility* program increases physical activity, primarily walking and cycling. To estimate the physical activity health benefits of the *Active Mobility* program, we used capital cost and biking and walking PMT estimates per mile of active mobility infrastructure from the Transportation and Climate Initiative (TCI) State Investment Tool.[42] Using these assumptions for walking infrastructure PMT and cycling PMT per biking facility type, we calculated the total walking and biking PMT per million dollars invested in *Active Mobility*.

These estimates were weighted according to population density in each county in Massachusetts: "core" (7.14 percent), "suburban" (57.14 percent), and "rural" (35.71 percent). According to this weighted average, a one million dollar investment in *Active Mobility* increases walking PMT by 19,426.1 miles annually, and biking PMT by 76,566.2 miles. The *Active Mobility* program allocated 50 percent of investments to walking infrastructure and 50 percent to biking infrastructure, so an average million dollar investment into the program increases PMT by 47,996.2 miles annually. We assumed a 20 year lifetime for active mobility infrastructure, which results in 959,923 lifetime miles walked and biked per million dollars invested.

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[39] California Climate Investments, "Implemented Projects Historic Database," *Accessed April* 2021.
[40] Boston Harbor Now, "Business Plan for New Water Transportation Service." 2018. is.gd/1rn8oa, is.gd/t2G0jL
[41] MassDOT, "East-West Passenger Rail Study Final Report: Alternatives Development and Analysis." January 2021, https://www.mass.gov/doc/chapter-4-alternatives-development-and-analysis-0/download
[42] Cambridge Systematics, Inc., "State Investment Tool Documentation." September 2020, t.ly/FS3T

5. AIR QUALITY BENEFIT ANALYSIS

5.1 Methodology Overview

To evaluate the health benefits of reduced air pollution in this study, we created a custom air pollution model for each project based on available pollution databases and project-specific literature. Out of the 29 total projects, 17 had sufficient data to derive county-level health benefits from investment.

Our modeling approach for air quality benefits follows five steps:

1. We used EPA's National Emissions Inventory (NEI) to extract the annual levels of local pollutants ($PM_{2.5}$, SO_2, NO_x, VOCs, and NH_3) emitted across 37 different point sources at the county level in Massachusetts.
2. We used reduced-complexity models (RCMs) to calculate the pollutant-specific, county-level annual health damages, in dollar terms, associated with each pollutant from each point source in Massachusetts. Each point source was defined as a "ground-level" pollution source or an "elevated" pollution source in order for the RCMs to properly calculate the downwind exposures of pollution to people.
3. We used Massachusetts' 2017 Greenhouse Gas Emissions Inventory data to aggregate and map the health damages from each point source to specific types of fossil fuel usage and/or greenhouse gas inventory emissions (i.e., light-duty vehicle gasoline, home natural gas heating, etc.). If a point source was in the NEI data, but not in the Massachusetts Greenhouse Gas Emissions Inventory, we dispersed the emissions from that point source according to the relative percentage of emissions of that pollutant in each county. Since the Massachusetts Greenhouse Gas Emissions Inventory reports emissions at the state level, we disbursed emissions to the county level by weighting by total $PM_{2.5}$ emissions in each point source in each county. This allowed us to find public health benefits by emission source in dollars.
4. We used project-specific literature to calculate the expected reduction in CO_2 equivalent (CO_2e) per million dollars spent on each project in each county, which can be found in sections 2 and 7 of this document. If the project wasn't location-specific, we evenly distributed air pollution reductions across all counties, weighted by existing concentrations of the given pollution source being reduced.
5. We adjusted public health benefit estimates upward by 7.71 percent, to reflect recent literature on non-mortality and child development health impacts from air pollution exposure that aren't reflected in the RCMs used in this study.

5.2 EPA National Emissions Inventory

The EPA National Emissions Inventory (NEI) is a detailed database of air emissions of criteria pollutants, criteria precursors, and hazardous air pollutants from air emissions sources across the United States. The NEI is released every three years based primarily on data provided by State, Local, and Tribal air agencies for sources in their jurisdictions and supplemented by data developed by the US EPA.[43]

This study uses 2017 NEI data, which was released in April 2020. The dataset includes pollutant emissions from five categories of pollution sources:

[43] https://www.epa.gov/air-emissions-inventories/national-emissions-inventory-nei

- ***Point sources***, which include emissions estimates for larger sources at fixed, stationary locations such as power plants and industrial facilities.
- ***Nonpoint sources***, which include sources that are too small to individually report, such as residential and commercial building heating.
- ***On-road sources***, which include emissions from on-road vehicles that use gasoline, diesel, and other fuels, such as light duty and heavy duty vehicles.
- ***Non-road sources***, which includes off-road mobile sources that use gasoline, diesel, and other fuels, such as construction equipment, locomotives, and marine vessels.
- ***Event sources***, which include unique sources of emissions, particularly wildfires and prescribed burns.

County-level emissions data for particulate matter ($PM_{2.5}$), sulfur dioxide (SO_2), nitrogen oxides (NO_x), volatile organic compounds (VOCs), and ammonia (NH_3) across 37 different sources from fossil fuel combustion were extracted from the NEI dataset.

5.3 Estimating Annual Mortality and Illnesses from Air Pollution

In order to assess the health damages associated with each pollutant from each source, we used publicly available data from the Center for Air, Climate, and Energy Solutions (CACES).[44] CACES uses three different reduced complexity models (RCMs) to estimate the public health damages associated with emitting a unit of $PM_{2.5}$, SO_2, NO_x, VOCs, or NH_3. RCMs connect emissions of local air pollution to ambient concentrations, exposures, physical health and environmental effects, and monetary damage.

CACES allows the user to specify location, spatial resolution, stack height,[45] statistical value of life (VSL), and C-R function.[46] We use the EPA's estimates for the VSL, which is $7.4 million in 2006 dollars. Adjusted to 2021, this gives us a VSL of $9.6 million. For every emissions source and pollutant, we derived CACES data at the county level. The CACES model provides geographic resolution on the source of pollution, but no geographic resolution on the location of mortality impacts. Since RCMs capture downwind effects of pollution, some of the health impacts captured in this study may occur outside of Massachusetts.

These CACES mortality damage estimates, which are provided in dollar terms, were applied to the NEI dataset in order to calculate the total mortality damages associated with each source of pollution in Massachusetts.

To prepare for subsequent project-level health and climate analysis, the 37 NEI pollution sources were aggregated and mapped to 24 pollution sources as defined in Massachusetts' 2017 Greenhouse Gas Emissions Inventory.[47] This resulted in a set of 24 "GHG-NEI-CACES" conversions, which allows us to derive local health costs of co-pollutants associated with emitting GHGs. A metric ton of CO_2e

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[44] https://www.caces.us/
[45] Stack height refers to the height at which pollutants are emitted into the air, which changes where the pollutant subsequently concentrates.
[46] C-R function refers to the assumed impact of a given unit of pollution on mortality. For a majority of emissions sources, we used a mortality estimate provided by the Harvard 6-Cities cohort. For more information, visit the CACES RCM user guide: t.ly/i8XP
[47] Massachusetts Department of Environmental Protection, "Greenhouse Gas Baseline, Inventory & Projection." https://www.mass.gov/lists/massdep-emissions-inventories

from any of these 24 pollution sources can be translated to a corresponding scale of co-pollutants, which then can be translated into projected mortality impacts from those co-pollutants.

We adjusted mortality impact estimates upward by 7.71 percent, to reflect recent literature on non-mortality and child development health impacts from air pollution exposure.[48,49]

5.4 Special Note - Diesel and Electric Trains

Commuter Rail systems in Massachusetts use diesel-powered locomotives, and are a major source of particulate matter pollution along their tracks. Electrified passenger rail systems have been investigated by the MBTA, including a fully electric commuter rail system in the state.[50] Based on the long lifetime of locomotives and rail systems, we assumed new construction of rail systems, such as the *East-West Rail* program, should be done with electrified trains to align with the state's target of net zero emissions by 2050. Electrifying the passenger rail system in Massachusetts would reduce particulate matter pollution and significantly improve public health for communities near their tracks. In Table 2, we show the difference in public health benefits between diesel and electric trains, assuming capital costs remain the same between the two alternatives.[51] There are drastic differences between health outcomes from diesel and electric trains.

Estimating the actual costs of electric trains requires further research for these projects, but in Table 2 we assumed the same capital costs for diesel and electric trains. In this report, we assumed the *East-West Rail* would be built fully electrified, however we could not make that assumption for the *South Coast Rail* project because construction is underway, and the *North South Rail Link* project would require all commuter rail service passing through to be electrified.

Table 2. Air Pollution Impacts for Diesel and Electric Rail Projects

Project	Type of Rail	Air Pollution Health Impacts
North South Rail Link	Diesel	-$1,327,280,487
	Electric	$255,955,116
East-West Rail	Diesel	-$594,687,954
	Electric	$123,051,749
South Coast Rail: Phase 1	Diesel	$31,610,588
	Electric	$45,525,811

A negative value in Table 2 above denotes net negative health damages from a new rail project, due to increased local pollution from diesel locomotives. A positive value denotes net positive health benefits from reduced personal vehicle pollution.

[48] Manion, Michelle et al., Abt Associates, "Analysis of the Public Health Impacts of the Regional Greenhouse Gas Initiative." *Abt Associates*, January 2017, t.ly/9egy
[49] Perera, Frederica et al., "Co-Benefits to Children's Health of the U.S. Regional Greenhouse Gas Initiative." July 2020, https://doi.org/10.1289/EHP6706
[50] MBTA (2020) Rail Vision Alternatives 5 and 6. https://www.mbta.com/projects/rail-vision
[51] Negative air pollution health benefits represent worsened health outcomes as a result of the investment.

6. *GREEN INVESTMENT PORTFOLIO* WEIGHTING AND ANALYSIS

6.1 Portfolio Weighting

Similar types of projects were combined into programs, and weighted according to their relative scale of funding needed. For example, the battery electric bus (BEB) replacement project and BEB charging depot installation project in the *Low Carbon Buses* program were weighted according to the ratio of bus-to-charger costs.

TABLE 3: Program Weighting in the *Green Investment Portfolio*

Investment Area	Program	Share of Portfolio
Clean Transportation and Sustainable Development	Light and Commuter Rail	17.5%
	Clean Vehicles	5.0%
	Low Carbon Buses	7.5%
	Transit-Oriented Development	5.0%
	Active Mobility	5.0%
	Ferry Expansion and Electrification	5.0%
	East-West Rail	5.0%
Renewables, Energy Efficiency, and Grid Modernization	Energy Efficiency and Building Retrofits	10.5%
	Residential Solar	5.3%
	Offshore Wind	6.1%
	Battery Storage	5.3%
	Transmission Infrastructure Upgrades	1.8%
	Community Microgrids	4.4%
	Broadband Connectivity	1.8%
Conservation and Natural Resources	Clean Water Infrastructure	3.8%
	Urban Greening	3.8%
	Aquatic Ecosystem Restoration	3.8%
	Sustainable Agriculture	3.8%

After the 29 projects were weighted and combined into 18 programs, these programs were subsequently combined into "investment areas" within the *Green Investment Portfolio*. The portfolio weighting was developed to align with the Governor's Draft 2030 Clean Energy and Climate Plan (CECP),[52] according to the scale of greenhouse gas emissions reductions that a sector or subsector is

[52] Executive Office of Energy and Environmental Affairs, "Draft Clean Energy and Climate Plan for 2030." December 2020, https://www.mass.gov/doc/interim-clean-energy-and-climate-plan-for-2030-december-30-2020/download

expected to contribute to meeting the state's 2030 climate target.[53] The portfolio spans three investment areas: *Clean Transportation and Sustainable Development* (50 percent), *Renewables, Energy Efficiency, and Grid Modernization* (35 percent), and *Conservation and Natural Resources* (15 percent).

Within investment areas, programs were weighted according to emissions reduction contributions within a sector or subsector outlined in the CECP. For example, in the buildings sector, the majority of emissions reductions are expected to come from building electrification, so the *Energy Efficiency and Building Retrofits* program makes up the greatest share within the *Renewables, Energy Efficiency, and Grid Modernization* investment area.

The *Green Investment Portfolio* was further adjusted according to the state's infrastructure needs, as well as capital intensity. For example, *Light and Commuter Rail* makes up the largest share of *Clean Transportation and Sustainable Development*, based on the scale of funding needed to meet the state's rail transportation needs, while light-duty vehicle electrification will contribute the greatest transportation emissions reductions by 2030 but requires less public investment.

6.2 Industry and Occupation Analysis

Industry Analysis

We used IMPLAN to model the jobs created by 29 *green investment* projects and the energy savings from 18 of those projects, respectively. Next, we weighted each project according to project and portfolio shares outlined in Table 3 above. We found the top industries supported by the *Green Investment Portfolio* by aggregating the portfolio-weighted jobs by industry code across each investment project.

Occupation Analysis

IMPLAN now offers data on 804 different occupations, of which 802 occupations exist in Massachusetts, that span all 546 economic sectors. We used IMPLAN to model the annual wages and labor-hours for these occupations in 29 *green investment* projects. We analyzed occupational data for the upfront investment into these projects, but did not examine the occupational characteristics of jobs created by long-term energy savings and spending power in Massachusetts. Jobs related to upfront investment are better suited for detailed IMPLAN analysis than long-term broader job creation from dollars circulating the state.

Next, we weighted each project according to project and portfolio shares outlined in the "Portfolio Weighting" section. We found the top occupations by summing the portfolio-weighted salary and hours across every project. We used the same method to find the top occupations by program and investment area. To find annual salary, we divided wages by hours and multiplied by the number of working hours in a year for a full-time-equivalent job (2,080).

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[53] The Governor's Draft 2030 CECP will have to be updated to reflect more recent legislation, including an interim 2025 emissions reduction target with a corresponding plan to achieve said target. Absent a new 2025 plan, we assume that the proportion of investment into the transportation, electricity, building, and natural resource sectors relative to each other is likely to hold consistent between the 2030 Draft CECP and a new draft plan.

6.3 Job Creation Comparison Benchmarks

To evaluate the job creation performance of *Green Investments*, we construct two generalized benchmarks in IMPLAN for comparison - an economy-wide average investment, and an investment into the state's ten largest industries. These benchmarks help designate the level at which a green investment is considered an "above average" job creator, as well as what rate of job creation per dollar the state's economy is expected to achieve without further stimulus intervention.

IMPLAN provides job "multipliers" for every industry sector in Massachusetts, defined as the direct, indirect, and induced jobs from a one million dollar investment into each industry. These multipliers were aggregated and weighted by output, to form the following two benchmarks.

State Average Benchmark - 8.5 FTE jobs per $1 million invested

This benchmark was constructed in a few steps. First, the jobs multipliers for each IMPLAN industry were multiplied by each industry's total state output to calculate the total direct, indirect, and induced jobs from each industry in a given year. The direct jobs in each industry were converted into full-time-equivalent jobs, using a standard coefficient for each industry as provided by IMPLAN. Every indirect or induced job was assumed to equal 0.907 full-time-equivalent jobs, which is the average conversion rate across all industries in Massachusetts.

The total jobs (direct, indirect, and induced) across all industries was then summed to a total of 8,290,565 FTE jobs. This is not equal to the total number of jobs in Massachusetts in a given year - it is rather the theoretical "FTE job-years" created by the state's economic output each year.

This total of 8,290,565 FTE jobs is divided by the state's total economy output across all industries ($972 billion), to calculate the rate of FTE job-years created per dollar, which is 8.5 FTE jobs per $1 million invested.

Ten Largest Industries Benchmark - 7.8 FTE jobs per $1 million invested

We constructed a more targeted industry benchmark in a similar fashion as the state average benchmark. We ordered all industries in IMPLAN in descending order by total yearly economic output, and extracted the ten largest industries. The following sectors were excluded from that list and replaced with the next largest industry code:

- 449 - Owner-occupied dwellings
- 545 - Employment and payroll of federal govt, military
- 542 - Employment and payroll of local govt, education

IMPLAN code 449 (Owner-occupied dwellings) was excluded as an "industry" because IMPLAN does not include any employment in that industry. All government-based codes were excluded to ensure this benchmark represents the foremost private industries in the state, rather than government activities. Excluding these sectors, the ten industries in Massachusetts with the largest economic output, in order of size, are:

- 464 - Scientific research and development services
- 490 - Hospitals
- 447 - Other real estate
- 442 - Other financial investment activities
- 441 - Monetary authorities and depository credit intermediation

- 444 - Insurance carriers, except direct life
- 469 - Management of companies and enterprises
- 448 - Tenant-occupied housing
- 428 - Software publishers
- 459 - Custom computer programming services

We aggregated the total jobs created by each of these industries by multiplying their individual job creators by their total economic output in the state. In total, these ten industries support 2.1 million direct, indirect, and induced FTE job-years in Massachusetts and provide $268 billion in total economic output, which can be re-expressed as 7.8 FTE jobs per $1 million in output.

DATA AND SOURCE APPENDIX

7. IMPLAN INPUT ASSEMBLY

This section includes the source data and assumptions used to convert every project and/or program into IMPLAN values and industry codes. The input data for each project and/or program is available upon request by contacting the study authors.

Light and Commuter Rail

Green Line Extension

The *Green Line Extension* project extends the Massachusetts Bay Transportation Authority (MBTA) Green Line light rail from Lechmere Station to new stations built in Somerville, Cambridge, and Medford. The light rail expansion will provide service in areas that previously did not have access to light rail service, and connect them directly to downtown Boston. Project-specific data for the *Green Line Extension Project* was derived and modified from the Massachusetts Department of Transportation (MassDOT) Green Line Extension Review Interim Project Management Team's Final Report.[54]

South Coast Rail

The *South Coast Rail* project provides commuter rail service between the southeastern region of Massachusetts and Boston. The commuter rail line will bring service to Taunton, New Bedford, and Fall River, which are the only major cities within 50 miles of Boston that do not currently have commuter rail access to Boston. Phase 1 of the project will extend the existing Middleborough/Lakeville line, and build the New Bedford and Fall River lines. Project-specific data for the *South Coast Rail* project was derived from the MBTA's 2020 South Coast Rail Phase 1 Update,[55] MassDOT's Early Action Culverts,[56] and MassDOT's Early Action 4 Bridge presentations.[57]

North South Rail Link

[54] MassDOT, "Green Line Extension Review: Interim Project Management Team Final Report." t.ly/b2tg
[55] Massachusetts Bay Transportation Authority, "South Coast Rail Phase 1 Update." https://cdn.mbta.com/sites/default/files/2020-05/2020-05-11-fmcb-17-south-coast-rail-update.pdf
[56] MassDOT, "SCR Early Action Culverts." 2019, https://www.mass.gov/doc/february-11-2019-south-coast-rail-early-action-culverts/download
[57] MassDOT, "SCR Early Action 4 Bridge." 2019, https://www.mass.gov/doc/april-22-2019-south-coast-rail-early-action-4-bridge/download

The *North South Rail Link* project builds a rail tunnel at South Station located in Downtown Boston. This tunnel would connect the MBTA Commuter Rail lines serving the northern and southern regions of Massachusetts, and enable through-running Amtrak trains as well. Project data for the *North South Rail Link* project was derived from MassDOT's North South Rail Link Feasibility Reassessment Final Report.[58]

Red and Blue Line Connector

The *Red and Blue Line Connector* project connects the MBTA Red Line and Blue Line by extending the Blue Line underground by 2,000 feet to the Charles/MGH Station on the Red Line. The Connector would link the only two MBTA light rail lines that are not currently connected, increasing transit access for residents and commuters along both lines and improving passenger mobility. Project data for the *Red and Blue Line Connector* project was derived from MassDOT's Summary Memorandum: Tunnel Constructability Study.[59]

Clean Vehicles

Clean Vehicles

The *Clean Vehicles* project includes direct financial assistance to low-income individuals who replace their vehicles with new or used cleaner ones, and funding to organizations that help low-income individuals finance the cost of cleaner vehicles. In addition, *Clean Vehicles* provides funding for the establishment of plug-in hybrid vehicles (PHEVs) and ZEV car-sharing fleets and mobility options in environmental justice communities.

Project-specific data for the *Clean Vehicles* project was derived and modified from the UCLA Luskin Center for Innovation, specifically from data on California's Financing Assistance Pilot Project, Enhanced Fleet Modernization Plus-Up (Clean Cars for All) Program, and Car Sharing and Mobility Options Pilot.[60]

Electric Vehicle Charging Infrastructure

The *Electric Vehicle Charging Infrastructure* project provides funding for the installation and equipment costs of electric vehicle charging stations. The project focuses specifically on workplace and public Level 2 charging stations and public 50 kW Direct Current Fast Charging (DCFC) stations to expand the state's public charging infrastructure.

Data for Level 2 chargers was derived and modified from the U.S. Department of Energy's "Costs Associated with Non-Residential Electric Vehicle Supply Equipment" report.[61] IMPLAN inputs for DCFC stations were derived from a University of Minnesota report on a statewide DCFC network in

[58] MassDOT, "North South Rail Link Feasibility Reassessment Final Report." January 2019, https://www.mass.gov/doc/chapter-6-7/download, https://www.mass.gov/doc/appendices-e-h/download
[59] MassDOT, "Summary Memorandum: Tunnel Constructability Study — Update to the 2010 DEIR for the Red Line/Blue Line Connector." October 2018, t.ly/w6Th
[60] Karpman, Jason et al., "Employment Benefits from California Climate Investments and Co-investments." UCLA Luskin Center for Innovation, 2018. is.gd/jRe1Al
[61] U.S. Department of Energy, "Costs Associated With Non-Residential Electric Vehicle Supply Equipment." November 2015, https://afdc.energy.gov/files/u/publication/evse_cost_report_2015.pdf

Minnesota.[62] Project-specific data were based on the share of Level 2 and DCFC stations needed to meet the goal of one million electric vehicles on the road by 2030, as outlined in the Massachusetts 2050 Transportation Roadmap.[63] This was estimated using the U.S. DOE Electric Vehicle Infrastructure Projection Tool (EVI-Pro) Lite tool.[64]

Low Carbon Buses

Low Carbon Buses
The *Low Carbon Buses* project expands low-emission and zero-emission heavy-duty vehicle use in public transit. This project provides funding for transit agencies to establish new or expanded bus service and intermodal transit facilities, and to replace or expand their fleets with battery-electric buses (BEBs). Project-specific data for the *Low Carbon Buses* project was derived and modified from the Luskin Center, specifically from data on California's Low-Carbon Transit Operations Program (LCTOP).[65]

Battery Electric Bus (BEB) Charging Infrastructure
The *BEB Charging Infrastructure* project funds the installation of battery electric bus (BEB) charging stations for electric transit buses. The project focuses specifically on depot charging infrastructure, which allows for charging during shoulder and off-peak demand times. Project data was derived from the Cambridge Systematics Transportation and Climate Initiative (TCI) State Investment Strategy Tool.[66]

Transit-Oriented Development

Project-specific data for the *Transit-Oriented Development* program was derived and modified from the Luskin Center, specifically from data on California's Affordable Housing and Sustainable Communities Program.[67]

Active Mobility

The *Active Mobility* program consists of road repair and road construction IMPLAN inputs. Investments in *Active Mobility* allocate 50 percent to *Industry 54 - Construction of new highways and streets* and 50 percent to *Industry 62 - Maintenance and repair construction of highways, streets, bridges, and tunnels*.

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[62] Tuck, Brigid. "Final Memo: The Economic Contribution of the Construction of a Statewide Network of Fast Charging Electric Vehicle Stations in Minnesota." September 2018, https://www.leg.mn.gov/docs/2020/other/200989.pdf
[63] Executive Office of Energy and Environmental Affairs. "Transportation Sector Report." December 2020, t.ly/rTTP
[64] U.S. DOE, Alternative Fuels Data Center: Electric Vehicle Infrastructure Projection Tool (EVI-Pro) Lite, t.ly/Qa85
[65] Karpman, Jason et al., "Employment Benefits from California Climate Investments and Co-investments." UCLA Luskin Center for Innovation, 2018. is.gd/jRe1Al
[66] Cambridge Systematics, Inc., "State Investment Tool Documentation." September 2020, t.ly/FS3T
[67] Karpman, Jason et al., "Employment Benefits from California Climate Investments and Co-investments." UCLA Luskin Center for Innovation, 2018. is.gd/jRe1Al

Ferry Expansion and Electrification

Ferry Expansion and Electrification extends ferry service in Boston Harbor and between the Cape and Islands and builds out the state's fleet with hybrid-electric ferries. The program would create a new route connecting Marina Bay in Quincy and Columbia Point in Dorchester to downtown Boston, expand existing ferry service between Charlestown and downtown Boston to serve East Boston and the South Boston Seaport. The program also makes upgrades to docks and ferry terminals along these routes.

Program-specific data on ferry expansion and dock upgrades was derived and modified from Boston Harbor Now's Business Plan for New Water Transportation Service reports on the Inner Harbor Connector and Quincy and Columbia Point Ferry routes.[68] Data on ferry electrification was derived from *Building Back Better: Investing in a Resilient Recovery for Washington State*.[69]

East-West Rail (High Speed Rail)

Program data was derived from MassDOT's East-West Passenger Rail Study Final Report.[70] The program models the number 3, 4, and 4/5 Hybrid Alternatives presented in Chapter 4 of the report.

Energy Efficiency and Building Retrofits

Residential Efficiency and Retrofits
The *Residential Efficiency* project offers financial assistance, technical support, and education services to homeowners, renters, and landlords for projects that reduce energy use in residential buildings. This includes funding for efficient lighting, appliances, and heating and cooling systems, demand reduction, weatherization, and retrofits. The project also provides residential energy assessments, funds workforce development and training, and supports education and research programs. It is modeled after *MassSave* residential initiatives. Project data for the *Residential Efficiency* project was derived from the Mass Save 2020 Electric and Gas Summary Report.[71] The project specifically focuses on planned Residential expenditures in 2020.

Commercial and Industrial Efficiency and Retrofits
The *Commercial and Industrial Efficiency* project offers financial assistance and technical support to small businesses, and commercial and industrial buildings. This includes funding for new, efficient equipment, system optimization, and building retrofits. The project also provides facility energy assessments, funds workforce development and training, and research and demonstration of efficient technologies. It is modeled after *MassSave* commercial and industrial initiatives. Project data for the *Commercial and Industrial Efficiency* project was derived from the Mass Save 2020 Electric and Gas Summary Report.[72] The project specifically focuses on planned Commercial and Industrial expenditures in 2020.

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[68] Boston Harbor Now, "Business Plan for New Water Transportation Service." 2018. is.gd/1rn8oa, is.gd/t2G0jL
[69] Climate XChange and Low Carbon Prosperity Institute, June 2020, https://climate-xchange.org/2020/06/30/building-back-better-investing-in-a-resilient-recovery-for-washington-state/
[70] MassDOT, "East-West Passenger Rail Study Final Report: Alternatives Development and Analysis." January 2021, https://www.mass.gov/doc/chapter-4-alternatives-development-and-analysis-0/download
[71] Mass Save, "2020 Electric & Gas Summary Report." https://www.masssavedata.com/Public/PerformanceDetails
[72] Ibid.

Water Efficiency
The *Water Efficiency* project funds efficiency projects that reduce water use, energy use, and greenhouse gas emissions for residential, commercial, and institutional consumers. The program also provides rebates for efficient household appliances, bathroom fixtures, and commercial and institutional cooking equipment. Project-specific data for the *Water Efficiency* project is derived and modified from the Luskin Center report, particularly California's Water-Energy Grant Program.[73]

Residential Solar

Program-specific data for the *Residential Solar* program was derived and modified from the Luskin Center, specifically from data on California's Single-Family Solar Photovoltaics Program and Large Multi-Family Energy Efficiency and Renewables Program.[74] The program's IMPLAN inputs were modified to include only solar PV installation costs.

Offshore Wind

Data for the *Offshore Wind* program was derived from the National Renewable Energy Laboratory (NREL) Jobs and Economic Development Impact (JEDI) Offshore Wind Model.[75]

Battery Storage

Data for the *Battery Storage* program was derived from an interview with Able Grid Energy Solutions in May 2019, which was provided by Synapse Energy Economics.

Transmission Infrastructure Upgrades

Data for the *Transmission Infrastructure Upgrades* program was derived from the National Renewable Energy Laboratory (NREL) Jobs and Economic Development Impact (JEDI) Transmission Line Model.[76]

Community Microgrids

Data for the *Community Microgrids* program came from the Massachusetts Clean Energy Center's (MassCEC) Community Microgrid reports. Program-specific data was derived from the Charlestown Navy Yard,[77] City of Melrose,[78] Raymond L. Flynn Marine Park District,[79] and the Wentworth Institute of Technology[80] Microgrid Feasibility Assessments.

[73] Karpman, Jason et al., "Employment Benefits from California Climate Investments and Co-investments." UCLA Luskin Center for Innovation, 2018. is.gd/jRe1Al
[74] Ibid.
[75] National Renewable Energy Laboratory. "JEDI Offshore Wind Model." https://www.nrel.gov/analysis/jedi/wind.html
[76] National Renewable Energy Laboratory. "JEDI Transmission Line Model." t.ly/UROS
[77] TRC, "Charlestown Navy Yard Community Microgrid Feasibility Study." t.ly/BYnn
[78] B2Q Associates, "City of Melrose Community Microgrid." June 2020, t.ly/InH1
[79] Microgrid Institute, "RLF Marine Park District Energy Microgrid Feasibility Assessment." June 2020, t.ly/QEZ8
[80] Willdan and MassCEC, "CoMWIT Feasibility Study." t.ly/hxwZ

Broadband Connectivity

Data for the *Broadband Connectivity* program was derived and modified from municipal broadband feasibility assessments for the city of Cambridge[81] and the town of Milton.[82]

Clean Water Infrastructure

Clean Drinking Water

The *Clean Drinking Water* project provides financial assistance to local governments to improve drinking water safety and public health. Funding can cover engineering, design, and construction costs of drinking water projects, including projects to upgrade or replace drinking water treatment facilities, storage facilities, or transmission or distribution systems. Project-specific data was derived from the Massachusetts Department of Environmental Protection's (MassDEP) 2020 Final Drinking Water State Revolving Fund Use Plan.[83]

Water Management

The *Water Management* project provides financial and technical assistance to municipal governments to upgrade water supply infrastructure, wastewater treatment plants and collection systems, and stormwater management infrastructure. The project helps municipalities comply with federal and state water quality standards, address watershed management, and improve public health. Project-specific data was derived from MassDEP's 2020 Final Clean Water State Revolving Fund Use Plan.[84]

Urban Greening

Data for the *Urban Greening* program is derived and modified from the Luskin Center report, particularly California's Urban and Community Forestry Program.[85]

Aquatic Ecosystem Restoration

Herring River Restoration

The *Herring River Restoration* project replaces or removes harmful water infrastructure, such as tidal gates, culverts, and dikes, to restore tidal flows and revitalize coastal wetlands in Wellfleet and Truro, Massachusetts. Project-specific data was derived from the Herring River Restoration Project Final Environmental Impact Statement/Report.[86]

Hoosic River Revitalization

The *Hoosic River Revitalization* project focuses on removing or replacing water management infrastructure and restoring riverine habitats along urban rivers. The project is modeled after the proposed Hoosic River Revitalization project in North Adams, Massachusetts. Project-specific data

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[81] Tilson, "Municipal Broadband Study for the City of Cambridge, Massachusetts." 2016, t.ly/qYqT
[82] CTC Technology & Energy, "Design and Cost Estimate for a Town I-Net." January 2019, t.ly/tOj4
[83] MassDEP, "Amended Final Drinking Water State Revolving Fund Intended Use Plan." September 2020, t.ly/EEXj
[84] MassDEP, "Amended Final Clean Water State Revolving Fund Intended Use Plan." September 2020, t.ly/7o53
[85] Karpman, Jason et al., "Employment Benefits from California Climate Investments and Co-investments." UCLA Luskin Center for Innovation, 2018. is.gd/jRe1Al
[86] Herring River Restoration Project, Final Environmental Impact Statement / Environmental Impact Report. May 2016, t.ly/mW4j

was derived from the Economic Impact of Hoosic River Revival report published by the Center for Creative Community Development.[87]

Dam and Culvert Improvements

The *Dam and Culvert Improvements* project removes dams and replaces culverts that are in poor condition and negatively impact stream ecosystems. These improvements help to mitigate flood risks, improve ecosystem function, and increase public safety. Project data was derived from the "Economic & Community Benefits from Stream Barrier Removal Projects" report published by the Massachusetts Department of Fish and Game.[88]

Sustainable Agriculture

Irrigation and Water Efficiency

The *Irrigation and Water Efficiency* project provides competitive grants to install irrigation systems that reduce water usage and greenhouse gas emissions. Data for the *Irrigation and Water Efficiency* project was derived and modified from the Luskin Center report, specifically from California's State Water Efficiency and Enhancement Program (SWEEP).[89]

Dairy Digesters

The *Dairy Digester* project provides competitive grants to support projects that reduce methane emissions from dairy waste. Applicants can use funds to install new covered lagoon digesters to trap the methane produced, which can be used to generate electricity or as a transportation fuel. The program also provides research and demonstration grants to enhance the efficiency and economic viability of dairy digester technology. Data for the *Dairy Digester* project was derived and modified from the Luskin Center report, specifically from California's Dairy Digester Research and Development Program.[90]

[87] Center for Creative Community Development, "Economic Impact of Hoosic River Revival." 2014, is.gd/TO76X0
[88] Massachusetts Department of Fish and Game, "Economic & Community Benefits from Stream Barrier Removal Projects in Massachusetts." March 2015, https://t.ly/ol56
[89] Karpman, Jason et al., "Employment Benefits from California Climate Investments and Co-investments." UCLA Luskin Center for Innovation, 2018. is.gd/jRe1Al
[90] Ibid.

8. PROJECT RESULTS

TABLE 4. Project Weighting into Programs

PROGRAM	PROJECT	SHARE OF PROGRAM
Light and Commuter Rail	Green Line Extension	15%
	South Coast Rail	25%
	North South Rail Link	35%
	Red and Blue Line Connector	25%
Clean Vehicles	Clean Vehicle Programs	80%
	Electric Vehicle Charging Infrastructure	20%
Low Carbon Buses	Low Carbon Buses	90%
	Battery Electric Bus Charging Infrastructure	10%
Transit-Oriented Development		100%
Active Mobility		100%
Ferry Expansion and Electrification		100%
East-West Rail		100%
Energy Efficiency and Building Retrofits	Residential Programs	55%
	Commercial and Industrial Programs	35%
	Water Programs	10%
Residential Solar		100%
Offshore Wind		100%
Battery Storage		100%
Transmission Infrastructure Upgrades		100%
Community Microgrids		100%
Broadband Connectivity		100%
Clean Water Infrastructure	Clean Drinking Water	30%
	Water Management	70%
Urban Greening		100%
Aquatic Ecosystem Restoration	Herring River Restoration	60%
	Hoosic River Revitalization	20%
	Dam and Culvert Improvements	20%
Sustainable Agriculture	Irrigation and Water Efficiency	90%
	Dairy Digesters	10%

TABLE 5. *Green Investment* Project FTE Job Creation per $1 Million Invested

PROJECT/PROGRAM	INVESTMENT JOBS	ENERGY SAVINGS JOBS	TOTAL JOBS
Green Line Extension	8.34	0.15	8.49
South Coast Rail	9.48	0.47	9.95
North South Rail Link	17.26	0.38	17.64
Red and Blue Line Connector	17.53	0	17.53
Clean Vehicle Programs	7.33	0.81	8.14
EV Charging Infrastructure	6.00	0	6.00
Low Carbon Buses	7.39	5.35	12.74
BEB Charging Infrastructure	5.21	0	5.21
Transit-Oriented Development	11.58	0.71	12.29
Active Mobility	8.41	0.26	8.67
Ferry Expansion and Electrification	10.88	0.54	11.42
East-West Rail	8.92	0.27	9.19
Residential Energy Efficiency	8.43	12.33	20.76
Commercial and Industrial Energy Efficiency	7.95	35.38	43.33
Water Efficiency	8.12	13.91	22.04
Residential Solar	8.10	5.36	13.45
Offshore Wind	7.23	6.19	13.42
Battery Storage	6.43	11.60	18.03
Transmission Infrastructure Upgrades	5.71	0	5.71
Community Microgrids	6.02	2.97	8.98
Broadband Connectivity	7.61	0.00	7.61
Clean Drinking Water	8.30	0	8.30
Water Management	8.18	0	8.18
Urban Greening	12.08	0	12.08
Herring River Restoration	9.05	0	9.05
Hoosic River Revitalization	9.50	0	9.50
Dam and Culvert Improvements	8.45	0	8.45
Irrigation and Water Efficiency	6.43	18.74	25.17
Dairy Digesters	7.22	0	7.22

TABLE 6. *Green Investment* Project Benefits per $1 Million Invested

PROJECT/PROGRAM	ENERGY SAVINGS	TRAVEL TIME SAVINGS	CLIMATE BENEFITS
Green Line Extension	$34,700	$73,000	$4,600
South Coast Rail	$107,500	$226,100	$7,500
North South Rail Link	$87,800	$184,800	$300
Red and Blue Line Connector	-	-	-
Clean Vehicle Programs	$168,100	-	$35,800
EV Charging Infrastructure	-	-	-
Low Carbon Buses	$1,244,300	$1,807,500	$105,900
BEB Charging Infrastructure	-	-	-
Transit-Oriented Development	$185,800	$416,700	$15,600
Active Mobility	$89,800	$177,000	$6,700
Ferry Expansion and Electrification	$123,900	$260,700	$7,200
East-West Rail	$62,500	$131,500	$1,200
Residential Energy Efficiency	$2,089,300	-	$331,700
Commercial and Industrial Energy Efficiency	$4,934,100	-	$759,300
Water Efficiency	$2,079,600	-	$1,165,900
Residential Solar	$907,400	-	$279,700
Offshore Wind	$926,000	-	$385,800
Battery Storage	$1,734,500	-	$44,500
Transmission Infrastructure Upgrades	-	-	-
Community Microgrids	$443,100	-	$114,300
Broadband Connectivity	-	-	-
Clean Drinking Water	-	-	-
Water Management	-	-	-
Urban Greening	-	-	$245,200
Herring River Restoration	-	-	$189,300
Hoosic River Revitalization	-	-	-
Dam and Culvert Improvements	-	-	-
Irrigation and Water Efficiency	$2,414,900	-	$926,400
Dairy Digesters	-	-	$2,057,700

PROJECT/PROGRAM	AIR POLLUTION HEALTH BENEFITS	PHYSICAL ACTIVITY BENEFITS	AVOIDED TRAFFIC FATALITIES	TOTAL PROJECT BENEFITS
Green Line Extension	$36,200	$1,872,100	$19,900	$2,040,500
South Coast Rail	$28,500	$161,100	$61,600	$592,300
North South Rail Link	-	$1,543,300	$50,300	$1,866,500
Red and Blue Line Connector	-	-	-	-
Clean Vehicle Programs	$192,100	-	-	$396,000
EV Charging Infrastructure	-	-	-	-
Low Carbon Buses	$493,900	$1,690,000	$492,200	$5,833,800
BEB Charging Infrastructure	-	-	-	-
Transit-Oriented Development	$85,900	-	$113,500	$817,500
Active Mobility	$36,500	$6,845,500	$48,200	$7,203,700
Ferry Expansion and Electrification	$53,800	$5,407,500	$71,000	$5,924,100
East-West Rail	$35,900	$22,400	$35,800	$289,300
Residential Energy Efficiency	$711,900	-	-	$3,132,900
Commercial and Industrial Energy Efficiency	$351,800	-	-	$6,045,200
Water Efficiency	$175,300	-	-	$3,420,800
Residential Solar	$45,900	-	-	$1,233,000
Offshore Wind	$56,700	-	-	$1,368,500
Battery Storage	$18,100	-	-	$1,797,100
Transmission Infrastructure Upgrades	-	-	-	-
Community Microgrids	$101,300	-	-	$658,700
Broadband Connectivity	-	-	-	-
Clean Drinking Water	-	-	-	-
Water Management	-	-	-	-
Urban Greening	-	-	-	$245,200
Herring River Restoration	-	-	-	$189,300
Hoosic River Revitalization	-	-	-	-
Dam and Culvert Improvements	-	-	-	-
Irrigation and Water Efficiency	$139,400	-	-	$3,480,700
Dairy Digesters	-	-	-	$2,057,700